UNIVERSITY OF KWAZULU-NATAL

Master of Architecture

ARCH80S Dissertation: Architectural Design

A Sustainable Architectural Approach towards Energy:

Through a Renewable Energy Research Facility on the Durban Harbour.

By

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A Dissertation Submitted in partial fulfilment of the requirements for the degree of

Master of Architecture to the School of the Built Environment and Development Studies

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Figure 1.1: *This Picture shows the climate change protesting in Port Elizabeth, South Africa*

Source: Shoba, Postman, Mbovane, Feni, 2019

Figure 1.2: *This Picture shows Thandi Magxotywa inside her shack home in Stjewtla, a rural settlement in Johannesburg, where she makes use of candles and paraffin for electricity and heating during load shedding.*

Source: Kamanzi, 2020

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DECLARATION

Submitted in fulfilment of the requirements for the degree of Master of Architecture, in the Graduate Programme in Architecture, University of KwaZulu-Natal, Durban, South Africa.

I declare that this dissertation is my unaided work. All citations, references and borrowed ideas have been duly acknowledged. I confirm that an external editor was not used. It is being submitted for the degree in Master of Architecture in the faculty of Humanities, within the school of Built Environment & Development Studies, KwaZulu-Natal, Durban, South Africa.

None of the present work has been submitted previously for any degree or examination in any other University.

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Ashmika Ramklass

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DEDICATION

To those who fight for a greener future.

“You can’t wait for something to happen; you have to make it happen” - Anand Sagar Ramklass.

I’m glad to have made you proud with heartfelt dreams and starlit seas.

ABSTRACT

With population increase placing a strain on natural resources, so comes the energy demand. Energy is a necessity however; the energy demand has resulted in a rapid depletion of non-renewable resources. This increase in energy consumption is seen within the industrial sector of South Africa. The lack of social consciousness and research on sustainable energy development has contributed to the biophysical and socio-economic challenges within the industrial sector of South Africa, namely the Durban Harbour.

This dissertation will analyse the biophysical and socio-economic challenges that have resulted in the development of energy within the Durban Harbour and how sustainable development has contributed to the city's green economic growth. The theoretical and conceptual framework of sustainability, hedonistic sustainability and hybridity, will aid the proposal in establishing a balance between renewable energy development and sustainable architecture within the Durban Harbour. A sustainable architectural model will be explored as a renewable energy research facility, that will be used as a tool to establish a social link through education and research, to create an interdependency on hybrid sustainable energy development, and mitigate biophysical and socio-economic challenges.

KEYWORDS

Biophysical and Socio-Economic Challenges, Green Economy, Hybridity, Industrialisation, Renewable Energy, Sectors, Sustainability

PART ONE

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND RESEARCH

Maslow's Hierarchy of Needs discusses the basic needs required for survival so as the accessibility to adequate food, water, and shelter (McLeod, 2018). Energy can be included as a form of provision for these basic needs. Over time people have depended on energy from renewable resources to non-renewable resources, as society has progressed and improved on their quality of life. As global population growth increased, biophysical and socio-economic challenges have occurred and placed a strain on many of these essential resources needed to sustain life (Pimentel, Pimentel, 2008:1). These challenges include climate change, over-exploitation of natural resources, lack of appropriate water management, deforestation, pollution through urban waste disposal, lack of education and infrastructure for over-population. These issues are occurring at a rapid rate causing a global crisis that influences other factors of livelihood (Environmental Professional Network, 2016).

The influence of South Africa's rapid population increases within central cities and the energy demand being coal-concentrated has resulted in major natural ecosystem depletion and an increase in greenhouse gas emissions. South Africa, namely Durban, has seen an increase in population, resulting in urbanisation growth and higher energy demand to cater for these needs. This increases the pressure on already threatened ecosystems as more natural resources are extracted. The occurrence of urbanisation in addition to social and physical implications has led to the negative impacts of urban sprawl and threatened biodiversity's throughout South Africa and in particular Durban (Conserve Energy Future, 2018). Durban has a history of biodiversity threats through the transformation of natural areas and over-exploitation of resources. Many of these biophysical and socio-economic issues have consequences that the city of Durban is still contending with today.

In a recent study of the South African New Growth Plan established in 2010, an action plan was put in place to address and combat these biophysical and socio-economic issues. Their vision is to create "an economy that is more inclusive and environmentally sustainable". This is to be achieved through the generation of employment and innovation of clean energy (GCIP, 2014). This will be administrated through environmentally positive partnerships between the government and the private sector, rendered by the 2011 Green Economy Accord. South Africa, amongst other countries, joined The Global Cleantech Innovation Program in 2014. The aim of this initiative focuses on addressing current energy, environmental and economic concerns through innovative 'clean technology' aided by small and medium scale businesses. The context of Durban has experienced challenges in implementing the recommendation put forth in the South African New Growth Plan, such as the lack of availability for sufficient research and public awareness, and effective case studies related to the development of infrastructure for the current energy concerns (Smith, 2015:3).

The green economy is the process of improving human quality of life and economic growth whilst decoupling environmental degradation. The Green Economy Inventory for South Africa: An Overview discusses the challenges occurring within South Africa that may be addressed through an approach of a sustainably resilient and low-carbon economy, as South Africa is heavily reliant on coal as an energy source which counteracts the significance of reducing greenhouse gas emissions (PAGE, 2017). The Overview (PAGE, 2017), explores Durban's multiple economic sectors, however, the transportation, industrial and commercial sector have the highest demand for energy usage and electricity, whilst The Durban State of Biodiversity Report identifies these sectors as the larger contributors of greenhouse gas emissions (Govender, 2017:14-23).

Durban was ranked the highest quality of life in South Africa, ranking 85th on a global scale according to the 2017 Mercer Quality of Living Survey. As an evolving economy, the ranking is distinguished by the high-end housing established, a diverse array of recreational activities accessible, and premium consumer goods available. As the city evolved, so did the need for advanced building services to cater for a higher standard of living. Energy is required within the built environment to achieve this so that buildings can maintain a comfortable and desirable space for living or working. Durban's Resilience Strategy identifies the city as a proactive society that is adapting to the challenges of climate change however, undermined by the many social, economic, and environmental issues that plague the city. Environmental systems are one of these concerns that can develop resilient cities, identifying threatened ecosystem services that support social cohesion and adapt to climate change. The constant threat to biodiversity in Durban cannot be averted without the development of ecological infrastructure to implement a resilient model that reduces the pressure on a failing ecosystem (Durban's Resilient Strategy, 2017:40). Biodiversities have also become vulnerable due to the lack of rehabilitation and protection (Mketeni, 2015:9).

Several renewable energy projects have been implemented in South Africa in recent years. The majority of the larger-scale projects are located within the Northern Cape, Western Cape, and Eastern Cape due to the vast land availability and constant reliable natural energy sources such as solar and wind. Projects in other regions are at a smaller scale due to the inconstant energy available. Government funding for renewable energy is an issue therefore the majority of these larger-scale projects are privately owned. Funding is also affected by the lack of education and awareness to the public. There are few alternative energy facilities established for research and education purposes. However, facilities that do provide research in renewable energy development are small-to-medium in scale, situated within tertiary education departments or governing services. This research is exclusive to the public. These challenges stagnate the progress of economic and energy development within the country. With funding, accessibility and education, the community will not only progress but the biophysical and socio-economic challenges can be alleviated.

1.2. JUSTIFICATION / MOTIVATION OF RESEARCH

As the city of Durban developed, along with the increase in population and industrialisation, the built environment has become highly susceptible to resource consumption, non-renewable energy dependency and carbon emissions compared to compact urbanised areas. This has resulted in many biophysical and socio-economic challenges occurring within the city (Yusuf & Allopi, 2010:418).

South Africa is heavily reliant on fossil fuels for energy production, resulting in the country contributing immensely to carbon emissions and intensifying climate change. Sustainability in energy allows for economic development to thrive and improve the social quality of life. The production of energy is a necessity for services in all sectors of the economy, especially within the built environment. Energy consumption and energy efficiency are some of the focus challenges faced in South Africa. As people spend a lot of time within buildings, energy is used within architecture to create desirable spaces throughout the seasons, and as architecture progresses so do buildings services and the need for energy demand.

The production of sustainable/renewable energy will improve efficiency within all sectors and mitigate against climate change. The industrial and transportation sectors are the primary locations identified for energy conservation due to these sectors having the greatest demand in energy consumption. By promoting energy efficiency and reliance on renewable energy resources, investors and funding will follow through. By creating public consciousness on energy saving potential and allowing collected research to be accessible to the public, many will be encouraged to create sustainable communities in any region that provides affordable and efficient clean energy solutions. The implementation of renewable energy solutions that is responsive to the region will mitigate the negative impact placed on threatened ecosystems and contribute to the reduction of carbon emissions.

Durban being a coastal city has the potential for the implementation of a sustainable architectural model due to the abundance of renewable resources available. By accessing multiple resources as a hybrid system, the energy collected will be constantly available during peak demands without the limitations of individual systems. This architectural model will be able to explore the balance of sustainability and architecture through a research facility on hybrid renewable energy production that will alleviate the pressures placed on the environment, society and economy.

1.3. STUDY AREA LOCALITY & ANALYSIS

This section will provide a study on the characteristics and understanding of the geographical context of Durban. The study area that will be analysed is the Durban Harbour that is located on the east of the KwaZulu-Natal province, near the Durban Central Business District (CBD). The development of industries and challenges of urbanisation along Durban Harbour completely buffers the coexistence of humans and ecology. There will be an outline of the relationship of the Durban Port to the sectors of industry, socio-economic, transportation, and ecology. In addition, the status of the area will provide an insight into the biophysical and socio-economic challenges taking place in the area, how the challenges can be addressed, and the current responses and initiatives in place to improve the city.

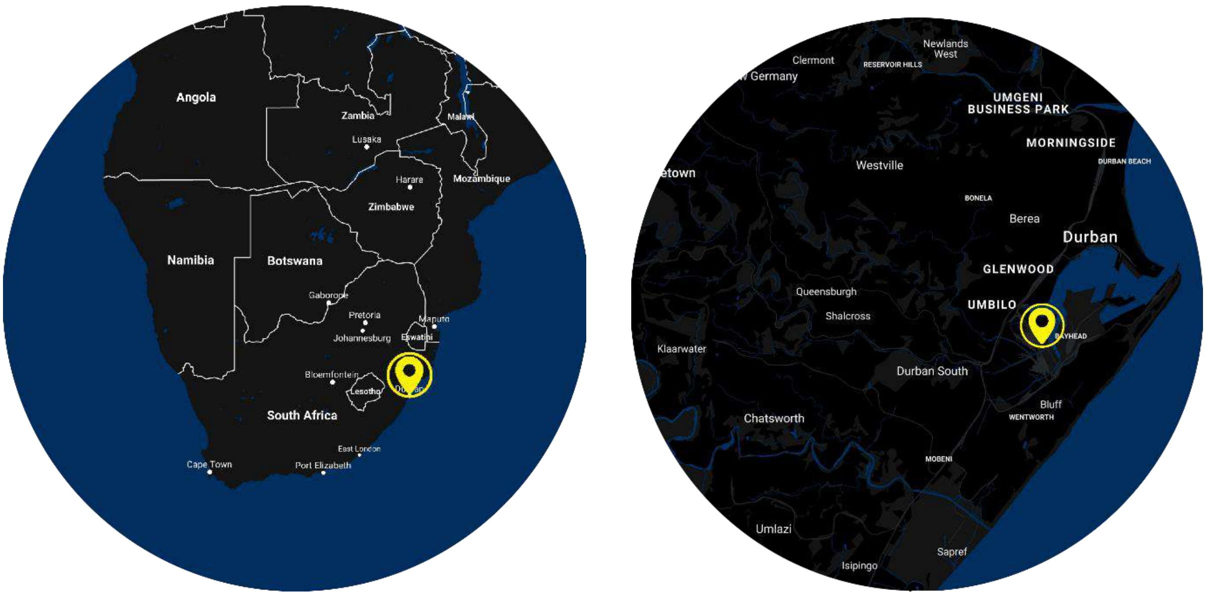


Figure 1.3: *Macro context to Micro context of the Durban Bay Harbour*

Source: Author, 2021

Figure 1.4: *Panoramic View of the Durban Harbour Entrance*

Source: Global Africa Network, 2017

Figure 1.5: *Panoramic View of the Durban Harbour from the CBD*

Source: Von Maltitz, 2021

Within a beautiful KZN coastline, the Durban estuarine bay is approximately 910 ha in size with ecological significance. The Durban Bay estuary is located at the interface of the marine and freshwater ecosystems (Mclean, 2016: 4). The Umhlatuzana River, the Umbilo River and the Amanzimnyama River catchments converge higher inland and flow through undisturbed natural vegetation, residential and dense industrial areas, until the Umhlatuzana River mouth runoffs in the Bayhead. Many of the Durban CBD stormwater drains into the bay at various points on the north side of the harbour. The maximum depth of the harbour is 20m at the dredged entrance point and 12.5m throughout (Environmental Affairs, 2015:6). The Harbour mouth has been dredged and controlled with breakwaters to widen the entrance, allowing larger shipping movement.

According to Durban's Estuaries (Mclean, 2016), the ecosystem services provided by the Durban Bay include nursing grounds and habitats for species, a supply of nutrients to the marine ecosystems, an increase in eutrophication, a constant water supply, waste treatment, food mitigation and recreational spaces. Communities in proximity benefit from the views and increase in land value. Recreational activities include canoeing, yachting, and fishing. The Durban Bay estuary is highly ecologically sensitive with unique bird and fish species.

The zoning surrounding the Durban Harbour consists of multiple land uses. The industrial zones near the Port include Transnet Engineering, Manufacturing warehouses, Tongaat Hulett Sugar, Container and Car Terminals, Mediterranean Shipping Company, Island View and Maydon Wharf. The prominent heavy industries service paper, pulp, food, textiles, chemicals, heavy metals, automotive and bulk cargo. The commercial and residential zones include Victoria Embankment which acts as the city and port interface, Point Waterfront Development, marine parks, shopping centres, low-income and middle-income households, education facilities, Transnet Maritime School of Excellence, and train stations which take a large amount of space within the harbour. The recreational zones include Wilson's Wharf, Bluff Yacht Club and the Yacht Basin, Craft Harbour (the B.A.T centre and Maritime Museum), various club facilities, and restaurants. The conservation zone includes Umhlatuzana River Park, Bluff Conservation Area, and the Bayhead Natural Heritage Site. (Environmental Affairs, 2015:27).

Figure 1.6: *This Map shows the zoning of the Durban Harbour*

***Source:* Environmental Affairs, 2015:30**

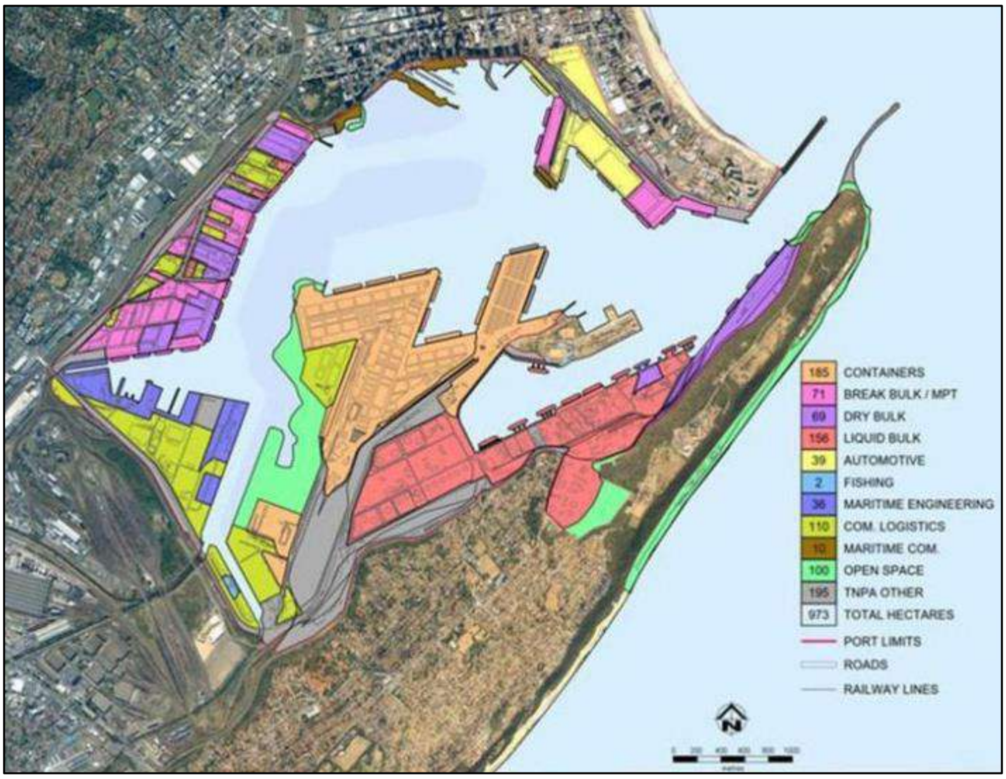


Figure 1.7: *This Map depicts the current layout of the 2015 National Ports Plan*

***Source:* Polaris, 2015**

1.3.1. Historical Context of the Durban Harbour

Rio de Natal was founded in 1497, by Vasco de Gama a Portuguese pioneer. In the early 1800s, A trading route and settlement was established along the Durban Bay, with the military taking advantage of the Bay's topography (Vahed, Rosenberg, Moodley, 2012:16). On account of British colonisation, Mr Richard King established the township as D'Urban which later became the city of Durban (South African History Online, 2019). John Milne, the first Port engineer in the 1850s, removed the shallow sandbar at the Bay entrance as a turning point for the expansion of trade and growth of the city and the port. Later, the mangroves and swamps near Albert Park and Congella were removed, and a breakwater on the South of the Bay and pier on the North were constructed to pave a way for the further expanding harbour (Arjunan, 2004:16). Moving forward from 1850, the area around the Harbour expanded with hotels, banks, parks, public buildings, religious centres, railway stations, city hall, markets, skyscrapers and so on. Later Durban was known as the largest container terminal and port in the southern hemisphere.

In the 1860s, the Durban Point became a significant trade point to the rest of the country, thus road and rail routes were constructed for the transportation of goods. With the arrival of Indian indentured labourers, markets and settlements were expanding exponentially. Although the natives of Durban predominately resided within rural areas, the Indians that had no settlement were permitted land within the city, particularly the Warwick precinct due to the thriving trade and transportation for commuting. Between 1930 to 1950, segregation and municipal boundaries were established on account of overcrowding. As the population increased, so did urbanisation and sprawl within these areas. Settlers slowly moved away from the Durban Port, but most remained within the CBD (Vahed, Rosenberg, Moodley, 2012:31-42). As Durban was segregated into racial, spatial and class zones due to the effects of apartheid, slow but transformative desegregation within the urban fabric took place. The economic standing and racial inequality within certain areas are factors that slowed the progress of urban transformation.

Decentralisation, suburbanisation, deindustrialisation, and greenfield development has initiated the urban sprawl. Housing policies were ineffective by forming racial exclusion of the underprivileged that tried to normalise the socio-economic state that they were in rather than improving and providing an opportunity for growth. Private developers had the economic power to encourage racial and economic segregation through high-end investments of greenfield developments sprawling out into the non-diverse suburbs. Apartheid's strategy on spatial division has left the city in an uneven divide of resources, infrastructure, and opportunity (FIGURE 1.8 and 1.9). High levels of unemployment and densified concentration of poverty prevented most of the city's economic opportunities. Industries and transportation became a focus since Durban was known as a tourist and economic hub (Schensul, Heller, 2010:3-6).

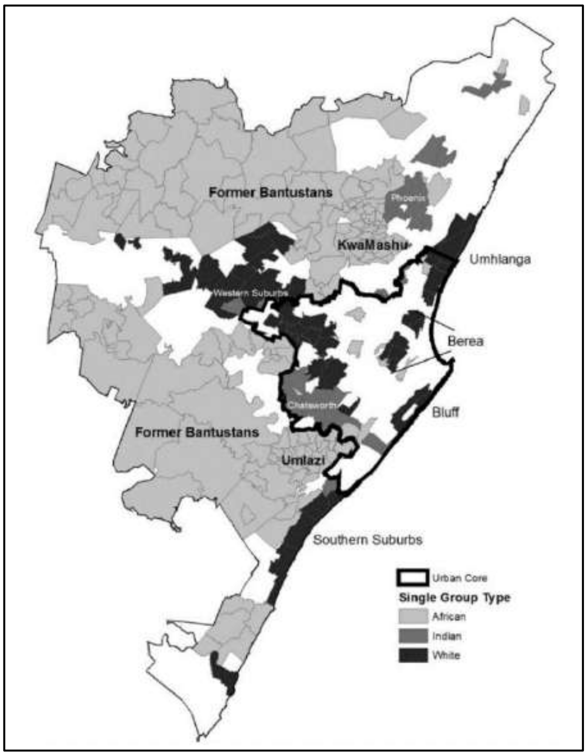


Figure 1.8: *Apartheid zoning and the urban core*

***Source:* Schensul, Heller, 2010:7**

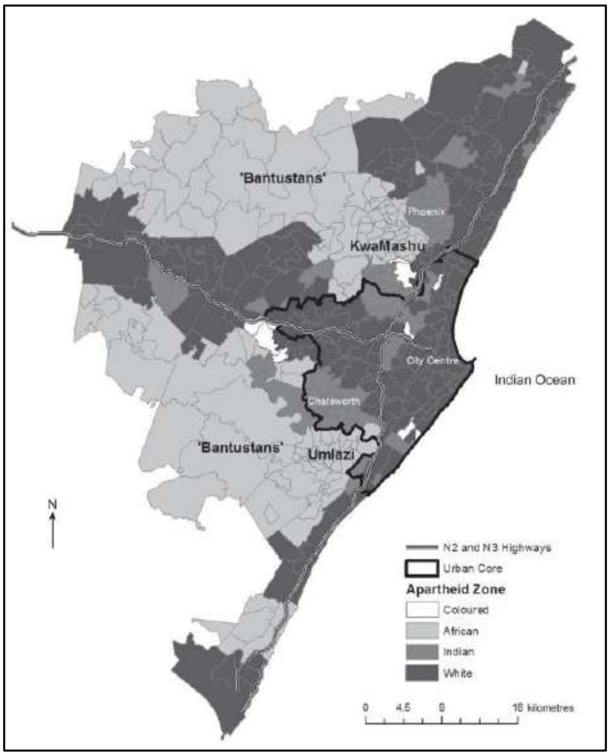


Figure 1.9: *Post-Apartheid single-group communities*

***Source:* Schensul, Heller, 2010:8**

The Durban CBD is ideally located for access to transportation and economic opportunity and its' residents are far more integrated into the fabric of the city than the outskirts. There are factors of change which include globalisation, which has significantly impacted the economy of the city, with the decline of the traditional manufacturing centres in the South Durban Industrial Basin and the growth of upcoming economic activity and a proactive government that has provided new infrastructure, built low-income/RDP housing, invested in new economic nodes, and extended/improved the road system (Schensul, Heller, 2010:26). As globalisation increased, so did the pressure on the South African economy. Allowing it to thrive largely through trading. As trading and capital grew, so did the infrastructure of the ports.

1.3.2. Challenges of the Durban Harbour within the different Sectors (Industrial, Socio-Economic, Transportation and Environmental)

The Durban Harbour, located on the eastern shores of South Africa, resembles some of the original geographies of the Bay when it was discovered. A thesis on *The Role of the Port of Durban in Strengthening the Platform of growth in eThekwini*, will be explored based on the Durban Harbour challenges, potential strategies taken to alleviate the challenges and several existing responses that have performed well (Arjunan, 2004).

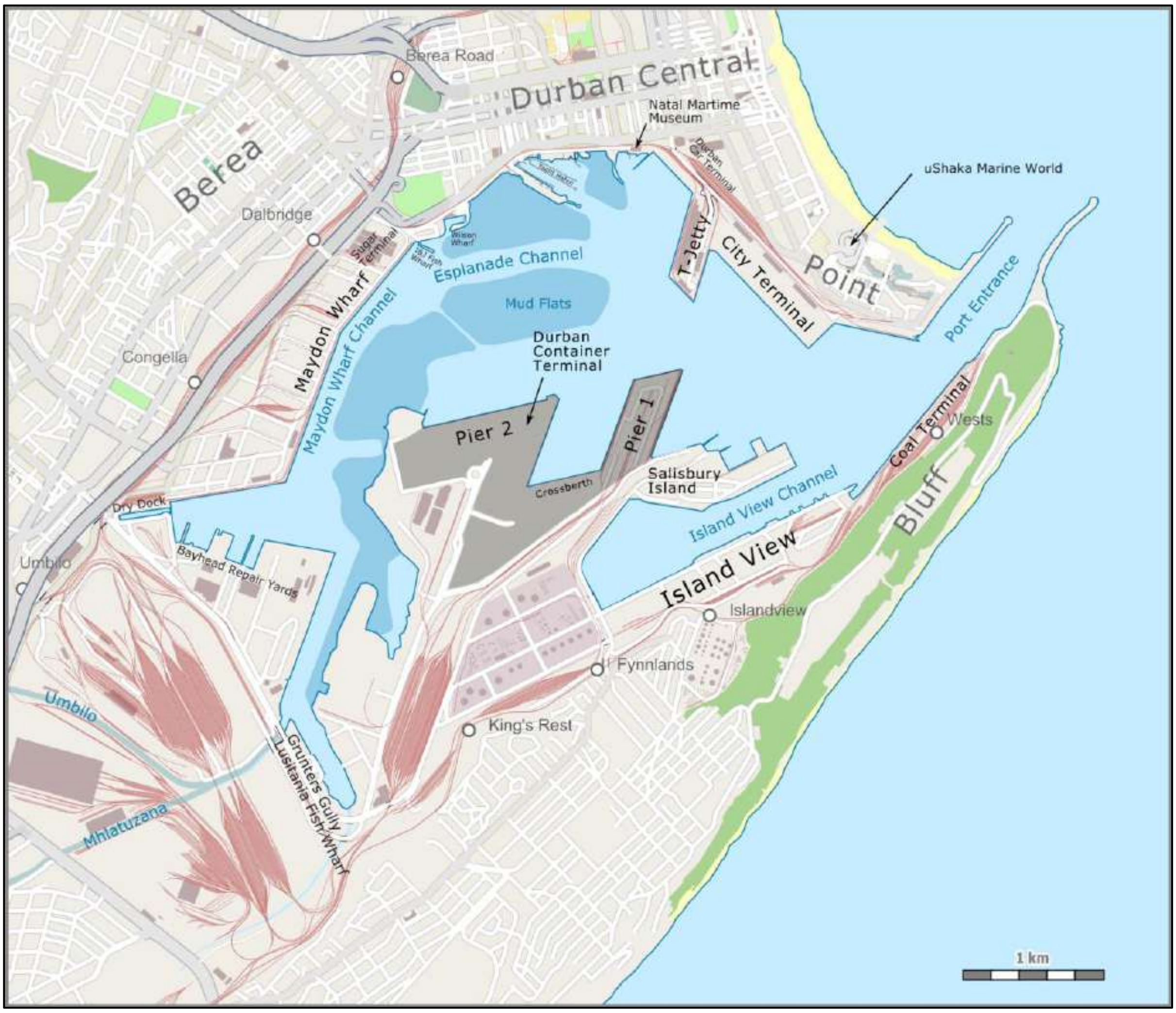


Figure 1.10: *This Map shows the Micro context of the Durban Harbour*

Source: Brugnetti, 2016

Being the second-largest economic hub and one of the two busiest ports in South Africa, Durban places a significant part in the growth of the national economy through trade, industry, tourism, and communication. The eThekwini Municipality surrounds itself with approximately 3 million people, an established national transportation network, and a largely reliant and expanding manufacturing district in the South Industrial Basin.

According to Arjunan (2004), once the socio-economic environment of Durban strengthened, decentralisation and sprawl followed. The opportunity for the commercial and retail sector to relocate became a trend as technology advanced and the property was available. The Durban tourism sector became essential to the socio-economic growth as the government invested in new development projects; however, security and crime became a weak point.

The industrial zone on the south of the CBD has experienced a positive output growth but negative formal employment growth. Due to economic diversity, the informal sector needed to be developed to progress from the challenge of unemployment and improve their livelihoods. The dependency of the industrial sector became an advantage as well as a disadvantage to the local economy. The advantage being the growing economy, employment, and service benefits. The disadvantage being the need and reliance to compete in the global trade market. However, this did not accommodate for the local challenges of poverty and unemployment in most communities (Arjunan, 2004:4). As decentralisation continued, many light industries took the opportunity of utilising pre-occupied spaces. Moreover, these spaces were not entirely suitable for the purposes needed and the redevelopment of existing industries within the city put a strain on the space required for expansion. (Arjunan, 2004:7-8).

Due to many of the industrial facilities needing to be allocated around the bay area, there was a constant conflict between the city territory and the port trade. In 2001, Portnet whom originally managed the port, split into the National Port Authority (Transnet as a parastatal organisation was part of this division) and the South African Port Operations. The Durban Port generated immense profits, thus the ongoing conflict between the privatisation of the port and the local government hindered many opportunistic structuring over the years (Arjunan, 2004:13). However, the participation of the private operations and the local government would maximise the potential of advanced development and improve infrastructure. This will allow all those involved to benefit economically and enhance the skills development of the local community.

The division and lack of management between the city and the Port affected the spatial planning of the area. There is also the inadequate planning and dispersion of industries within the South Industrial Basin. This weakened the economic dependency placed on the industrial sector, also limiting the spatial expansion and threatened the social well-being of those within and surrounding the area. The disconnect and neglect of planning led to urban blight and derelict land. There was a lack of interest in the organisation of the Port and the surrounding areas linked to it whilst the inner-city experienced development. These areas have abandoned shipping yards, dilapidated buildings, poorly maintained port infrastructure and transportation routes, pollution on land and in the water, and a disregard of the natural environment. New development and management of derelict areas will allow the Port to enhance its character and encourage more development to take place. Investors and development programmes would become intrigued by the potential the Port has on revitalising the city and enhancing the urban fabric.

With the Durban Port competing in the global trade market and encouraging investment, the biophysical and socio-economic challenges affected decision-makers and how they view the city. By improving technology, investing inadequate infrastructure, and addressing these challenges, the Port can return to the competitive global market successfully. Arjunan, 2004:34). Clustering geographically allocated areas thereby strengthens the social growth and the economic potential, such as the South Industrial Basin clusters with industries and the tourism sector clustered in the Northern and Central areas. Once these challenges are resolved, tourism and businesses will flourish, and the integration of the public will strengthen the Port.

The Port also places pressure on local resources. With most of the focus on contributing to the economy and less concerned about the effects placed on the local environment. This places the increasing population of the local community at risk as they are unable to benefit from any resources available. This includes the accessibility of transportation networks becoming deteriorated due to the heavy loads transported, the threatened ecology and water quality, noise and air pollution, and the scarcity of land due to the port utilising an expansive space than needed and at a lesser cost. Transparency and fair benefits towards resources between the Port Authority and the local community can decrease any conflict that may arise.

The Durban Harbour has access to the sea, rail, and road infrastructure as a form of transportation which plays a key role in national trade. Rail covers the majority of the Port employing efficiently transporting excessive loads, however, the infrastructure has become derelict. The back-of-port road infrastructure is not conducive for the high traffic volumes of large vehicles. The congestion also affects the local communities with noise and air pollution. This issue could be resolved through the cooperation of the local government and port authorities by restoring the transportation infrastructure and promoting efficient intermodal means. Transportation management can be achieved through, improved service amenities, designating trunking yards, on-site service and repair stations, formalised routes between facilities, easier administration of goods and restricting the movement of goods to designated times, and most importantly upgrade the rail network. (Arjunan, 2004:87).

The Durban Port, once integrated well with the public, has now become inaccessible and isolated from the public. As urban renewal projects brought in investment and tourism to the city, and the Port expanding into the city interface, this affected the way the public interacted with the waterfront and the aesthetics of the area. With the challenge of Port privatisation, the National Port Authority does not have sufficient resources to redevelop blight areas. By investing in these development programmes, the port will be able to tackle several biophysical and socio-economic issues and improve the quality of life within and around the port. This in turn will contribute to the growth of the city and port, especially to the global market. This can be done by urban renewal programmes of existing decayed buildings and spaces, also the preservation of species and vulnerable ecosystems.

The environmental implications on the Durban Harbour have deteriorated over time. The undermined ecosystem services are a result of urban impacts including rapid urbanisation, increase in population densities, the natural species within and around the area being threatened, energy demand, the lack of management facilities, waste pollution, stormwater and sewage runoff, a deterioration in water quality, extensive effluent and chemical disposal or spillage, and a deficiency in biota. These challenges increased as the river was canalised. There is a continuous trade-off with heavy industrial facilities and residential areas requiring the usage of this watercourse and the negative impacts created along the watercourse (WRC, 2002:24).

The concrete river canals have affected the environment and society that reside near the Bayhead area as illegal dumping and pollution build-up blocking the rivers from a continuous flow and escalating flooding that takes place. This bridge is marked unsafe for residents and transportation to cross. The river mouths have become dark and foul-smelling, with water discolouration, and a strain put on established estuaries, marine life and wildlife. The swamp/mangrove areas of the Bayhead have been under constant threat from oil spillages and pipe leakages, and the canalisation destroyed many mangroves. This area is seemingly inaccessible to an ordinary individual unless they commute in the Durban Harbour the one can navigate through the industrial area, however traffic congestion in the Harbour area can become an obstruction from social and cultural enrichment.

As explored in "*The Role of the Port of Durban in Strengthening the Platform of growth in eThekwini*" (Arjunan, 2004). Several existing responses have been taken by the government towards improving the state of different sectors within the Durban Harbour and the surrounding cities. The Durban Events Corporation had introduced entertainment and recreational activities along the Point Waterfront to promote tourism and engage with the global audience. The Point Waterfront Development has revitalised the disconnect between the Port and society. It not only boosts the city's image but encourages economic growth and attract tourism. There are various rejuvenation schemes within the city and along the Point Waterfront that bring tourists and locals back into the city whilst providing pleasurable architectural planning and safe amenities. This includes parks, restaurants, local markets, cycle and running routes, and maritime activities.

ITRUMP (Inner eThekwini Regeneration and Urban Management Programme) along the Inner-City development focused on the revitalisation of dilapidated sites within the city to welcome future growth, and target safety and social issues. Urban Improvement Precinct presented the co-existence of the private and public sectors on working together to improve the urban fabric. The Waste Water Treatment Works created interventions to restore damaged ecosystems like the mangroves and remove any source of pollution that they have caused. They focus on upgrading their systems to become more sustainable.

An Environment Education Centre was appointed to facilitate the natural swamp/mangrove area in Bayhead unfortunately, it has been under-utilised from a lack of promotion to attract visitors and locals. The Department of Environmental Affairs have expert researchers and scientists on areas affected by chemical spillage (from the factories alongside the local rivers) under observation and conclude that natural processes will allow the area to clean up over time as human interference might worsen the surrounding ecology. The National Estuarine Management Protocol in 2013 and the Integrated Coastal Management Act in 2008, are some of the laws and policies used to administer the ecology of the bay. Whilst the Estuarine Management Plan was set in place to identify the factors that impact the bay, regulate, and monitor these impacts, and provide opportunities to alleviate these factors.

1.3.3. Conclusion

There are key challenges identified within the Durban Harbour and the city surrounding it. These biophysical and socio-economic challenges play a crucial role in achieving sustainable development within the city. The challenges include; the privatisation of the port which slows new development, urban decay and blight, inadequate spatial planning of the industrial areas, insufficient accommodation and transportation available to cater for the rapid population increase, crime and the need for security, lack of marine and port infrastructure, limited accessibility to the port and ecological sites, ecological degradation that occurred as industries, businesses and accommodation expanded, lack of management on facilities regarding waste pollution and illegal dumping, increase in smell and air pollution from waste, exploitation of resources such as sand mining and quarrying up-river, and the deterioration of the water quality due to effluent, chemical disposal, and spillage.

Potential strategies towards the biophysical and socio-economic challenges need to be explored in reshaping the city and achieving sustainable development within the Durban Harbour and surrounding areas. These strategies include; cooperation and transparency between the private port authority and local government on facilitating a cohesive city, propose development and management programmes of blight and dilapidated areas, clustering land uses to maximise their potential and needs, provision of employment and skills development, provide innovative means of improving the quality of life within the city, increase safety within the city, improving the upkeep of rail routes and provision of adequate road infrastructure, preserve and restore vulnerable ecosystems, reducing pollution, and management plans set in place to ensure sustainable practices are being implemented within the Durban harbour and surrounding areas. Along with some of these strategies, awareness and education are crucial to the sustainable development of the Durban Harbour.

DEFINITION OF THE PROBLEM, AIMS & OBJECTIVES

1.4. DEFINITION OF PROBLEM

Mitigation towards carbon emissions, conservation of ecology, enhancement of the social quality of life, and renewable energy alternatives are key concerns to South Africa's sustainability. The negative impacts of trade development, and the importance placed on industry and transportation, has also contributed to the degradation of the Durban Harbour. Population increase, industrialisation and the rise of energy consumption within the built environment have created an unbalanced cycle of sustainable development thereby threatening the society, economy and ecology within the Durban Harbour. As the city evolves, so does the need for advanced building services to cater for a higher standard of living. Energy efficiency is required within the architecture to achieve this comfortable living or working environment. The lack of awareness and education within communities and industrial sectors on energy efficiency has also contributed to a cascade of biophysical and socio-economic challenges. Social consciousness and education not only enhance the social quality of life but builds up sustainable energy dependency. Innovative sustainable research is unavailable or inaccessible to the public due to withheld data exclusivity, affordability of energy solutions, reliability on renewable resources, the lack of funding to conduct comprehensive research, as well as the lack of architecture in place to aid in the collection and advancement of research. These overall challenges have caused stagnation in the progressive development and implementation of clean energy production (Nahman. A, Wise. R, De Lange. W, 2009).

1.5. AIMS

This research proposal will develop an architectural response through education and awareness towards the challenges of sustainable energy development on the Durban Harbour, as well as a mechanism that will foster the production of hybrid renewable energy. In turn, this architectural model will enhance Durban's sustainable development in combating its' biophysical and socio-economic challenges.

1.6. OBJECTIVES

- To investigate the contextual implications of energy development within the environmental, social, and economic systems of the Durban Harbour.
- To explore a sustainable architectural model of a renewable energy research facility that is responsive to the local context and aid in the alleviation of the biophysical and socio-economic challenges of the local context.
- To promote education and social consciousness towards hybrid sustainable energy through an architectural model.

SETTING OUT THE SCOPE

1.7. DELIMITATION OF THE PROBLEM

This research problem will attempt to identify the bioclimatic conditions and sustainable energy availability within the proximity of the area of study. The development of the hybrid renewable energy facility will consider the sensitivity of the surrounding area of study and local economic sectors. The scope of the area needs to be managed on a smaller scale to ensure its effectiveness. Availability of research collection and cost dependency will be a constraint to the implementation of the proposal. This research will aim to persuade and influence government applications for future sustainable planning.

1.8. DEFINITION OF TERMS

Biodiversity is the rich diversity of species that thrive together in a system and have the natural ability to bounce back through stress.

Biophysical and Socio-Economic challenges are interrelated concerns that are social, economic, and environmental. They are considered through undervalued public goods. E.g., Pollution, Biodiversity depletion, Crime, Food insecurity, Non-renewable resource exhaustion~~,~~ and Climate change.

Clean Energy is a power source that is reliant and efficient in the production and supply of electricity, with greenhouse gas emission reduction technology. It maximizes the potential of abundant resources such as water, wind, solar and biofuel, which do not threaten ecosystems. It is a form of green infrastructure which features zero to low greenhouse gas emissions that have a low impact on the environment.

Energy Efficiency is a global normative action taken towards reducing greenhouse gas emissions and improving the utilisation of energy that is consumed.

Ecological Footprint is the impact a person/country has on the planet based on the number of resources they need to consume. This includes land, water, and natural resources. To decrease one’s footprint, it means that they should replace to the environment that which one takes.

Ecosystem Services is the natural dependency placed on healthy biodiversity’s and the benefits they provide in terms of reliance on health, social, cultural, and economic needs. This includes Absorbing and filtering air and water pollution, controlling floods, regulating micro temperatures, provision of recreational opportunities and a sense of place, and agricultural opportunities.

Futurity is defined as natural and social capital that is passed down to future generations to ensure an equalling of living within supporting ecosystems.

Green Economy is the fostering of economic growth and improving social equity whilst decoupling natural resource usage and environmental impacts.

Hybridity is the combination of two different elements to create a new third element. Concerning energy generation, hybridity will allow for multiple sources of renewable energy to be produced at any given time to maximize its potential.

Renewable Energy is a natural source of energy that will not deplete when it is used but does naturally replenish within a human lifetime.

Sectors refer to the keys economic sectors within South Africa such as Residential, Local Authority, Industrial and Commercial, and Transportation.

Social & Physical Implication with regards to Poverty and Inequality; Land Transformation through Soil degradation and Deforestation, Invasive Alien Species, Human-induced impacts of Pollution and Waste Disposal, and Climate Change.

Sustainable architecture attempts to create an efficient environmental approach to buildings using materials and methods of design, spatiality, and the direct connection to the ecosystem.

Urbanisation is resulted from rapidly growing cities due to an increase in various progressive social and economic factors. It has an impact on racial integration, economic growth, education, and the standard of living.

Urban Sprawl is the low density, unplanned, residential development in outlying areas of the city resulting in excessive vehicular travel for basic services and amenities. This is a result of suburbanisation where the population shifts from the central district to the outlying suburbs and commute through mass transportation systems. Urban Decay is the result of many sprawled areas being neglected and the cause of blight. These areas are derelict and poorly maintained.

1.9. STATING THE ASSUMPTIONS

A renewable energy research facility will be focusing on research and educational component to create social consciousness towards the sustainable energy challenges of the Durban Harbour, and allow for the hybrid renewable innovations to be researched and implemented within the Durban Harbour, whilst contributing to the municipal power grid. This intervention will in turn address the biophysical and socio-economic challenges of the area and mitigate carbon emissions and climate change. The futurity of this research will encourage other regions to establish similar interventions beneficial to that specific region.

1.10. HYPOTHESIS

The development of a renewable energy research facility will educate the public on the futurity of sustainable energy and the benefits of implementing hybrid renewable energy innovations within their community. This intervention will provide excess energy supply to the municipal power grid during peak demands, and in turn resolve the biophysical and socio-economic challenges of the area.

1.11. KEY QUESTIONS

1.11.1. Primary Question

1. How can a renewable energy research facility act as a sustainable architectural response to energy in the Durban Harbour?

1.11.2. Secondary Questions

1. What are the contextual implications of energy development within the environmental, social, and economic systems of the Durban Harbour?
2. How can sustainable architecture be used as an appropriate response towards renewable energy and alleviate the biophysical and socio-economic challenges of the Durban Harbour?
3. How can sustainable architecture be used as a tool to promote education and social consciousness and create an interdependency on hybrid sustainable energy?

<u>RESEARCH METHODS & MATERIALS</u>

1.12. INTRODUCTION

The research philosophy will be explored through an Interpretivism paradigm. This paradigm emphasises subjectivity on the need of "understanding the individual and their interpretation of the world around them" (Kivunja, Kuyini, 2017; 33). This dissertation will not only analyse the biophysical, social and economic systems of the Durban Harbour, but also the contextual response towards energy, and how all three systems might be interrelated or influence each other in any way. Therefore, a grounded theory methodology will be more suitable as a research approach. This allows for the data gathered to be interpreted and informed through interaction and cognitive processing. The grounded theory aims to connect evolving research to existing theoretical frameworks. "The procedures of grounded theory are designed to develop a well-integrated set of concepts that provide a thorough theoretical explanation of social phenomena under study" (Corbin, Strauss, 1990; 5).

A mixed methods research approach will be taken through semi-structured interviews and snowball referrals of 20 community members questionnaires that will be thematically analysed and graphically represented. The information collected will motivate and inform the sustainable architecture that is responsive to the context. All data collection will be thematically analysed and graphically represented for an insight into the study.

The methods of research will be divided into primary and secondary research. The primary data will be collected from interviews with key informants within the industrial sector of the Durban Harbour and with expertise on renewable energy development, and questionnaires of those within the context that experience the biophysical and socio-economic issues, and an observation on a local case study. The secondary data will be gathered through published books, journals, articles, papers, electronic media, and literature based on the theoretical and conceptual framework of Energy and Architecture, Sustainable Development, Hedonistic Sustainability, Hybridity, and case studies and precedent studies that will relate to the theoretical conceptual framework.

1.13. PRIMARY DATA COLLECTION

1.13.1. Interviews

The research will be conducted online-based or through minimal physical contact due to the Coronavirus (Covid 19) outbreak in South African, as well as globally. Semi-structured interviews will be conducted with; Transnet Engineering, situated within the industrial zone close to the Durban Harbour The Bluff Ward Councillor, whose area of demarcation falls within the Durban Harbour, will be interviewed to gain an understanding of the research they have conducted within the area and how it will relate to the challenges at hand, and with key informants to gain an understanding on the research they have conducted and how it will relate to the challenges at hand. These interviews will be used to gain insight into the systems that are required to counteract the challenges faced, such as the development of a sustainable architectural model and the proposed integration of a renewable energy research facility.

1.13.2. Questionnaire

Questionnaires will be conducted to a few members of the community, at different proximities to the industrial zones and port, to gain a better understanding of the issues about the contextual area of research. The research study will include the effects of the port and non-renewable energy on architecture within the context, and the social challenges that arise from those that interact with the Harbour. This questionnaire will aim to gain information on the significance of the energy services provided and the biophysical and socio-economic challenges that occur within this area.

1.13.3. Case Study

The study will focus on an architectural model that combats renewable energy consumption. This is where interviews with the community members will be conducted and observations will be taken to gain an understanding of the area. The data collected will include the investigation of the case study through research, visual analysis, and primary investigation. The case study will be investigated through the lens of energy, sustainability and hybridity. The case study that will be investigated is the Biorefinery Industry Development Facility (BIDF) within the Council for Scientific and Industrial Research (CSIR) in KwaZulu-Natal. The Council for Scientific and Industrial Research is multidisciplinary research and technology innovation centre that focuses on research and collaboration to find solutions on improves the quality of life of society, economy and the environment. Primary data, a site visit and an interview with a key informant will be conducted to gain a better understanding of the case study. The case studies will allow for direct observations on the architectural space, research and education, and implementation of sustainable energy.

1.14. SECONDARY DATA COLLECTION

1.14.1. Precedent Study

The precedent studies will be examined as a secondary source of data to gain knowledge based on the investigation of existing studies that relate to the research topic, theoretical and conceptual framework. The precedent studies that will be investigated are the Energy Academy Europe in Groningen, Netherlands, and the Copenhill / Amager Bakke in Copenhagen, Denmark. The precedent studies allow for an understanding of architectural space, the theoretical and conceptual framework of sustainability and hybridity, the implementation of architectural solutions toward energy sustainability, and an education facility based on sustainable energy.

1.14.2. Literature Review

The literature review will aim to explore the historic and current contextual analysis, energy development and its influence on architecture. This literature will gain further information on the relationship between energy development, sustainability and architecture on a global scale and then specific to the focus area within the Durban Harbour. The literature review will also gain knowledge of the site, history of the context, and current challenges within the context. The data will be collected through published books, journals, articles, and electronic media. Literature is extracted from various published references to gain further information about the research investigation and the relationship and impact of people and the environment so that there can be an understanding of architecture. The purpose of the literature review will be to further investigate this concept and formulate possible solutions based on previous research models.

1.15. THESIS STRUCTURE

Chapter 1 is the introduction that outlines the research background, justification of the research study, the study area locality, the research problem, aims and objectives, a delimitation of the problem, the definition of key terms, assumptions and hypothesis, key questions, and research methods and materials.

Chapter 2 is the literature review on energy and architecture. This chapter will analyse the development of energy in South Africa and Durban, and its influence on architecture. The analysis will be concerning the problem statement and research scope.

Chapter 3 is the theoretical and conceptual framework on sustainability concerning the context of Durban and energy development, the reshaping of research facilities as a solution to the problem statement and research scope, and the influence of hedonistic sustainability in energy and architecture.

Chapter 4 is the theoretical and conceptual framework on hybridity concerning energy development and architecture. The analysis will be concerning the problem statement, aim and objectives.

Chapter 5 is the investigation of the precedent studies that are relevant to the literature, theoretical and conceptual framework, and architectural analysis that is significant to the research aim and objectives.

Chapter 6 is the investigation of the case study relevant to the literature, theoretical and conceptual framework, and architectural analysis that is significant to the research aim and objectives.

Chapter 7 is the analysis and discussions of the interviews and questionnaires conducted. Conclusions will be drawn to gather research findings.

Chapter 8 is the concluded research that will provide the necessary recommendations needed for the architectural design component of the dissertation.

CHAPTER 2

ENERGY AND ARCHITECTURE

2.1. INTRODUCTION

This chapter investigates the historic and current development of energy within South Africa, namely the city of Durban, and how it has influenced architecture. The research includes the factors contributing towards the energy demand and the effect it places on the economy, society, and environment. Some strategies and approaches through sustainable development and green economy are set out by the government to alleviate the use of fossil fuels and produce renewable energy, which are key factors considering the sustainable way forward.

The use of natural resources had been a fundamental component of the development of the cities. Urbanisation and development have put significant pressure on these already threatened natural resources and ecosystem services. Population boom and increased urbanisation have led to the need for the security of conserving natural resources, which results in the built environment disturbing these existing ecosystems that are meant to be supporting them.

Urban sprawl within the Durban Harbour occurs as social, commercial, industrial and residential sectors are further away from each other. This puts pressure on the resources – such as infrastructure, energy and transportation- that need to span throughout all these sectors to cater for them. The lack of governing policies on the management of natural resources, as well as sustainable urbanisation, is a contributing factor to the deterioration of ecosystems within the surrounding environment (Gungapersad, 2012:43). The decline in biodiversity can be seen in the historical lack of environmental awareness and green infrastructure by building professionals during the conceptual stage and construction stage of the development.

The Diagram below created by the Student Energy Organisation explains that Climate Change is a key issue that is influenced by the production and consumption of energy due to the energy sector being the highest carbon dioxide emitter of fossil fuels. Energy is sourced through means of fossil fuels (i.e., coal and oil), alternative energy (i.e., Geothermal, and nuclear), and renewable energy (i.e., Solar, Wind and Hydro). The Diagram goes on to show that Solar, Wind and Hydro Energy can be converted through several means into Electrical Energy that can be distributed to an Electrical Grid, Smart Virtual Grid, Transportation fuels or Energy Storage. This Energy can then be used for power, lighting, transportation, heating, and cooling. By targeting the cleaner and more sustainable form of energy, there would be a decrease in resource depletion, an increase in energy security and ecological preservation and an uplift in the social quality of life.

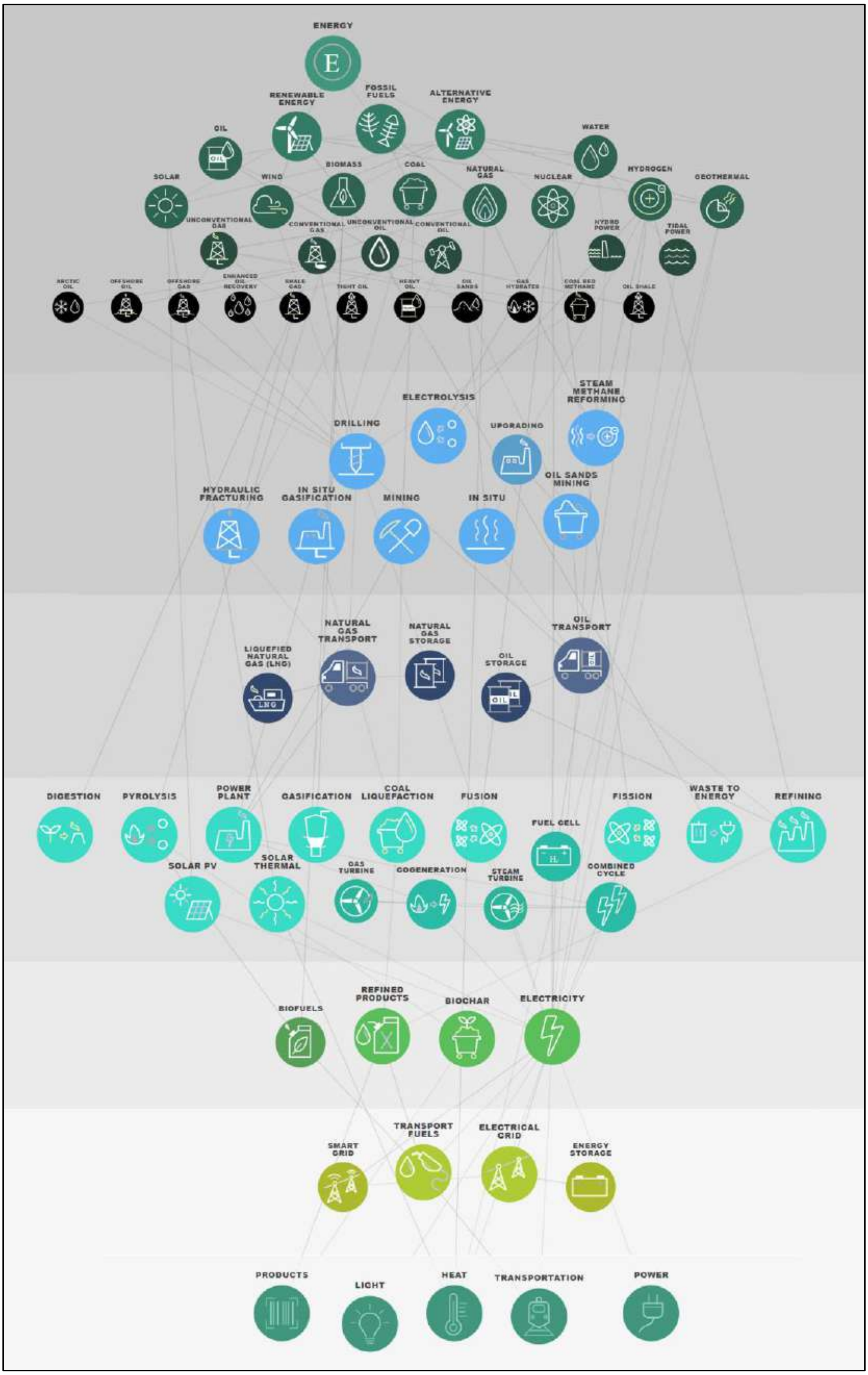


Figure 2.1: *The Global Energy Systems Map below shows the flow of Energy from the source, its production, the way it is transported, the conversion process, the form of energy produced and where it is utilised.*

Source: Student Energy, 2019

2.2. ENERGY DEVELOPMENT WITHIN SOUTH AFRICA

2.2.1. History of Energy Development in South Africa

Research and Development in South Africa were spread across five overlapping historical eras. The 1800s established an interest in astronomic research and the first Royal Observatory institution. This laid the research foundation on maritime navigation and geological exploration of natural minerals. The early 1900s focused on utilising the nation's natural resources for agriculture, marine and forestry research. Several institutes and laboratories were established afterwards. World War 1 played a prominent role in industrialisation and research development. Eskom was established after World War 1, along with Iscor and the Industrial Development Corporation, and the Council for Scientific and Industrial Research (CSIR) was established soon after. The mid-1900s gave significant focus towards military, food and energy security. This gave rise to the exploration of oil and gas by Soekor and parastatal organisations such as the Atomic Energy Board and Sasol played a higher role in governance. As the industries evolved, so did the demand for energy from Eskom. After apartheid was abolished in 1994, policymakers and stakeholders had to shift from segregation to an integrated global sphere. Research shifted from an isolated economic and political profit to a social benefit. South African National Energy Research Institute was then established. (ASSAf, 2014:23).

South Africa has constantly faced many challenges in developing the country as a modern economic hub. Industries and innovation contributed to its' economic development. Rapid urbanisation followed this economic growth. As the population within cities grew, many moved over to the outlying areas resulting in a sprawling movement. As the population increased, so did the production and consumption of natural resources. This demand for natural resources posed pressure on the environment for these resources to be extracted, resulting in ecosystems and diversity of species being threatened.

Due to urbanisation, cities within sprawl areas are highly susceptible to resource consumption compared to compact urbanised areas and industrial areas. Biophysical and socio-economic issues exceeded within these sprawled areas due to the population increase, as there is a large number of resources and energy dependency and green space occupancy for development (Yusuf, Allopi, 2010:418).

2.2.2. Current Energy Development in South Africa

Urbanisation plays a crucial part in economic growth as the population increases, demands for resources and energy increase. This can only be achieved through the economic development of sustainable management and resource production and consumption. The provision of infrastructure and architecture will aid in the implementation of a sustainable and green economy. Architecture that implements energy efficiency is one of the focus areas of challenges faced in South Africa. The South African Green Economy aims to develop and manage energy efficiency strategies, wide accessibility to clean renewable energy alternatives and balance the production of sustainable energy to energy consumption. The integration of a green economy promotes the concepts of sustainable development.

Renewable Energy has yet to make a breakthrough in South Africa. Investments are essential for national targets to be met and off-grid systems to be implemented, especially in areas of low economic standing. Apart from investments, there is a lack of priority in educating and establishing awareness on the benefits of energy efficiency. Long term energy security and accessibility are also primary challenges that have not played a prioritised role in South Africa's energy development.

Coal has always been a primary indigenous resource that South Africa has relied on for energy and power supply. However, coal is a finite resource. The majority of this non-renewable resource is utilised within the industrial sector for electricity and the transportation sector as fuel sources. In 2008, The Department of Science and Technology devised a 10 Year Innovation Plan for leading energy organisations to advance in clean innovations, the development of local expertise on nuclear energy generation, to advance with global trends on renewable energy technology, and the inclusion of hydrogen technology in South Africa's growth (ASSAf, 2014:25). Many renewable energy projects had been funded for implementation rather than research. Funding in this sense is spent timelessly rather than being invested for research inducing long term benefits.

Adhering to the global citizen responsibility in 2009, the South African government announced its' reduction in greenhouse gas emissions to 34% by 2020 to mitigate climate change. The reduction was through the country's transition from coal-intensive energy production to renewable energy alternatives. To achieve this transition, there needed to be social development, energy security and economic expertise. The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) was introduced to grow the country's reliance on renewable energy technology. Investments increased the security of this growth. This Programme aided the diversity of energy supplied throughout the country through; solar, wind and bioenergy resources (ASSAf, 2014:43). The affordability of renewable resources needed to be cost-effective to attract the interest of investors, stakeholders, and the public. This is achieved through local manufacturing and available local materials.

According to the State of Energy Research in South Africa report, the cost of solar energy alternatives has decreased over the years, making it more affordably competitive compared to the non-renewable energy supplied by the municipality. This report states that hydropower is limited due to the water restrictions and number of small rivers running across the country, and its' capability of contributing to more small-scale energy generation facilities. However, hydropower plants established throughout the country prove that hydropower can cater for large-scale facilities and local communities, and the generation of hydropower extends to the tidal power of the sea. There has not been much innovation for tidal energy and wind energy that is easily accessible along with a majority of South Africa's coastal regions.

According to the State of Energy Research findings, renewable energy researchers have discovered that there is always a lack of social capital and long-term research funding in their field with an estimate of R600 million p.a. allocated towards research, however, only R12 million is contributed by the private sector (ASSAf, 2014). This funding is not conducive due to the implementation of renewable energy only appealing to a small economic market. This market includes rural priority areas with small scale off-grid systems and suburban areas. These areas are predominant within South Africa therefore progress and employment are essential. However, The REIPPPP may be able to change that. There is also a lack of inter-participation between global and national expert researchers and institutions. With this, a lack of management from private companies and independent power producers contribute to the process and funding of the field. There is insufficient funding and inadequate facilities granted towards research especially within areas that have access to those resources (ASSAf, 2014:49).

By investigating the diagrams below, there is an immediate consciousness towards South Africa's impact on being a top 20 carbon contributor on a global scale. This is in opposition to the aim of being a sustainable global citizen. These statistics also highlight the primary non-renewable contributors to global carbon emissions.

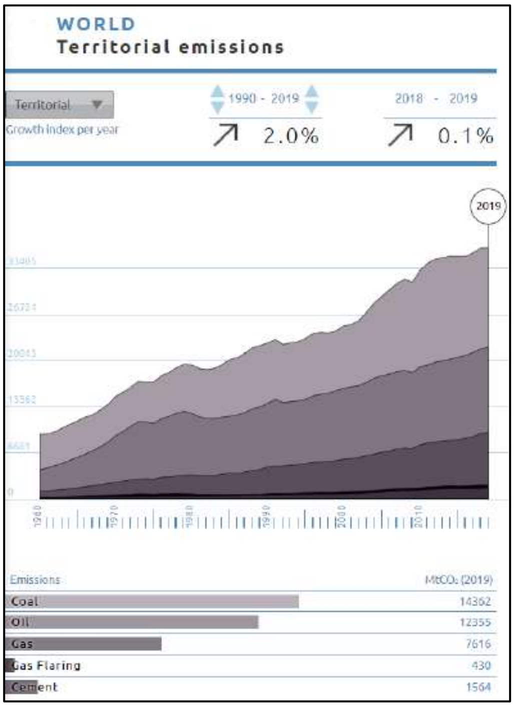


Figure 2.2: *This Diagram shows the increase of prominent global CO2 emitters between 1960 to 2019. The highest emitter being coal and oil.*

Source: Friedlingstein et al., 2020

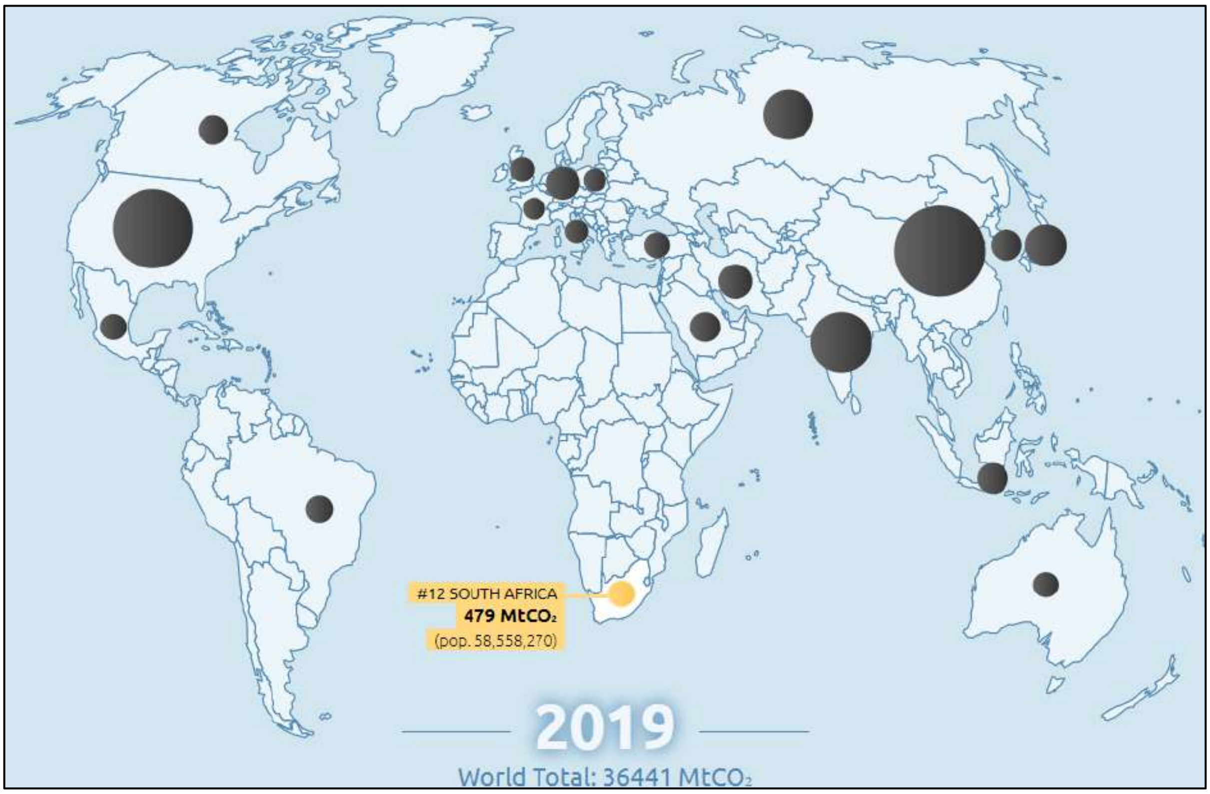


Figure 2.3: *This Map shows the Top 20 Map of Global CO2 Emissions in units of 1 million tonnes of CO2. South Africa holds the 14th rank of Territorial Fossil Fuel emissions in 2019. That includes gas, oil, coal, gas flaring and cement.*

Source: Friedlingstein et al., 2020

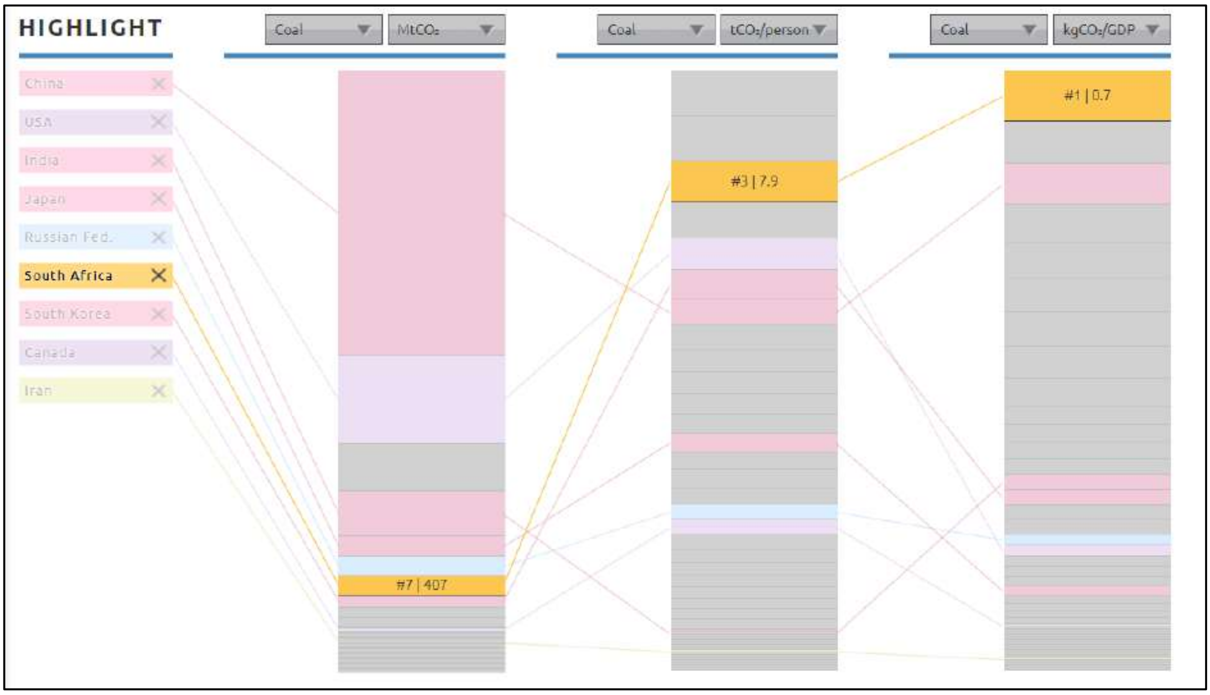
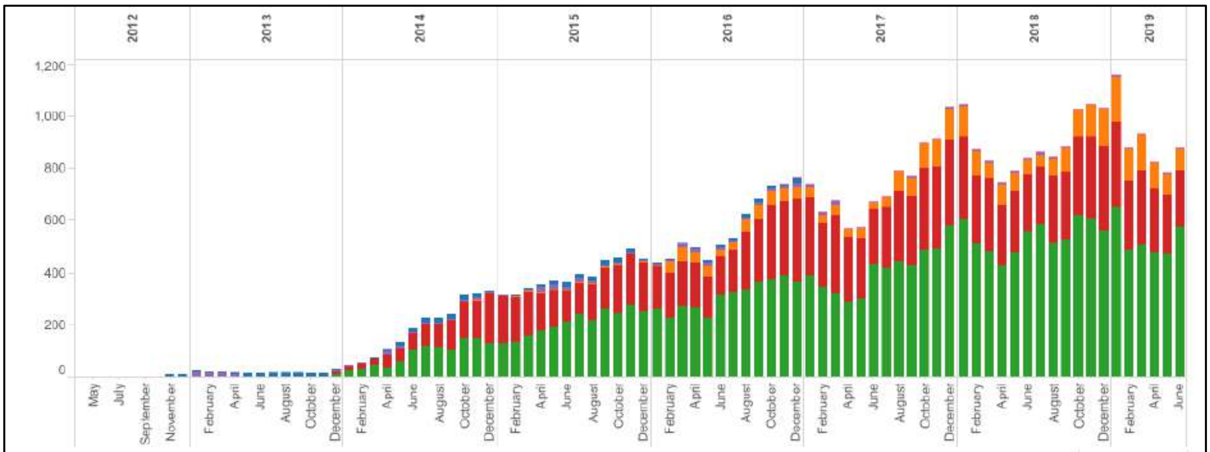


Figure 2.4: *This Diagram shows the CO2 Emissions in South Africa through the use of Coal and its ranking on in the global sphere. MtCO2 is per 1 million tonnes of CO2. KgCO2 is the carbon intensity of total CO2 emissions divided by GDP. TCO2 is the tonne emissions per person. It can be deduced that South Africa holds a high ranking towards carbon emissions.*

Source: Friedlingstein et al., 2020



Technology Category	2012	2013	2014	2015	2016	2017	2018	2019	Grand Total
Onshore Wind Power		10	1,057	2,484	3,698	4,924	6,467	3,161	21,799
Photovoltaic Power		19	1,008	1,946	2,509	3,249	3,212	1,569	13,510
Concentrated Solar Power					498	687	1,029	691	2,905
Small Hydro Power		82	62	122	102	101	75	22	567
Biomass Power	16	120	119	122	108				486
Landfill Gas Power							26	14	40
Grand Total	16	230	2,246	4,873	6,915	8,960	10,808	5,457	39,307

Figure 2.5: *Monthly Electricity Production (GWh) of Existing Renewable Energy in South Africa from 2012-2019*

Source: Department of Energy, 2019

2.2.3. Exploring Management Incentives towards Renewable Energy

Eskom is a primary parastatal company that deals with electricity generation, transmission, and distribution in the country of South Africa, and with partial contribution within Africa. This electricity is utilised in all sectors of the nation. Eskom generates an estimate of 95% of power throughout the country (Bloomberg, 2019). The Eskom Power Plant Engineering Institute is set in place to provide education and skills training within the technical field. The institute focuses on current and future necessities.

Over the last few years, the state has faced dire financial constraints in meeting the demand for energy generation and the maintenance of existing coal power plants. Eskom's biggest coal power plants, Medupi and Kusile, are failing due to the mismanagement of power stations, unexpected exceed in costs and corruption which has led to the implementation of 'load shedding' has weakened the development of the country (Areff, 2021). According to 2019 *Bloomberg* article, there were several renewable energy proposals in 2011 that were held back due to the governmental extortion of new nuclear energy plants. Eskom has an ongoing struggle towards the health impact on residents from the facilities generation of pollution. There is a need for private investments to aid in new infrastructure, therefore independent renewable energy producers were persuaded by the government into assisting the economy with reliable power. The innovative and sustainable solutions have become a global interest that most investors are willing to side with.

Jeffrey Radebe, serving as the former South African Mineral Resources and Energy Minister between 2018 and 2019, deduced that the global shift towards sustainability encourages South Africa to replace massive, centralised power stations with distributed generation and mini-grids, and batteries (Bloomberg, 2019). Energy development will play a catalytic role in improving the economic growth of the country. This is achieved through innovative feasibility, economic growth, social involvement, and political will. Labour unions have expressed their concern about possible unemployment due to the rapid development of renewable energy production. Unfortunately, this concern is highly miscommunicated, rather education and training play a vital role in securing employment and awareness. The current South African Mineral Resources and Energy Minister Gwede Mantashe acknowledges that renewable energy has a way of increasing the generation capacity whilst creating industrial opportunity and building a resilient economy (Creamer, 2021). In 2021, Mantashe sets to procure more energy from various sources to supply to the electricity grid 2022, the majority of 6800MW coming from renewable sources. This will alleviate the current energy crisis and allow for suitable maintenance on existing failing infrastructure. However, the use of coal will not change the country's climate change responsibility. The REIPPPP will be able to generate faster and more affordable renewable energy to the grid.

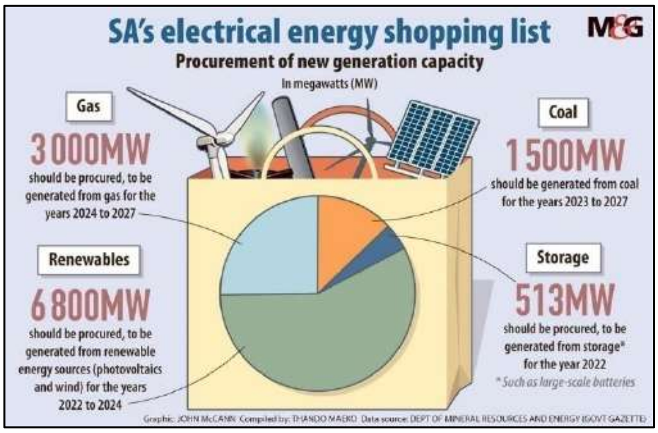


Figure 2.6: *This Picture depicts the amount of new energy that will be procured by the government from 2022.*

Source: Maeko, 2020

Several large-scale companies have been established to focus on the growth of renewable energy projects around the country. These privately-owned companies include Mulilo, Juwi, Gobeleq, Biotherma Energy and so on. In wake of the energy crisis taking place in South Africa, the G7 Renewable Energies Pty Ltd is constructing Africa's largest Oya Energy Hybrid Facility in Matjiesfontein, near the border of Northern and Western Cape (ESI Africa, 2021). The project is set to begin at the end of 2021 with an estimated contracted capacity of 128 MW. Competing with the global market, this project is expected to exceed technological advances, efficient energy storage, and generate affordable wind and solar energy. The site was investigated through criteria of resource availability, appropriate topography, grid proximity, accessibility, and ecological constraints. This project will boost economic development and sustain local communities. Extensive research needs to be recognised within other regions of the country to apply similar hybrid projects within vulnerable communities.

2.2.4. Durban's Strategy on Energy within the Sustainable City

The eThekwini Municipality is the metro authority that manages the city of Durban. Durban is a coastal city with a multicultural society that reside within rural and urbanised areas. These diverse cultures add to the city's multicultural experiences. The effects of carbon emission are evident within local communities, especially those that reside adjacent to industrialised areas. The eThekwini Municipality devised an Energy Strategy in 2008. The eThekwini Municipality Energy Strategy aims to "encourage sustainability in the energy sector development and energy use through efficient supply-side and demand-side practices and increased uptake of renewable energy sources, thereby minimizing the undesirable impacts of energy use upon human health and the environment, particularly climate change and contributing towards secure and affordable energy for all" (Mercer, 2008:2). A low-carbon economy focuses on the mitigation of natural resource consumption and environmental impact through the development of clean energy initiatives. Environmental and natural resource management protects vulnerable biodiversity's and ecosystem services through climate adaptation and mitigation initiatives of resource management.

The Durban Strategy identifies trade, manufacturing, and tourism along the coast as being significant sectors that contribute to the city's economy (Mercer, 2008:1). This Strategy focuses on; improving social health and ecological welfare, encouraging sustainability in every sector, increasing the usage of renewable resources, mitigating against climate change, and establishing provisions for affordable energy (Mercer, 2008:4). The establishment of a renewable energy facility that will produce alternative-modern sustainable carriers for the generations to come, is one of South Africa's long-term goals. These alternatives will optimise the efficiency and utility of renewable energy. Although energy generated is primarily dependent on non-renewable resources, over the years investment in renewable sources has grown immensely. These forms of renewable energy will radiate from solar, wind, hydro, and biofuel. Energy efficiency practices in architecture are significant, as 50% of global greenhouse gas emissions are contributed from the built environment (Knox, 2013). Architecture is transformed to tackle greenhouse emissions as it is a major contributor. Currently, LEED and Green Star rated buildings achieve sustainable and energy-efficient standards. Standards that are appropriate to the context are adopted from the National Building Regulations.

By studying the FIGURES 2.7, 2.8 and 2.9 below, it is concluded that the majority of energy demand is needed within the industrial and transportation sectors of the Durban region. This in turn results in the highest CO2 emissions is generated from these areas. By supplying renewable energy to the industrial and transportation sectors of the Durban region, will alleviate the strain placed on threatening natural resources being extracted for energy demanded and decrease the excessive carbon emissions radiated from these areas. An architectural model of a research facility can be implemented to promote awareness and educate communities on the benefits of renewable energy and how the low demand for energy within the industrial and transportation sectors can impact their lives for the better.

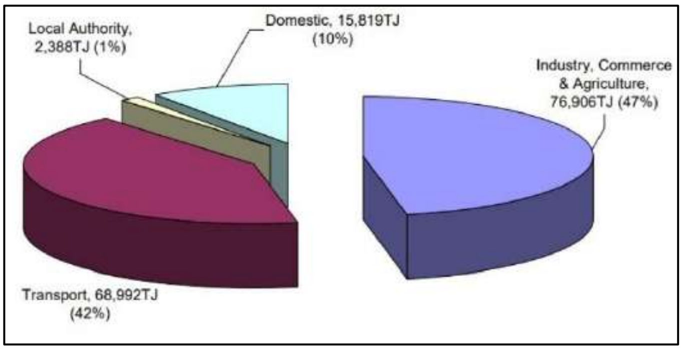


Figure 2.7: *This Diagram indicates the eThekwini Energy demand within the Prominent Economic Sectors*

Source: Mercer, 2008:4

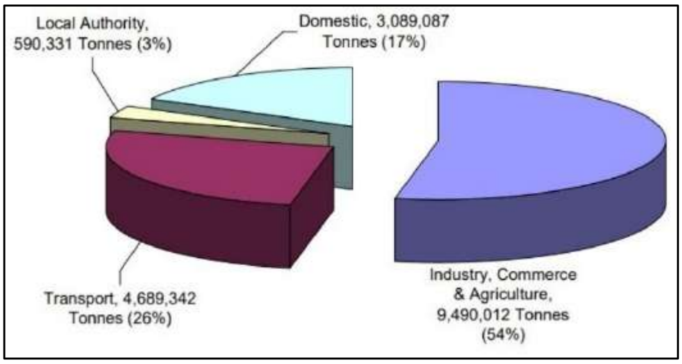


Figure 2.8: *This Diagram indicates the eThekwini CO2 emissions within Prominent Economic Sectors.*

Source: Mercer, 2008:5

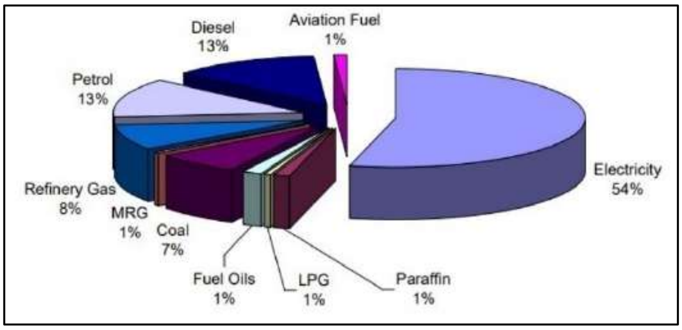


Figure 2.9: *This Diagram indicates the eThekwini CO2 emissions according to Prominent Energy Usages*

Source: Mercer, 2008:5

2.3. ENERGY DEVELOPMENT AND ITS INFLUENCE ON ARCHITECTURE

This section will highlight the beneficial significance of the green economy and how green building has contributed to architecture. There will also be an investigation on the production and generation of renewable energy systems within Durban. The area of study places a crucial role in analysing the availability of natural resources that would aid in creating renewable energy. The investigation of innovative renewable energy strategies will also be explored. These strategies will encourage education and research to be developed, advancing the country in the global market. The key strategies will be extracted from solar, wind, hydro, and tidal energy.

2.3.1. Energy in the Built Environment

The built environment requires energy and power generation to control systems such as; HVAC (heating, ventilation and air conditioning), noise transmission, insulation, and electrical power. Over the years, energy consumption has increased to maintain buildings. This is due to the increase in population, the higher standard of living, the longer period spent within buildings, and the enhancement of building services available. Energy consumption varies on several factors: the location, bioclimate, the building typology, the building services and maintenance, energy systems, the occupants' activities and quality of spaces, and the indoor environmental quality (Sonetti, 2013: 8). The essential need for energy within buildings is to maintain a comfortable living and working environment. Energy is needed to establish this sense of spatial and thermal comfort.

Occupants within small flats require less energy due to the small transfer space, whilst occupants within high-edge buildings will require more energy due to high-performance appliances. The main energy users come from HVAC, then lighting and appliances. A commercial and retail building consumes a larger amount of energy than residential buildings and releases more carbon emissions. Social awareness plays a crucial role in establishing rapid energy conservation. By promoting energy consciousness directing to the public, people would have a better understanding of their interaction with energy usage daily.

There are many existing buildings, particularly within the Durban CBD, that are older than 40 years. These buildings are at a slow process of being retrofitted and renovated that will improve their energy performance and reduce emissions. This can only progress if there is more environmental awareness and education on sustainable development and the implementation of sustainable building energy policies. Regulative policies will improve the energy efficiency within buildings and raise social awareness of the benefits of these practices. Retrofitting practices are not necessarily large changes, but small improvements such as window replacements would make a difference to the heating and lighting of the internal spaces.

Energy efficiency within the built environment can be improved by implementing active and passive energy efficiency strategies. Active strategies include HVAC systems, electrical lighting etc. Renewable energy strategies are also considered active strategies. There is an on-site supply of energy within the building such as solar photovoltaic panels, small wind turbines, solar thermal and heat pumps. Off-site energy supply includes large systems such as hydroelectricity, biomass, solar and wind farms. Passive strategies include the design of the building envelope, natural ventilation and lighting. Passive systems seem to be the most viable to solve the ongoing energy crisis and environmental effects. Passive design can be dated back to vernacular architecture. The design of buildings and spaces has progressed over time through trial and error. The influence of vernacular techniques and design aid sustainable architecture to develop and suit the region it sits within, whilst applying cost-effective methods and local materials. Active and Passive strategies act as a hybrid approach where one system can rely on the other for energy conservation.

As the built environment progresses in the future, there will dramatically transformation in energy efficiency, the reliance on less polluting energy resources and the contribution of sustainable material production through the life cycle phases. Buildings need to be considered holistically as dynamic systems that work together to provide comfort. The biophysical, social and economic impacts throughout the design to construction phase are crucial if energy efficiency is to be achieved. Policies and initiatives can provide advanced technologies and environmentally friendly solutions. In turn, reducing the energy demand from the built environment and educate the public on energy-saving potential (Sonetti, 2013: 11).

2.3.2. The South African Green Economy and its Implementation in Sustainable Architecture

The Green Economy stems from the plunge of the global economic crisis in 2008 that also resulted in the decline of valuable nature-based assets. Development out a strain on natural resource demands. The United Nations Environment Program proposed a Global Green New Deal that aimed to achieve an efficiently managed economy that provides high employment and economic growth whilst minimising environmental risks and low carbon emissions. This initiative was slowly integrated into the economy through sustainable architecture, retrofitting of energy efficiency in buildings, adopting renewable energy usage in technology, sustainable transportation technologies, and restoring ecological infrastructures, such as adequate clean water and freshwater capacity (Sutherland, 2018: 19). These initiatives not only mitigate environmental risks but decrease poverty and increase social equity and security of resources by improving the quality of life, especially in areas that rely on ecosystem services for self-sufficiently.

Sustainable Development in South Africa highlights the importance of a green economy that will uplift the country and mitigate many biophysical and socio-economic challenges. This can be executed in multiple sectors and stakeholders in society including government, business, and individuals. These approaches can be achieved through policymaking, initiatives, and educational programmes.

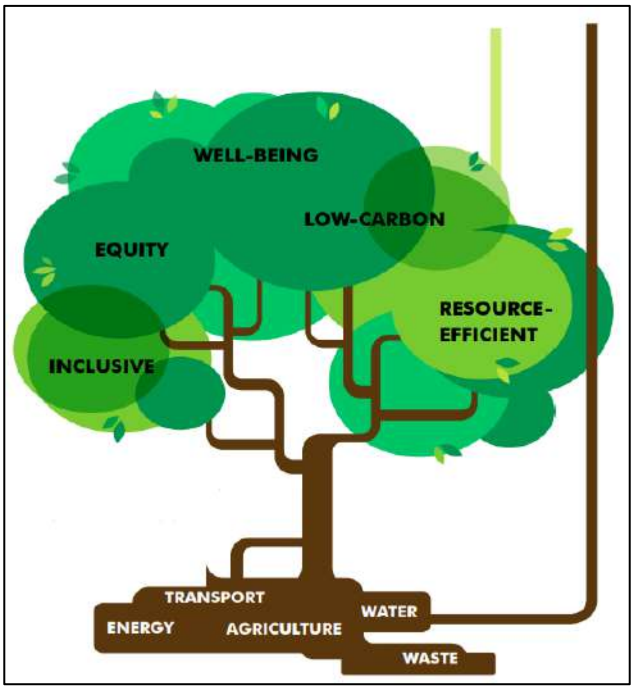


Figure 2.10: *The Diagram represents the Key Characteristics that defines the Green Economy in South Africa*

Source: Stafford, Faccer, 2017:40

According to *The Green Economy* (Sutherland, 2018) and *Steering towards a Green Economy* (Stafford, Faccer, 2017), Green Growth and Sustainability can be achieved in Architecture through various approaches, such as.

- Green tourism involves rural areas.
- Retrofitting of existing buildings with energy efficiency strategies.
- Research and adopt renewable energy production such as solar and hydro.
- Provide inclusive accessibility to clean energy services.
- Green building design and green building materials and methods of construction.
- Establish efficient planning of urban environments.
- Improve spatial planning of transportation systems. Promoting mass-transportation systems that introduce low emission transportation such as cycle and walking.
- Secure and restore dwindling natural resources such as water and food.
- Management of waste by recycling, reusing and reducing.

These focus areas can be applied in any region to combat the biophysical and socio-economic challenges and improve the social, economic and environmental futurity within that region.

Spatial and urban planning allows for society and services to connect and be easily accessible, whilst densification prevents urban sprawl. By creating and protecting green spaces within urban areas, ecosystems are less vulnerable. These green spaces with the provision of efficient transportation will lower the deterioration of the air quality within the area and increase workforce productivity as these spaces act as a breakaway space for commuters. Mass transportation systems also discourage large parking areas.

Green building design optimises the use of energy through analysis of the context, building orientation, materials and technology utilised. The initial focus was on commercial buildings, but with increasing investment, residential and public buildings have followed suit. The National Buildings Standards added SANS 10400 XA energy efficiency guidelines to ensure that new buildings adhere to sustainable codes. The Green Building Council of South Africa introduced the Green Star SA Rating system that set sustainable guidelines that could be used in architectural design, construction, and management of a building. Awareness is raised by reducing the environmental impact of the development and promoting an integrated sustainable system. (Stafford, Faccer, 2017:46). Energy efficiency strategies can be implemented and managed to mitigate the demand placed on resources for energy supply. These green building designs include insulation systems, passive cooling and heating, renewable energy usage, rainwater management, reduction of waste, resource-efficient building materials, energy-efficient lighting, solar water heaters, smart electrical meters, and enhanced smart appliances. This can be applied to new buildings and retrofitting of existing buildings. The benefits of these green building strategies will encourage others to part-take. This will also increase employment rates. Although the cost of these green buildings is slightly higher than a conventional building, the operational costs over time reduce the overall cost.

For energy efficiency strategies are to be achieved in architecture, renewable energy resources need to be investigated. Based on the contextual analysis of the Durban Harbour, the next section will explore of availability of various renewable energy resources within the context.

2.3.3. Investigating Renewable Energy Resources Accessible on the Durban Harbour

Durban has various types of renewable resources available however these resources are not necessarily reliable to the region's climatic conditions. There is an evident link between sustainable development and renewable energy as they rely on the other to encourage sustainability. Renewable sources easily available in Durban include solar energy, wind energy, hydropower, and biomass energy. Hybridity within energy deals with various systems that work together to capture energy efficiently and produce energy on a continuous demand. Renewable energy ensures the futurity of energy security will have minimal impacts compared to the conventional non-renewable sources. Once the energy has been harnessed, the excess power can be stored in an energy power storage system.

Examples of Renewable Energy Applications used in Architecture include Solar panels mounted on rooftops, car parks and canopies; Thermodynamic Panels and Building Integrated PV panels installed on the building façade; Solar Heat Pumps; Solar Chimneys; Micro-Wind Turbines and Vertical Axis Wind Turbines. (Ogunkeye, 2019).

- **Solar Energy**

Solar energy is abundantly available throughout South Africa. This has the potential for clean and reliable energy production. This source is limited by the variations in sunlight visibility, season, and location. Solar energy can produce more than 10 000 times more electricity than that needed on a global scale (Tran, 2019).

Through contextual analysis, Durban falls within the Climatic Zone 5 – a humid subtropical climate with high summer rainfalls and mild winters. The Durban coast is affected by the maritime climate where there is a slight temperature difference during the day and night, and there are longer days during the summer due to the high sun angle. The Durban Harbour has a low-lying topography with sparse industrial building density and low to medium-high building typologies. This allows for many sites within the Harbour to have full access to the north orientation of the sun, for solar energy to be harvested.

Solar energy can be captured in two forms: passive solar and active solar. Passive solar energy is the immobile means of capturing direct and indirect heat for the energy produced. This is executed through design elements such as greenhouses. Active solar energy has mechanical components that use electromagnetic radiation to produce electricity. This is executed by heat-carrying liquid flowing through mechanical systems such as pumps and fans. Solar thermal can be used in commercial or residential buildings.

Solar energy can also be harnessed through Photovoltaic (PV) technology, which uses semiconductors to convert direct sunlight into electricity. When the sun's rays hit the semiconductor within the PV cell, electrons are free and form an electric current. Solar PV has the advantage of transitioning electricity from large-scale centralised facilities to small-scale households at an affordable rate, a deficiency in smell and noise pollution, and require lesser expertise in the installation and repair process. It can also be harnessed through Solar Thermal energy that uses the suns heat to produce electricity and heating. (Tran, 2019). There is some form of emissions during the manufacturing process, but over time challenges of cost and efficiency have been resolved. Solutions have been made through grid compatibility, expertise, simple technologies with low maintenance, and the availability of materials needed.

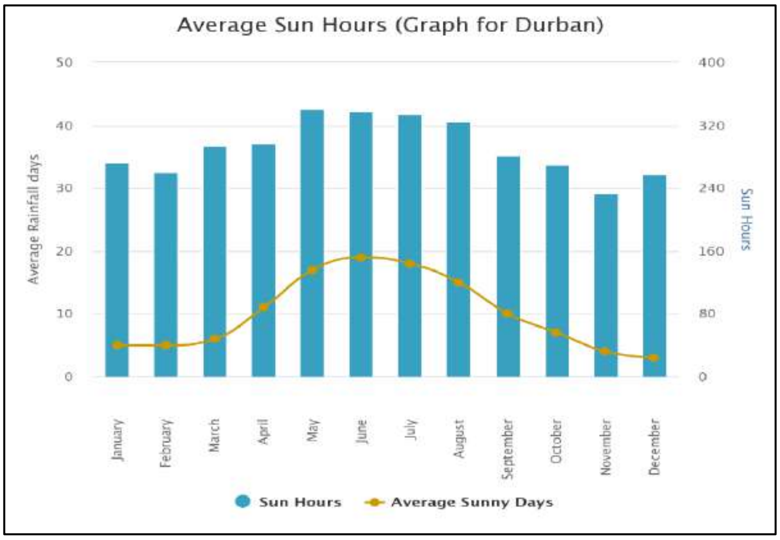


***Figure 2.11:** The Diagram represents the Monthly Average Sunlight hours and Sun Days within the year in Durban.*

Source: World Weather Online, 2019

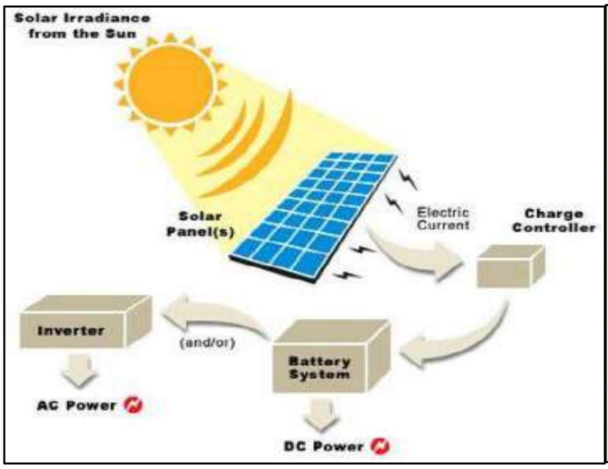


***Figure 2.12:** The Diagram represents the conversion of Solar Energy into Electrical Energy using Photovoltaic Cells.*

Source: Srinivasarao, Kumar, Ansari, 2014:4

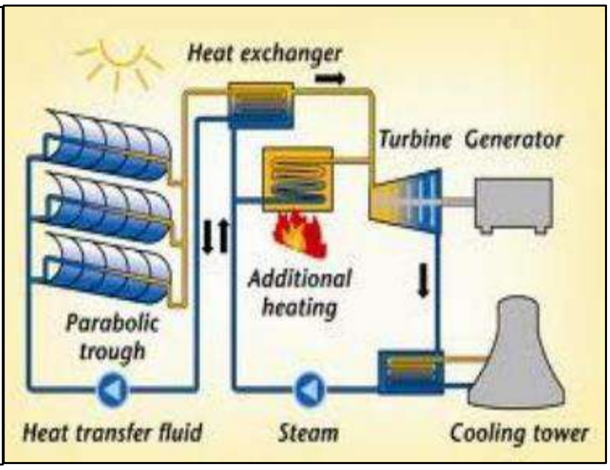


***Figure 2.13:** The Diagram represents the conversion of Solar Energy into Electrical Energy using Concentrated Solar Thermal Power*

Source: Srinivasarao, Kumar, Ansari, 2014:5

- **Wind Energy**

Wind energy is abundantly available along the South African coast and Western regions. This source is limited by the location, topography of the landscape, seasons, and physical obstructions along the landscape (Elen, 2019). Wind kinetic energy is the flow of air through differences in atmospheric pressure through mechanical components to produce electricity. Electricity is produced in an electromagnetic generator that is connected to a turbine that turns as the wind moves through it.

Through contextual analysis, Durban experiences pleasant onshore breezes during the day which are North Easterly winds, offshore breezes occur during the night which are North Westerly winds and harsh South Westerly winds. The Durban Harbour has a low-lying topography with high-rise buildings within the CBD on the North and a high Bluff on the South East. The Bluff acts as an obstruction from the harsh Southern and Western winds on the southern side and provides mountain breezes on the northern side. The high-rise buildings in the CBD and Point Waterfront allows for wind tunnelling to take place.

According to the online video by titled *Wind Energy* (Elen, 2019), The advantages of wind energy are the lack of emissions during the harnessing process, the system is safe, minimal costs and maintenance on the installation and operation process. However, wind speed variations, electric field currents, birds and noise may be a challenge. The architectural intervention would need to be placed within an area that can harvest wind energy with the highest wind speeds, such as areas on the northern side of the Bluff or closer to the high-rise buildings of the CBD or Point Waterfront. The Durban Harbour, even though a predominately industrial area, accommodate residential areas and ecological site. Hence, bird safety and noise reduction during wind energy harvesting can be a challenge. To prevent birds from striking the wind turbines, Innovation designs need to be implemented to increase the height and decrease the length of the blades, to increase the visibility of the blades through colour, and to cap the rotational speed of the blades so they do not spin too fast. Wind turbines would need to be on a smaller scale, and mechanisms would need to be applied to the turbines to mitigate the noise generated. The cost of wind generation has decreased over time as more wind energy interventions trending. Wind energy can be harnessed through a mechanical turbine system that uses the motion of the air through spinning blades to generate electricity.

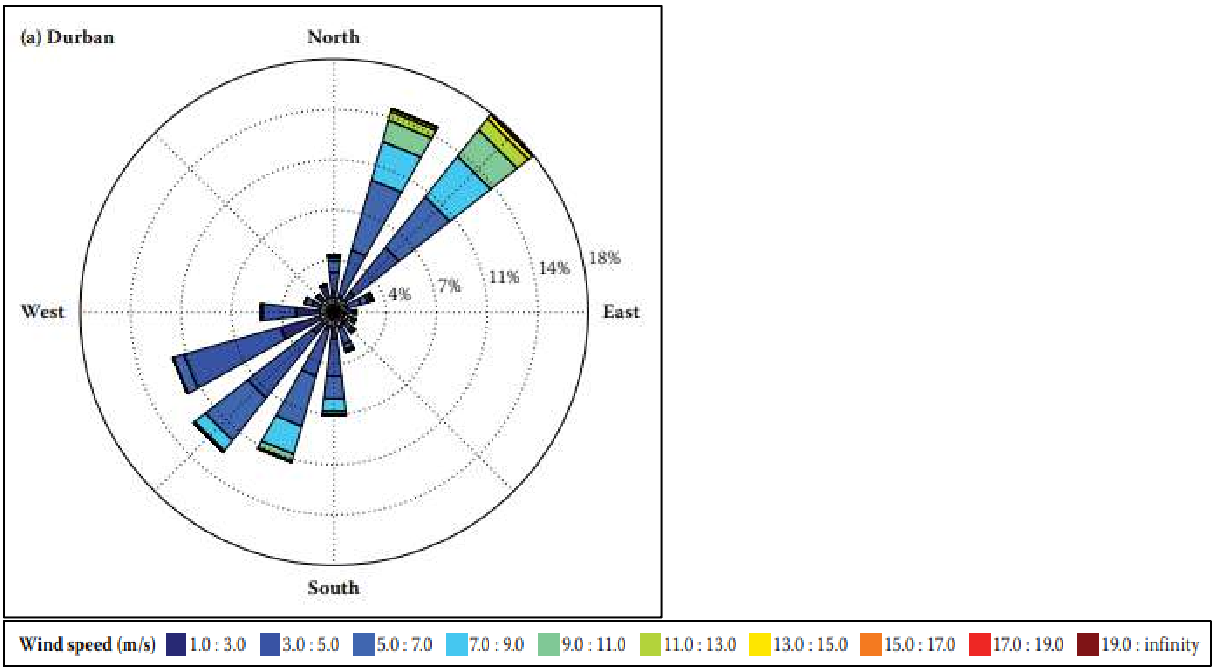


Figure 2.14: *The Diagram represents Durban's Wind Rose captured from 2007 to 2013.*

Source: Corbella & Stretch, 2019

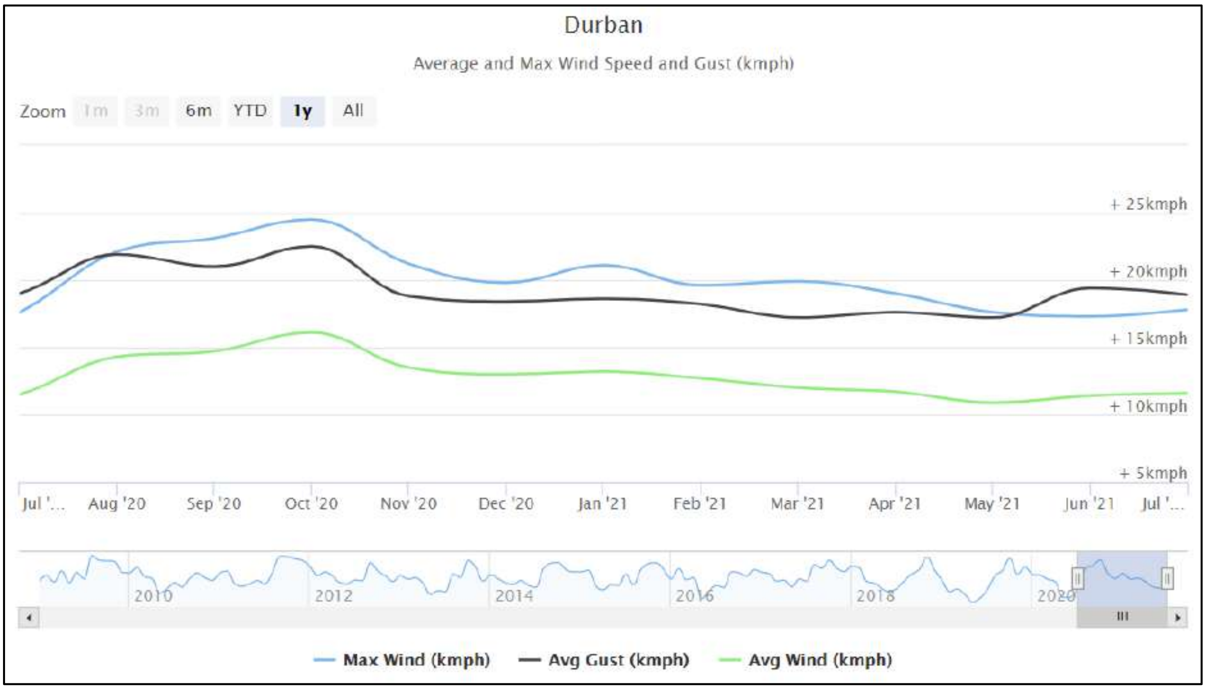


Figure 2.15: *The Diagram represents the Maximum and Average Wind Speed and Gust within the year in Durban.*

Source: World Weather Online, 2019

- **Hydro Energy and Tidal Energy**

Hydropower is abundantly available along the South African coast and inland river systems. Hydropower has the largest contribution of renewable energy and produces 6.7% of electricity globally (Muise, 2019). The advantages include reliability, provide a water supply, control flooding, and low output costs despite the high installation costs. This source is limited by the ecological degradation and local community displacement around the dams, and the emissions of greenhouse gas during construction. Hydropower can be harnessed in several systems and variations, one of them namely being a mechanical turbine and generator system that uses the motion of water through spinning blades to generate electricity.

There are three types of large-scale hydropower facilities for inland rivers; Impoundment, Pumped Storage and Run-of-River. The Impoundment facility exists within a dam, where water flows through turbines to generate electricity. The Pumped Storage facility exists within two dams that are at different levels, where water flows down through turbines to generate and store electricity and then pumped back up. The disadvantages of a pumped storage facility are the disruptive impact the dams and rivers have on the communities and biodiversity beyond the river. (Muise, 2019). Another disadvantage is the intensive energy resource that is required during the construction stage and when the water is pumped up from the lower reservoir to the upper reservoir. The Run-of-River facility lies on an existing river, where diverted water flows down through turbines to generate electricity. This disadvantage of the run-of-river system is the reliability of a constant run flow. Hydro facilities depending on their scale can produce from less than 100kW to 30 MW.

According to the Online video by titled *Tidal Energy* (Kabeya, 2019), Tidal energy is also a form of renewable energy source abundantly available along the South African coast that converts the energy produced by the ocean waves into electricity. The ocean water is 832 times denser than air, therefore wave energy can produce more power than air. Tidal energy can be harnessed through tidal barrages, tidal fences, and tidal turbines. The Tidal barrages are the most efficient, which is a dam that uses air compressed by the change in wave height to generate electricity. Tidal fences are like giant turnstiles and Tidal turbines are like wind turbines underwater. The tidal fences and turbines use mechanical components to generate electricity as the waves flow through the turbines. This source is limited by the nautical behaviour, spatial requirements needed for the facility, and the height of the waves that need to reach 5m ASL (between low tide and high tide). The advantages of tidal energy include easy installation, reliability, and the lack of greenhouse gas emissions.

According to Joubert and Van Niekerk's (2013: 34) findings of Durban wave power generation, the results were fairly low at a mean annual median of 10 kW/m. These results were taken from the recording station located on the shore of the Durban Oil refinery. Even though the energy generation is low in the southwest, recording stations can be implemented at various locations along the northern shoreline and within the Harbour for analysis. Through contextual analysis and study of onshore wind energy, The Durban Harbour mouth as seen in FIGURE 2.16 would be a suitable location for tidal energy to be harvested, as it is closer to the ocean and access to the North Easterly winds.

Figure 2.16: *Micro context of the Durban Harbour mouth with a suitable location to capture tidal energy*

Source: Author, 2021

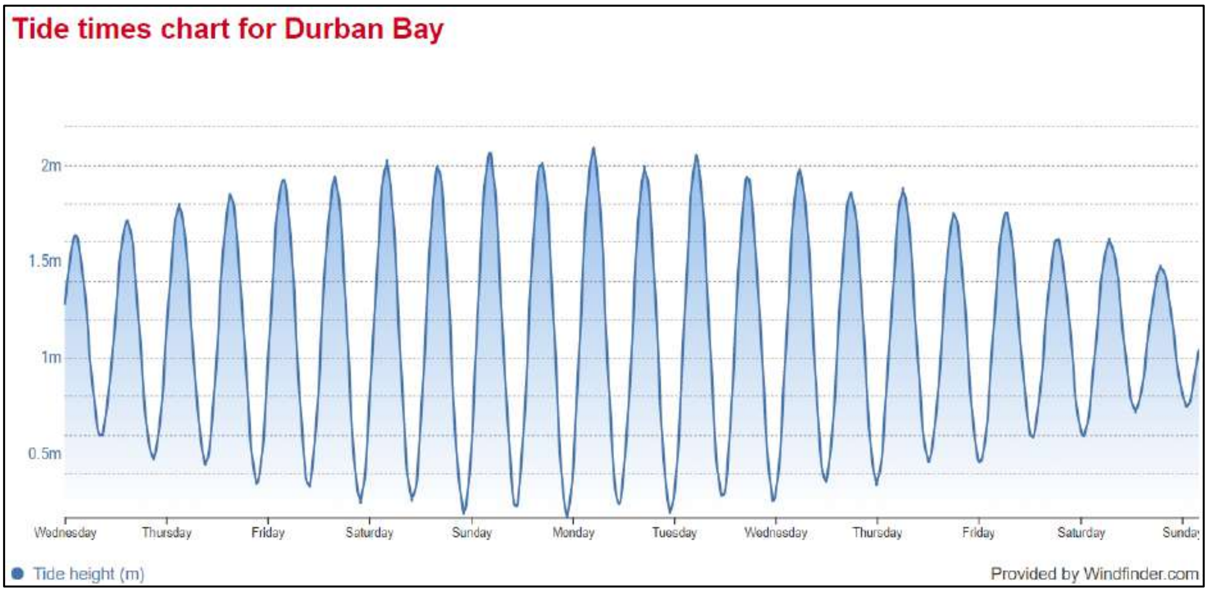


Figure 2.17: *This Diagram presents the Tide Time Chart during March 2021 in Durban Bay*

Source: Windfinder, 2019

2.4. CONCLUSION

This chapter concludes that with the adoption of an inclusive green economy, in a city or community can grow self-sufficiently and sustainably. They can rely on energy-efficient technologies and infrastructure that improves their quality of life and contribute to the futurity of other generations. With the energy development in South Africa turning to renewable sources, this alleviates the energy crisis being experienced and further contribute to the carbon emissions on a global scale. Reconsidering the biophysical and socio-economic challenges of the Durban Harbour in conjunction with the energy consumption in various sectors, there is a relationship that contributes to the energy demand. These challenges co-relate and affect the economy, society, and environment at different levels. Interventions are set out from a local to a national scale; however, funding, education and resource availability are key components to working towards a sustainable livelihood.

By studying the possible renewable sources of solar energy, wind energy, hydro, and tidal energy, available on the coast of the Durban Harbour, strategies can be investigated and implemented. This will contribute to the energy grid locally and nationally. For these innovative approaches to succeed, the public needs to be conscious of how to maximise the advantages and reduce the disadvantages. When these technologies are implemented, awareness and education will be available first-hand. The potential of these technologies will aid in future development that will intrigue investors and funding.

The next chapter will explore the theory of sustainability within the context of energy development in Durban and the built environment. The chapter will also show that by targeting the cleaner and more sustainable form of energy, there would be a decrease in resource depletion, an increase in energy security and ecological preservation, and an uplift of the social hedonistic quality of life.

CHAPTER 3

SUSTAINABILITY

3.1. INTRODUCTION

This chapter explores the biophysical and socio-economic challenges within Durban as a result of energy development in Durban and how sustainable development has contributed to the city's growth in the residential, industrial, local authority and transportation sectors. The chapter also investigates the reshaping of research facilities to allow for a more sustainable architectural approach towards social integration, digital infrastructure, and spatial planning. These approaches enable the city to progress in a sustainably hedonistic way that establishes a balance between improved quality of life and energy development.

3.2. DEFINING SUSTAINABLE DEVELOPMENT

The theory of sustainability in urban environments refers to the city's consumption of resources and production of waste that is of a lower level to the ecosystem carrying capacity whilst ensuring a level of futurity. Sustainability is responsive to urban challenges and social issues, and the dependency placed on ecosystems. Economic development plays a significant role in enhancing social well-being, in turn solving issues of environmental exploitation through mitigation (Romero-Lankao et. al., 2016:3-4). Sustainable development, as an overarching framework, is achieved through a transformative approach of collective core systems that are interdependent. These core concepts are Ecological Integrity, Social Capital, Economic Development and Governance.

Sustainability was introduced at the UNEP Stockholm Conference in 1972. The conference discussed the liberation of society from environmental challenges that were originally developed by them. There was a focus on an ideal habitable environment that rid of socio-economic concerns where awareness was promoted through education, and the interdependency of physical, social, economic, and political systems. Sustainability synthesised development and the environment. The issue arose within developing countries whereby access and affordability of achieving sustainability had to be dealt with in an immediate demand rather than compromising the futurity of sustainability. This was dealt with in the 1987 'Our Common Future' report at the United Nations World Commission on Environment and Development, also known as the Brundtland Commission. (Sutherland, 2018:12,17).

The 1987 Brundtland 'Our Common Future' report was set as a global agenda for change. This report focused more on ecological modernisation and defined sustainability and sustainable development through principles of:

- Responsive policymaking in the economy decreases the demand for resources.
- Social systems that redistributed benefits for equal development to occur.
- A sensitivity of production within the ecological carrying capacity.
- The development of innovative technology to improve the utility of resources.
- Initiatives that are supported through global alliances.
- And flexible governance of local participation.

The International Council for Local Environment Initiatives (ICLEI) outlined sustainability as development that delivers basic social, economic, and environmental needs without threatening the natural, built, and social systems that depend on it. Futurity to improve one's quality of life is essential. The World Conservation Union focused on increased the quality of life whilst living within the supporting ecosystem. This is relating to the application of Hedonistic Sustainability rather than its theory. Being the first in South Africa, the city of Durban consented to the Local Action 21 in 2003, adopted from the World Summit in 2002. Local Action 21 takes heed of local authority obligations and actions that ensure a social, economic, and environmental implementation of sustainable development.

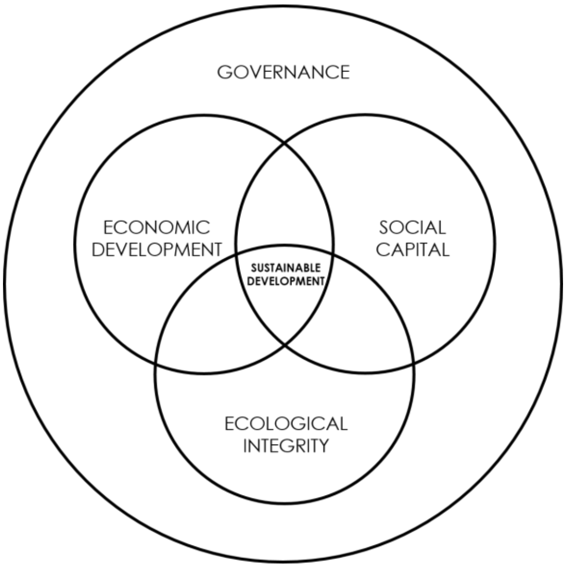


Figure 3.1: *This Diagram represents the Four Core Concepts of Sustainable Development*

Source: Author, 2019

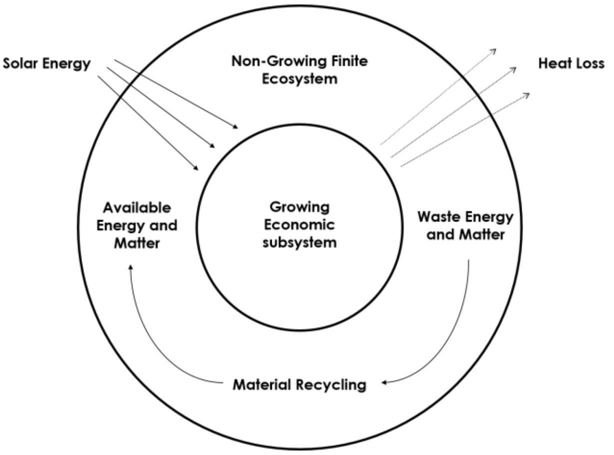


Figure 3.2: *This Diagram represents an example of Strong Sustainability achieved through a Transformative Approach.*

Source: Author, 2019

3.2.1. Core Concepts of Sustainable Development and its Implementation by the eThekwini Municipality

- **Economic Development**

Economic development is a global trend in which key informants at all levels of society, such as stakeholders and institutions within the public and private sector, collectively contribute towards the business sector of the region through influence and remove challenges that will hinge it. As these key informant's progress, so does the growth of the region. There is an approach for efficient and equitable utilisation of resources within the business sector. This is managed through budgets and investments. (Sutherland, 2018:24). The provision of affordable and efficient renewable energy, especially to the low-income sector, will contribute to the progressive wealth of the economy. This can be achieved by commerce and industries being encouraged to conduct their business in an energy-efficient manner and instil cost prepositions when delivering that energy. The intensive development of renewable energy technologies for resilient models to combat climate change, will strengthen the economy and provide employment. (Mercer, 2008:25). Employment will be provided in all stages of manufacturing, installation, retrofitting and operation. Participation in the development of energy will improve the productivity and quality of work-life at a rapid pace. (Mercer, 2008:69).

- **Ecological Integrity**

The value of nature needs to be recognised to maintain and conserve ecology. The carrying capacity of resources is essential and how they are utilised. The reduction of waste is considered and implemented to protect multiple facets of threatened ecology. Regarding energy production and consumption, there is concern about the extraction of fossil fuels, pollution, and effluent. The most detrimental impact on the environment within Durban is air and water pollution. The effects range from local species and people within the micro context and emissions that contribute towards climate change in a global context. (Sutherland, 2018:20). By introducing renewable energy practices and alternatives that are responsive to the context, these effects will be mitigated and contribute to the reduction of greenhouse gas emissions (Mercer, 2008:25). Incentives will protect the ecology and achieve zero-waste by managing waste and pollution that emanate from the city (Mercer, 2008:37).

- **Social Capital**

Participation and social networks encourage education on improving development and enhancing an inclusive quality of life. Through interaction, basic needs are emphasised, and a sense of place is established. This platform allows people to develop a long-term identity within the community they have created. Citizenship allows for accountability towards the development and spaces created. (Sutherland, 2018:23). The primary concern within Durban is employment, health, and the affordability of energy to the people. The positive impact of renewable energy allows for sustainable consciousness of individuals which improves the health conditions of affected locals and provides employment. (Mercer, 2008:37). Education and training will not only provide locals with a long-term beneficial skill set but also alter their perceptions of development. This in turn will encourage individualistic development and opportunities.

The South African National Energy Development Institute has introduced a mandate that will improve sustainable development in South Africa. This mandate will act as a catalyst for the innovation of sustainable energy, transformation, and the distribution of technology (ASSAf, 2014:18). The Department of Science and Technology focuses on improving productivity, innovation, economic growth, and social development. The Department of Energy focuses on policymaking, provisions for energy security and reliable energy sources that are accessible to all. Humans and nature are interconnected through an ongoing adaptive system, where both rely on the other.

- **Governance**

The top-down approach of governance is not functional towards being responsive to the society, economy, and ecology of the region. Democratic decision-making and solutions are implemented by an array of actors. These actors include the government, stakeholders, businesses, researchers, and civil society. The bottom-up approach is most favourable where these actors’ network with locals of the region to develop solutions that directly impact their livelihoods. (Sutherland, 2018:25). These actors remove any barriers that prevent the low-income sector and the public from being aware of or practising energy efficiency. This involvement strengthens the relationship and communication within governance and allows for interaction between companies and investors. The issue of information privacy can also be solved through management that better captures data for research and study within specific sectors. These actors can influence the city through densification that reduces the carbon footprint, better utilises its energy resources and develop efficient infrastructure. (Mercer, 2008:69). Educational institutions also play a crucial role in building a stable and sustainable future.

3.2.2. Biophysical and Socio-Economic Challenges as a result of Energy Development seen within the Major Sectors and Core Concepts of Sustainable Development in Durban

The eThekwini Municipality has targeted major sectors within the city that highlight key biophysical and socio-economic challenges within the sector and sets objectives on combating these challenges through sustainable practices. These sectors consist of the residential, the local authority and public, the industrial and commercial, and transportation. These challenges are investigated through the core concepts of sustainable development (society, economy, ecology, and governance).

- **Residential Sector**

According to the *eThekwini Municipality Energy Strategy* (2008; 24), approximately 72% of Durban's the residential sector relies on electricity for heating, lighting, and cooking. However, energy usage varies with residents of different income standards. The low-income and rural communities predominantly use non-renewable energy, such as paraffin and wood, because it is easily accessible and affordable (Mercer, 2008:24). Sustainable and affordable clean energy is not easily accessible to low-income communities. Non-renewable fuels are used within these households within poor ventilation, resulting in detrimental effects on health and air quality. There is a gap between energy-saving potential and actual investments taken. By introducing the security of clean energy that is affordable and better managed, these social health effects will be mitigated. This can only be achieved through awareness and education.

- **Industry and Commercial Sector**

The industrial and commercial sector is the largest contributor to global warming in Durban shown in FIGURE 2.7. This industrial sector has the potential to achieve maximum energy saving as it is the biggest sector within the city that consumes energy shown in FIGURE 2.8 (Mercer, 2008:52). Energy efficiency allows for savings and input cost reductions. The industrial sector is mostly private therefore data availability relating to energy utilisation and the monitoring of regulations within the facilities, is not easily accessible to the public. This is a challenge as the availability of data would aid the research and study of energy efficiency implementations and alternatives within facilities. The opportunity for education and training providers will aid industries and their employees in implementing these practices into the facilities. With the study area being within the Durban Harbour, primarily in an industrial area, there is a greater potential for sustainable and renewable energy interventions to take place, thereby achieving energy efficiency and decreasing the demand for non-renewable energy.

- **Transportation Sector**

Transportation infrastructure contributes highly to the emissions within the city. There is an extensive demand for public transportation within the Durban CBD as shown in FIGURE 2.7. The eThekwini Transport Authority are aware of the lack of infrastructure and lack of safety associated with public transportation This infrastructure includes pedestrian thoroughfares and outdoor lighting. Energy efficiency is not promoted enough due to the increasing privatisation of transportation. An advanced integrated public transportation system that requires clean energy that is safe and affordable, is the key to sustainability within this sector. (Mercer, 2008:68).

- **Local Authority and Public Sector**

The local authority utilised its' energy through the management of public buildings, service operators, public space lighting, fuel for municipal transportation fleet, waste, and waste treatment facilities. The local municipality adheres to the ICLEI through the implementation and retrofitting of affordable energy strategies within the city. Training programmes have been implemented for municipal officials. These programmes equipped officials to recognise energy conservation techniques and implementation within the city. Media plays a role in publicity and communicating awareness (Mercer, 2008:36).

3.2.3. Conclusion

The new chapter will explore an architectural model of a transformed research facility that will incorporate social collaboration, improve productivity within the spatial sphere, and efficiency of infrastructure. These objectives can be set in place to create a responsive architectural approach in combatting the Durban Harbour biophysical and socio-economic challenges. This model will include the core concepts of sustainable development to establish a balance between society, economy, and ecology within the sectors of Durban.

3.3. RESHAPING RESEARCH FACILITIES THROUGH SUSTAINABLE APPROACHES

Research facilities within South Africa are in the slow progress of advancing and keeping up with the global market. The reason for this is mainly due to the lack of funding and resources available to conduct research. The few facilities that have advanced technologically are either privately-owned or globally invested. *ARUP: Future Labs* (Schemel, et al., 2018) will be explored on how labs and research facilities can advance and compete with global trends through green building design, efficient spatial planning, and innovative technologies. These strategies are not only cost and energy-efficient but establish a balance between society, research and architecture. The futurity of reshaping research facilities can be advantageous to improving failing infrastructure, improving productivity and quality of space of those occupying the building, and create a cohesive link between the building and its surroundings. The continuity of similar architecture can be applied to any region so as it relates to the contextual analysis of that region.

Given the research problem, facilities that do provide research in renewable energy development are privately conducted within tertiary education departments or governing services. This results in the research being exclusive to the public. Public consciousness and education are essential for energy saving potential and promoting innovative research. This will encourage communities in any region to apply sustainable and efficient energy solutions. This can be achieved through social collaboration between researchers and the public. The built environment plays a significant role in creating collaborative spaces that not only engage with the public but to increase productivity and interactions between researchers.

More so, there is a lack of advanced facilities set in place to conduct explorative research. These overall challenges have caused stagnation in the progressive development and implementation of sustainable energy production. Besides a longer time spent within buildings, energy is needed for enhanced building services to maintain a desirable working environment. This can be achieved through digital infrastructure and advanced spatial operations. This will not only increase work flexibility, but research findings can be easily accessible to the public.

The design of a new research ecosystem is explored into key drivers such as social collaboration, space and operation, infrastructure, and place. These influential drivers will be explored to get a better understanding of achieving a cohesive research ecosystem that establishes a balance between society, research and architecture. This can be seen as a hybrid approach of social, spatial, and infrastructural systems that will work together to create a cohesive research ecosystem.

3.3.1. Social Collaboration

The involvement of people and interdisciplinary research influence social collaboration. There are several means of achieving social collaboration, such as;

- Spaces that encourage researchers and the community to interact. E.g., break-out spaces, common areas and workspaces
- The organisation of interconnect working spaces that are flexible to ease the flow between people and research equipment. This creates hybrid spatial planning. E.g., open-plan layouts, clear sightlines, and circulation between spaces
- Spaces that are adaptable to different forms of research. E.g., bench-based experiments, group and individual workspaces, informal stand-up meetings.
- Designing dynamic social spaces that promote wellbeing and productivity, and connection with the environment. E.g., natural lighting for distinctive spaces, modern amenities to accommodate those working there.
- The accessibility of all to the research conducted and the engagement of the community through open interactive spaces. E.g., the involvement of universities and skilled professionals that engages the public as patrons of the research conducted through DIY community-based labs and maker spaces.
- The access of all too invested technologies and training of digital infrastructure. E.g., Wireless communication systems, online source platforms, high-capacity data storage, transportation systems that allow for movement of people and technology.

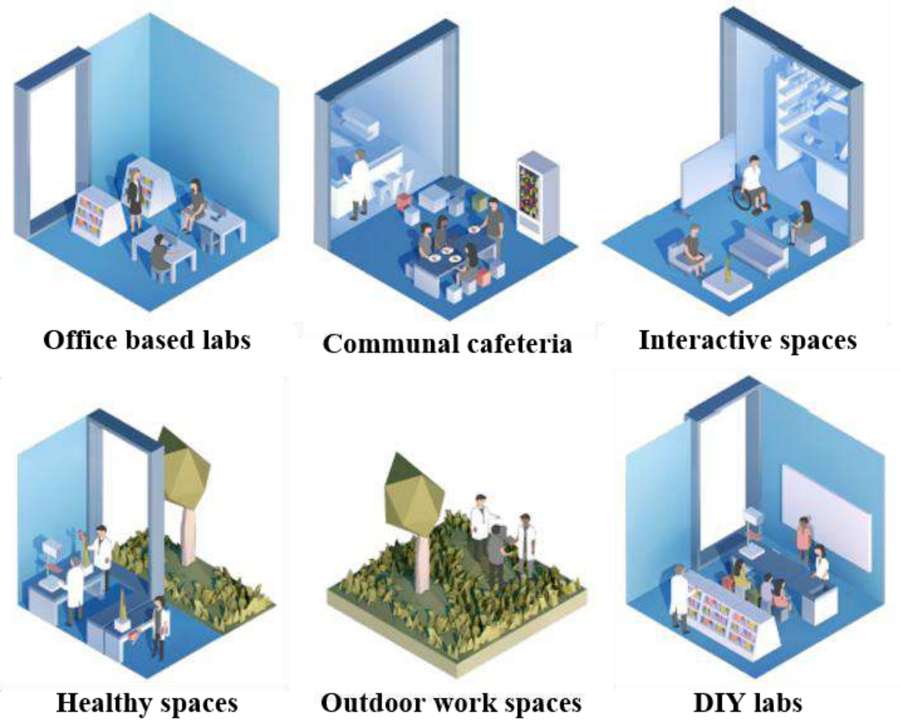


Figure 3.3: *The Diagrams by Arup Future Labs represents the different spatial planning that can be used to achieve social collaboration.*

Source: Schemel, et al., 2018: 58-59

3.3.2. Space and Operation

Advanced technologies and systems need to be considered to operate future research facilities. There are several means of achieving advanced operations and spaces, such as;

- The flexibility and adaptability to spaces to accommodate changing uses over time. E.g., mobile benching, structural grids that allow for a multitude of functions that is easily interchangeable, open-plan research studios with circulation and sightlines between spaces, informal collaborative meeting spaces, semi-private stations, and unplugged quiet spaces.
- Reconfigurable infrastructure that services plug and play feature so that all have access to digital systems wherever they work.
- Smart technologies that are cost-effective and energy-efficient simplify working environments and share research findings so that less time is spent on conventional labs and more time on collaborative research analysis. The green design allows the building to be upgraded and changed easily over time. E.g., digital lab equipment that responds directly to a shared database, green building design principles for water recycling, smart energy management, improving air quality, waste management, green spaces and sustainable building materials used.
- A shared database that manages and stores research conducted. These systems allow for research findings to be based on real-time feedback. E.g., cloud storage technology for data processing and storage.

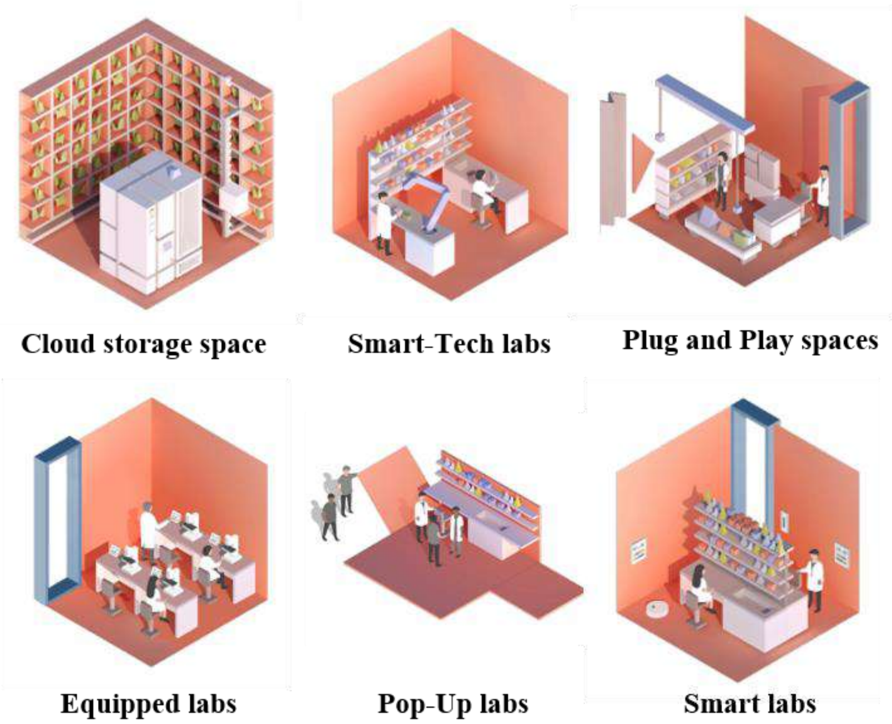


Figure 3.4: *The Diagrams by Arup Future Labs represents the different spatial planning that can be used to achieve space and operation.*

Source: Schemel, et al., 2018: 60-61

3.3.3. Infrastructure and Place

The network of advanced digital infrastructure can be integrated into the urban fabric and the people within it. There are several means of achieving social and digital connectivity, such as;

- To establish a shared digital infrastructure that is accessible to all those that require it. This allows community members and researchers to share data and work together.
- These facilities open the city to innovation and can compete in the global innovative market. E.g., physical space for research to be conducted, training and mentorship programs, funding and investing from public and private sectors.
- This will aid start-ups, institutions, larger research companies to work together so that research conducted can be transformed into real-world applications.
- Redeveloping and improving urban planning so that the community has access to mixed-use developments. E.g., creating a community that has housing, services, open space, and mass transportation.
- The engagement of the public through live and interactive labs. This will attract the public and increase awareness of the challenges within the community and how the innovations created can be a solution to these challenges. E.g., university and pop-up research parks, live labs within the city, public gathering spaces, open-view labs, exhibition spaces.

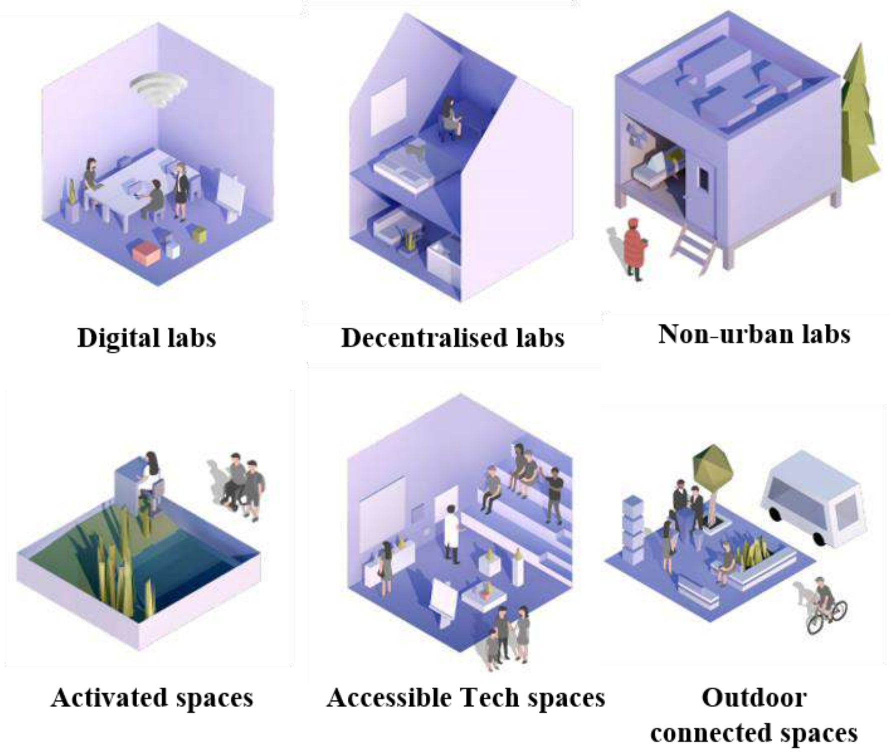


Figure 3.5: *The Diagrams by Arup Future Labs represents the different spatial planning that can be used to achieve infrastructure and place.*

Source: Schemel, et al., 2018: 62-63

Figure 3.6: *The Diagram above presents a new Research Ecosystem by Arup Future Labs that encompasses the key drivers of social collaboration, space and operation, infrastructure, and place.*

Source: Schemel, et al., 2018: 53

The design of a new research ecosystem is influenced by a hybrid integrated system of people, technology, and spatial planning. By focusing on collaboration, flexibility and accessibility, researchers can share knowledge of research to all in turn creating innovative technology based on these findings. By improving infrastructure, spatial planning and architecture, these collective hybrid principles can be contributed to the community’s quality of life and further positively impact the city in a hedonistic sustainable way.

3.4. HEDONISTIC SUSTAINABILITY

Branching off the understanding of Sustainable Development, Bjarke Ingels' TEDx presentation on Hedonistic Sustainability (Kth Arkitekturskola; 2012) explores the development of sustainable solutions to challenges and morphing it into something playful that is the basis of Hedonistic Sustainability.

Hedonism is described as behaving in a particular way or an action that is being self-centred and egotistically motivated. Pleasure determines a choice of action however pleasure is shown in a sense of positive well-being (Canavan: 1912, 65). Bjarke Ingels has become a distinguished figure in the revival of "Hedonistic Sustainability" by developing solutions to challenges and morphing them into something exploratory. Ingels envisions architecture as a synergy of art and science to create something that enhances the quality of life of those interacting with it. Ingels studied the global crisis of climate change and economy, in turn, focused on introducing architecture that was profitable and sustainable. Sustainability does not demand a moral sacrifice, but to establish a conscious design challenge that will improve one's quality of life whilst capturing human leisure. Hedonistic Sustainability can be seen as a transformative approach to architecture that is economically profitable, socially enticing and environmentally sustainable. This process of design can take place whereby architecture is not seen as mere structures but as contextual ecosystems (Basulto, 2011). This ecosystem is an enclosed loop of positive social integration and resource management that decreases environmental impacts and increases the quality of life. Public and private space becomes an overlapping dynamism, regarding spaces interlinking. Design becomes a represented object that allows people to experience it in its presence.

Estika, et. al (2020) states that "According to Ingels, the need in architecture today is not revolution, but evolution. Architecture should adapt progressively to the development of life. It should follow the way of life, rather than slowing the progression of life by adjusting to obsolete ideas from the past. Perfect architecture should say "yes!" to every desire and need."

Hedonistic Sustainability is a contemporary thought that analyses every design context to maximise its greatest potential, rather than be limited by constraints. It accommodates the way people live rather than imposing restrictions. People can live in a utopian world whilst being responsible. Ingels has a pragmatic utopian approach to architecture and morphological planning. There is a sense of seeking sophisticated futurology in a creative means of solving an issue, whilst the normative approach is disregarded. The approach of pragmatic utopianism influences innovative solutions to not just be discussed but implemented for all to appreciate and reproduce it where necessary.

The biophysical and socio-economic challenges analysed in Chapter 1 play a crucial role in reshaping the Durban Harbour and achieving sustainable development within the city. Hedonistic sustainability will be used as an architectural conceptual framework to create a transformative contextual ecosystem that maximises the city's potential and create a pragmatic utopian quality of life, whilst alleviating the city's biophysical and socio-economic challenges through explorative means. The architectural intervention will not just stand as a structure but create an inclusive relationship to the context of the Durban Harbour through sustainable means, and a socially enticing space for people to experience its presence.

3.4.1. The Influence of Energy and Hedonistic Sustainability in Architecture

The built environment is one of the key consumers of energy, in the form of electricity. The use of energy within architecture develops from the initial construction, the functioning of the building and the demolition stage. This energy is utilised through the process of manufacturing and transportation. To maximise sustainability potential, solutions need to be determined at the initial stage to mitigate energy consumption.

The sustainable design aims to assist educators and developers to create environments that satisfy the needs of the user without compromising the future generation. For sustainability to be achieved, buildings are being designed for long-term use so that the demand for energy consumption does not increase and carbon neutrality is reached. Carbon neutrality in buildings means offsetting the use of energy in the form of electricity with ecological practices such as vegetation and sustainable practices during construction and during the lifespan of the building (Iyengar, 2015:9). Hedonistic sustainability takes place when you stop thinking of buildings as structures but as ecosystems. The urban environment is regarded as a metabolism like an organism, which studies the convergence of infrastructure, transportation, and resources within the urban fabric. The development of ecological infrastructure improves the biophysical challenges whilst essentially reducing the ecological footprint of the city. The efficiency of resources usage and closed cycles of waste produced will improve the city's sustainability management. By introducing a green economy strategy, the city will follow policies that will not only benefit the economy but the society and ecology that are established within the city and interrelate with each other. (Williams, 2007:1).

Over the years, architecture in South Africa has developed to comply with the global trend of sustainability. With the increase in energy costs, occupants are also driven towards energy conservation. This compliance is adhered to through municipal regulations and bylaws made in every stage of the development. Within South Africa, progress is limited to constraints of investment, knowledge, and governance. There is not enough knowledge on the incentives given to the occupants when implementing energy strategies therefore progress is limited to the industrial and economic sector (Ahmed, 2010:1-2). As Durban progresses, architects and city planners are implementing these principles of sustainability enabling society to become better aware of the biophysical and socio-economic impacts surrounding them and the solutions to avoid them in the future.

To achieve sustainability within the built environment, architects and developers are knowledgeably skilled in passive architecture that allows for comfortable conditions to be achieved through energy conservation (Ahmed, 2010:1). Architecture that designs for appropriate climatic conditions and the usage of renewable energy, aid in the reduction of energy necessity. According to Iyengar (2015; 21), Sustainably Design Principles that are considered include cultural and formal aesthetic consciousness, contextual sensitivity, exploration of materials and energy-efficient methods of construction, minimising of waste, a design that maximises contextual topography, bioclimate, views, air quality and lighting. Hedonism influences spaces to adapt to the occupant’s comfort. Designing sustainably entails innovative thinking that; enhances the productivity of the environments created, management of waste, positive human quality of life, and the impact of the building on the ecological.

With the investigation of the biophysical and socio-economic challenges within the Durban Harbour, as explored in page 20, in conjunction with the influence of energy development within the study area as explored in page 57, hedonistic sustainability will aid as an architectural solution in establishing sustainable energy development and enhancing social consciousness within the city fabric.

3.5. CONCLUSION

This chapter concludes that the implementation of Sustainable Development, within the context of Durban, can be successful if a transformative approach is taken through economic influence, social initiative, ecological consciousness, and management through governance. By achieving these core concepts, the city will be able to prosper by mitigating environmental exploitation, enhancing the social quality of life, educating the public on the futurity of resources, in turn, uplift economic growth.

Adopting a reformed research facility, social integration and innovative infrastructure can create a sustainable architectural model. This model will provide a social consciousness and educate the community on the futurity of renewable energy development, whilst alleviating many biophysical and socio-economic challenges of the area.

Hedonistic Sustainability will focus on the Durban Harbour and surrounding context as an ecosystem that integrates social participation, energy consumption, economic profitability, and ecological awareness. Whereby architecture, acting as a living organism, will establish a balance by introducing conscious-sustainable design solutions to increase the social quality of life and improve human enjoyment, whilst catering for the energy demand in a sustainable manner.

The next chapter will explore the concept of hybridity within the discourse of its understanding and its applications within the field of energy development and architecture.

CHAPTER 4

HYBRIDITY

4.2. INTRODUCTION

The term 'Hybridity' originated in the 19th-century biological field. Homi Bhabha, a cultural theorist, defined hybridity in horticulture as the "cross-pollination of two species to form a third". Hybridity can naturally occur within genetic modification as climate change affects habitats, species amalgamate to survive allowing their appearance and behaviour to change.

Bhabha extends this definition in post-colonial discourses where Hybridity is the buffer space between colonialism and post-colonialism, that is culturally transformative (Mambrol, 2016). Bhabha states that hybridity exists within a space of transformation between two opposing forces. This in-between space allows for opposing forces (past and present, public, and private) to touch, interact and be discussed (Jevremovie, 2017: 244). Hybridity is not an object but the transition process through fusion.

Hybridity is a vast concept that is interpreted in multiple disciplines, however, literature on hybridity and architecture is quite limited. Frank Gehry interprets hybridity as a collaboration of various arts that enhances design and architecture. Gehry believes that architecture needs to detach from the normative underlining of what modern architecture is expected to be. Charles Jencks's interprets hybridity in his work as a "disharmonious harmony by putting together elements from different sources" (Acquarone, 2019: 9).

Hybridity in modern globalisation can be seen in several products such as technical gadgetry, eco-vehicles, interracial and cross-cultural societies, and modified sorts of seeds for cultivation (Jevremovie, 2017: 245). Hybridisation in architecture requires integrated approaches from various disciplines to unlock new perspectives and design forms.

Hybridity is explored as a conceptual framework since the research design is a form of hybrid architectural intervention of education through public consciousness on energy saving potential and allowing collected research to be accessible to the public, in conjunction with the production of hybrid renewable energy solutions that is responsive to the region and alleviate the pressures placed on the environment, society and economy.

4.1.1. Hybridisation in Renewable Energy

Hybridity in this sense is the co-existence of systems that work together to create a new synergised system. These systems will consist of renewable energy practices that stand alone, such as a hydropower mechanism that works with a solar energy system. Individually these systems exist within their limitations, such as a hydropower facility needs to be located near a water source and a solar energy facility is only viable during the daylight. The hybridisation of multiple systems will overcome the limitations of the individual systems. (Frewin, 2019). Although these renewable energy systems are successful on their own, hybrid energy systems can co-generate on an array of landscapes to provide a reliable source of energy during peak demands. The hybridisation of conventional energy production allows for an increase in clean energy supply and an immense reduction in the carbon footprint. Hybrid systems also provide more economic feasibility compared to independent systems (ASSAf, 2014:44). If natural energy systems become unpredictable, South Africa has a high potential for renewable energy production due to the availability of resources.

4.1.2. Influence of Hybridity in Architecture

‘Hybrid’ as an architectural theory originally appeared in the second half of the 20th century. According to Psilopoulos (n.d.:1), although nature played a vital role in evolution, humankind's advancement in the technological and industrial age empowered man over nature. With industrialisation and population increased, there was a focus on poor planning and rapid consumption that disregarded tradition and maintaining an essence of identity. Architecture, as a hybrid form, infused nature, and technology to generate a self-sustaining ecosystem that introduced a sense of dignity and identity.

Hybridity interprets architecture as a living organism that encourages a cohabitation between the object, landscape, and infrastructure to combat a specific challenge. Functioning as one intervention, space designed for human interaction is integrated within the physical landscape and conforms to a regulatory system (Pinto De Freitas: 2013). Hybridity is established through the amalgamation of infrastructure that will transform the context, the architecture that is integrated inseparably to the landscape, and a realm that will stimulate social interaction. This harmonious combination constructs a new synergy of interdependent systems that work simultaneously. In the early practices, hybridity in architecture was seen in mixed-use buildings. In Hybridity In and Beyond Architecture: Liminal Conditions (2017:253), theorist Joseph Fenton explains that “hybrid buildings are the way of solving economic problems and design issues in such a manner that the solution is sought through the function and history, rather than stylistic order or theory separately”. Hybrid architecture must create cohesion of resolving biophysical and socio-economic challenges, reduce resource demands, building forms, functions, and technology.

Many historic cities and structures have become a vector as they started losing their relationship to the city and modern structures started transforming the city. Hybridisation allowed for contemporary typologies to be juxtaposed with the existing and establish a harmonised relationship between the built environment and nature. This allowed for a reinterpretation of the past with a contemporary context. This created a new element or architecture that encouraged its characteristics for people to interact with. This hybrid architecture responds to the context of the landscape and the built environment. If the context is neglected, the architecture becomes a negative attribute to the city. Kostas Terzidis (2003: 57) describes architectural hybridisation as a form of morphology. Morphology is termed as a man-made interconnection between different entities. Architecture is the characterised overlapping of the preserved past and future to form a new entity with a new dimension of perception.

Steven Holl discusses the formation of hybrid buildings as “Certain previously neglected forms of associations have been wrenched together in the modern city to generate buildings which might stand as an anti-typology if examined under current theoretical preoccupations. Building functions are mixed, disparate uses combined; structures collected here are ‘Hybrid Buildings’ with respect to use” (Holl, 2014: 70).

Hybridity within architecture developed in the 20th century. Architecture and functions within cities have evolved from homogeneity to heterogeneity. Hybrid buildings introduced hyper-urbanisation that paved the way for unconventional architectural typologies and functions within city spaces. Hybridity in cities amalgamated social identities, innovative technology, and green practices. Many cities today try to include cultural identities into the design but there is no or minimal physical evidence to showcase this. Public space, urban porosity and overlapping mixed-use functions are significant in hybrid architectural planning. This increased the chance of social interaction and community development. Unprecedented conceptual design can present new typologies that will allow the city to have an expression of its own.

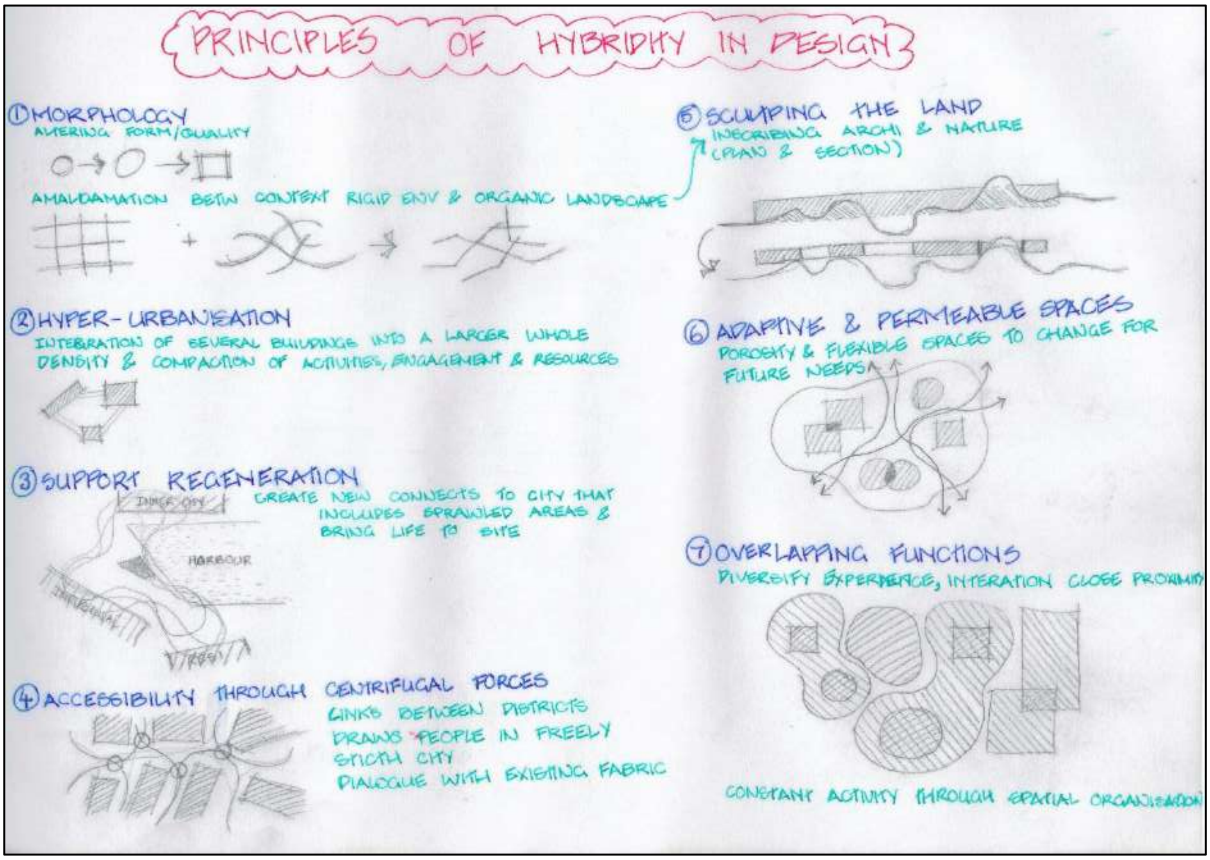
Architecture, in a way, is a form of hybrid intervention. This intervention utilises natural systems with advanced technologies to create a self-sustaining built ecosystem that manipulates the climate of the region and establishes a minimal ecological footprint. Through technological advancement, society today has been entirely focused on individuality and independence, rather than interdependency. Hybrid architecture can re-establish interdependency through design practices. Three conditions allow for hybrid architecture to exist; the Physical which is the quality of space designed for human interaction, the Architecture that is inscribed with the natural landscape, and the infrastructure that is transformed by adapting to regulations. In the 1960s, modernists neglected the human scale in city development however, by introducing hybrid architecture, human scale and accessibility within the city became a continuous flux of activity.

Hybrid sustainable systems have been an ongoing inclusion within the built environment. Modern Architecture in South Africa has used these hybrid systems that are culturally and contextually responsive, especially during urbanisation. These hybrid systems included the use of local materials, urban farming, renewable energy generation, social housing, communal engagement, the synergy of functions within a space, and revitalising urban space that is sensitive to the context. Hybrid architectural forms can be represented through; the volumetric language or external façade of the building, or building elements integrated into the building shell without revealing the internal structure.

“Identifying the urban scale was important due to urban sprawl and city degeneration” stated Jane Jacobs (Derome-Masse, 2015: 32). Rem Koolhaas looked at an old city as having a fixed identity that historically defines it, later leading to urban sprawl and community detachment. Koolhaas’s ideology of a new generic city is sort of a hybrid concept. This generic city has a chance to reflect on the historic models and reconstruct them to suit conscious modern opportunities (Jevremovie, 2017: 255). Hybridity in a city responds to densification, diversification, and intensification. Density is achieved through compaction to allow for social interaction, dynamism between sectors, the efficiency of resources and energy usage. Diversity is achieved through the proximity of individuals that encouraging engagement and experiences. Intensity is achieved through the adaptation of infrastructure to accommodate for the dense city and land uses, also to create activities that always keep the city alive.

Derome-Masse (2015:47-58) identifies ten conditions that are needed to achieve architectural hybridity within a city:

- Support urban regeneration by merging old and new to re-create the city’s character.
- Urban accessibility through centrifugal forces of activities.
- Architecture and Nature are inscribed into the other.
- Develop adaptive and permeable spaces.
- Intensify and overlap diverse functions to create an urban experience.
- Establish functions that allow for a continuous flux of activities.
- Encourage communal interaction through the spatial organisation.
- Introduce recreational activities as social drivers.
- Introduce horizontal and vertical within the contextually responsive design.
- Create a dialogue within the site through interrelations between public and private spaces, and the dynamism that takes place within the site.



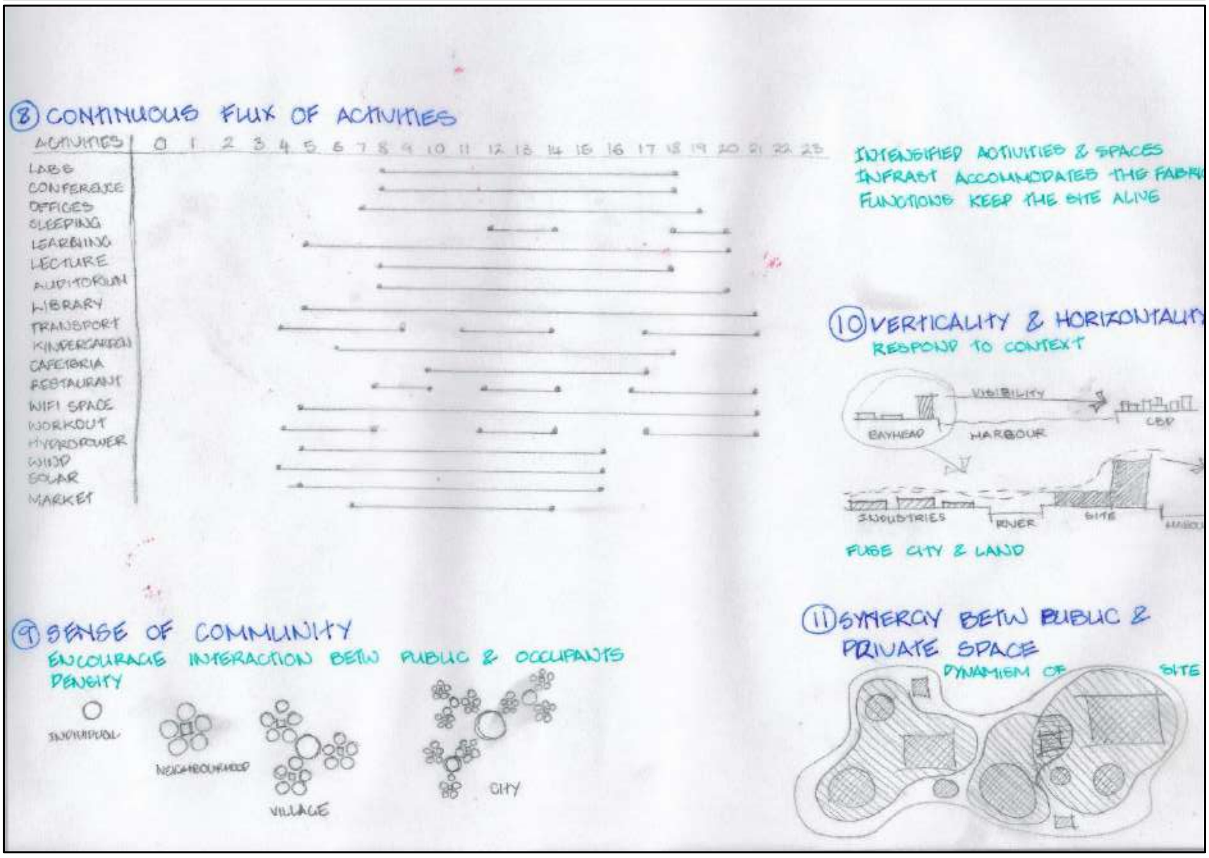


Figure 4.1: *The Diagrams above represents ten conditions that are needed to achieve architectural hybridity within a city by Derome-Masse (2015:47-58)*

Source: Author, 2019

4.3. CONCLUSION

This chapter concludes that hybridity maintains a balance of social, economic and environmental factors to form a positive utopia. There is also a responsibility of reconsidering historically factors to create a unique and modern consciousness. Hybridity will be used as a tool to signify the role in the morphology of natural landscape to an infrastructural coastline that responds to the urban scale. The urban context of the Durban Harbour being accountable for the development of its' biophysical and socio-economic challenges. Architecture and nature, context and the community will be amalgamated into a self-sustaining habitat that reintroduces diverse interdependency between people, energy and industry to overcome the challenges of urban sprawl, non-renewable energy demand and ecological depletion within the Durban Harbour.

CHAPTER 5

PRECEDENT STUDIES

5.1. INTRODUCTION

The precedent studies that have been chosen will explore the developments concerning the themes of energy development, sustainability and hedonistic sustainability, and hybridity that have been discussed within the literature review. The precedent studies that will be investigated are the Energy Academy Europe in Groningen, Netherlands and the Copenhill / Amager Bakke in Copenhagen, Denmark. These precedent studies will allow for an in-depth understanding of the research problem, theoretical drivers, and architectural space that will aid in the implementation of a hybrid renewable energy facility.

5.2. ENERGY ACADEMY EUROPE BUILDING: GRONINGEN, NETHERLANDS

Figure 5.1: *The Energy Academy Europe in Netherlands set within the surrounding context.*

Source: Gonzalez, 2018

5.2.1. Introduction

The Energy Academy Europe was designed by Broekdakema and De Unie Architecten in 2016. The Energy Academy has received several acclaimed awards and is regarded as one of the most sustainable education facilities in the Netherlands with an outstanding BREEAM-rating of high sustainability and energy consumption standards. The building is an initiative of the University of Groningen, Hanze University of Applied Sciences, Gasterra and Energy Valley. There will be an exploration of the project's approach to sustainably reshaping research facilities to create an inclusive research ecosystem. Through analysing this precedent study and linking it to the literature, a developed understanding of the design approach can be obtained.

5.2.2. Research and Education Facility Objectives

The institution is a research ecosystem that focuses on three pillars of education, research, and innovation in sustainable energy, also the transitioning from non-renewable to reliable renewable energy solutions. These three pillars are translated into the building design. The institute caters for the engagement of researchers, students, and entrepreneurs. Their goal is dependent on global markets, technology, governance, and society (Energy Academy, 2019).

Education is provided for at all levels of expertise, from skilled researchers to multidisciplinary professionals in the field. Research programmes are given to expand the knowledge and experiences of private and public disciplines. These programs assist in integrated energy systems, the built environment, industrial energy efficiency and the bio-based economy. System integration looks at hybrid renewable systems that efficiently aid in the transition of future energy development. A lot of attention is given to cooperation, education, and training of the industrial sector where energy demand is prominent. By approaching these institutions and local governance, will give way to market barriers and promote sustainability within these start-up ecosystems.

Figure 5.2: *The Picture shows the natural lighting that is provided by the Atrium to the internal workspaces through large glass windows. This visibility and large open pause spaces allow for social interaction and improve productivity to take place.*

Source: Gonzalez, 2018

5.2.3. Theoretical and Conceptual Analysis

The architects share the similar theory of 'inspire by nature, powered by people' as a basis for the design (Gonzalez, 2018). The guiding principles were to create a natural research ecosystem with the use of natural lighting and ventilation, the use of geology for natural heating and cooling, rainwater harvesting, innovative renewable energy solutions, and efficient digital infrastructure.

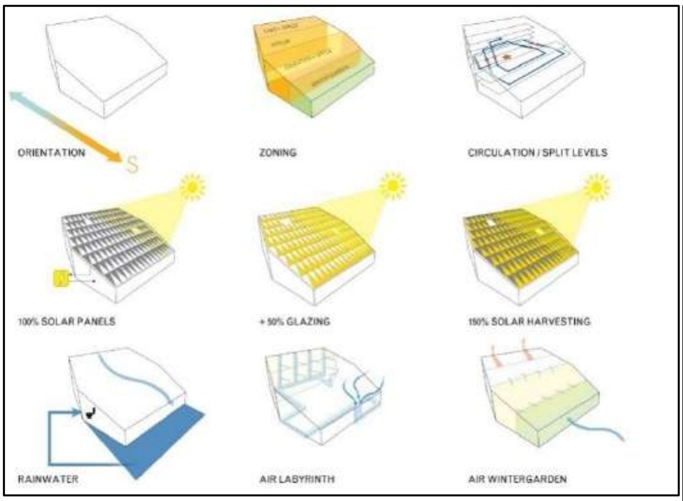


Figure 5.3: *The Diagrams above Energy Academy Europe design development diagrams based on Sustainable Approaches.*

Source: Gonzalez, 2018

Facts & Figures | Energy Academy Building

BREEAM-nl score	Outstanding (more) 89,62% of points
Gross floor area in m² (NEN 2580)	14.819 m²
Total site area in hectare	4.350 m²
Floor areas by function and dimensions (NEN 2580) a) Meeting area b) Communal area c) Industry function d) Office area e) Educational function f) Other designated use g) Traffic arteries h) Storage / Facilities	a) 2.097 m² b) 895 m² c) 2.492 m² d) 5.513 m² e) 750 m² f) 3.071 m² g) 1.159 m² h) 275 m²
Expected energy use in kWh / m² gross floor area	12,6 kWh / m² gross floor area / year electrical
Expected use of fossil fuels in kWh / m² gross floor area / year	0 kWh-elektrical / m² gross floor area / year
Expected use of sustainable energy sources in kWh / m² gross floor area	- Solar panels: 64 kWh primarily / m² gross floor area / year - Geothermal heating: 13 kWh primarily / m² gross floor area / year
Expected water use in m³ / person / year	7,1 m³ / person / year
Expected % of water use from precipitation or gray water	29%

Figure 5.5: *The Table above shows The Energy Academy Europe Sustainable Strategy Figures*

Source: Energy Academy, 2019

Figure 5.4: *The Image on the left shows the Triangulated Solar Panels maximises solar rays captured and natural daylighting within the building.*

Source: Gonzalez, 2018

Figure 5.6: *The Diagram on the left shows The Energy Academy Europe sectional Elevation of internal spaces*

Source: Archello, 2019

The building form is aligned to the sun and compact for a small surface area to minimise heat loss. The building is sloped from the first floor on the south side to the fifth floor on the north side. With 50% of the covered roof slope having triangulated photovoltaic panels, 150% of the roof surface has the opportunity to achieved maximise solar harvesting. This triangulated panel configuration allows the surface area of the roof to accommodate more panels. Energy-efficient LED lighting is used when there is no natural lighting.

The institute implements sustainable solutions of the natural elements in the building concept design and services. Therefore, allowing the building to consume less energy. These innovations are depicted in the solar chimneys, winter gardens, atrium, and air labyrinth. The design of the large, centralised atrium links the two building structures. On the north side resides the research areas with laboratory and workspaces. On the south side resides the educational spaces, work areas and winter garden. Decks within the atrium between levels allow for social interactive spaces. The atrium also acts as an air duct ventilating the air from all the spaces within and provide natural lighting to the internal spaces of the building. The external climatic conditions are bridged using plants and a greenhouse garden with glass shafts on the north façade. The natural ventilation is contributed from the south air flows through the winter gardens, then enters a 200m walkable thermal labyrinth beneath the building is designed to circulate external air flowing. The earth acts as an air cooling or heating agent and provides appropriate temperature variations to the rest of the building during the seasons. This constant airflow continues from the labyrinth, through the atrium and offices and out a solar chimney above the roof which allows for natural ventilation throughout the building structure. (Energy Academy, 2019).

Back-up systems are only operation for heating, ventilation, and lighting. The CO2 levels within the internal spaces and constantly observed with smart technology. Mechanical ventilation systems will only activate within a space if the CO2 levels are high. This enhances a pleasant working environment. Two ground reservoirs at a 100m depth are also utilised for the heating and cooling of the spaces during the seasons. During summer, the cold-water reservoir pumps throughout the building, the heat is then absorbed and pumped back into the warm water reservoir. The process is reversed during winter. Heat is distributed throughout the building as under-floor thermal systems and climate ceilings. A pond on the south of the site acts as an alternative cooling agent. Rainwater collected from the sloped roof is stored in a reservoir and is used for irrigation and ablutions. The facades used can manage with any form of external distortions. As the area is prone to earthquakes, the structure is designed to be earthquake resistant by incorporating split-level ramps adding rigidness to the structure. (Arup, 2019).

The building can produce energy or electricity that is equivalents to or more than the energy it consumed. Thus, creating a building with zero-emission. Occupants of the building can choose the environments they would like to conduct their work in. Spaces are designated between natural and fully conditioned spaces. Hedonistic sustainability enables natural spaces and pause breakaways to add to the well-being of the occupants and provides a pleasant social ecosystem. Workspaces were designed with the requirements of the users.

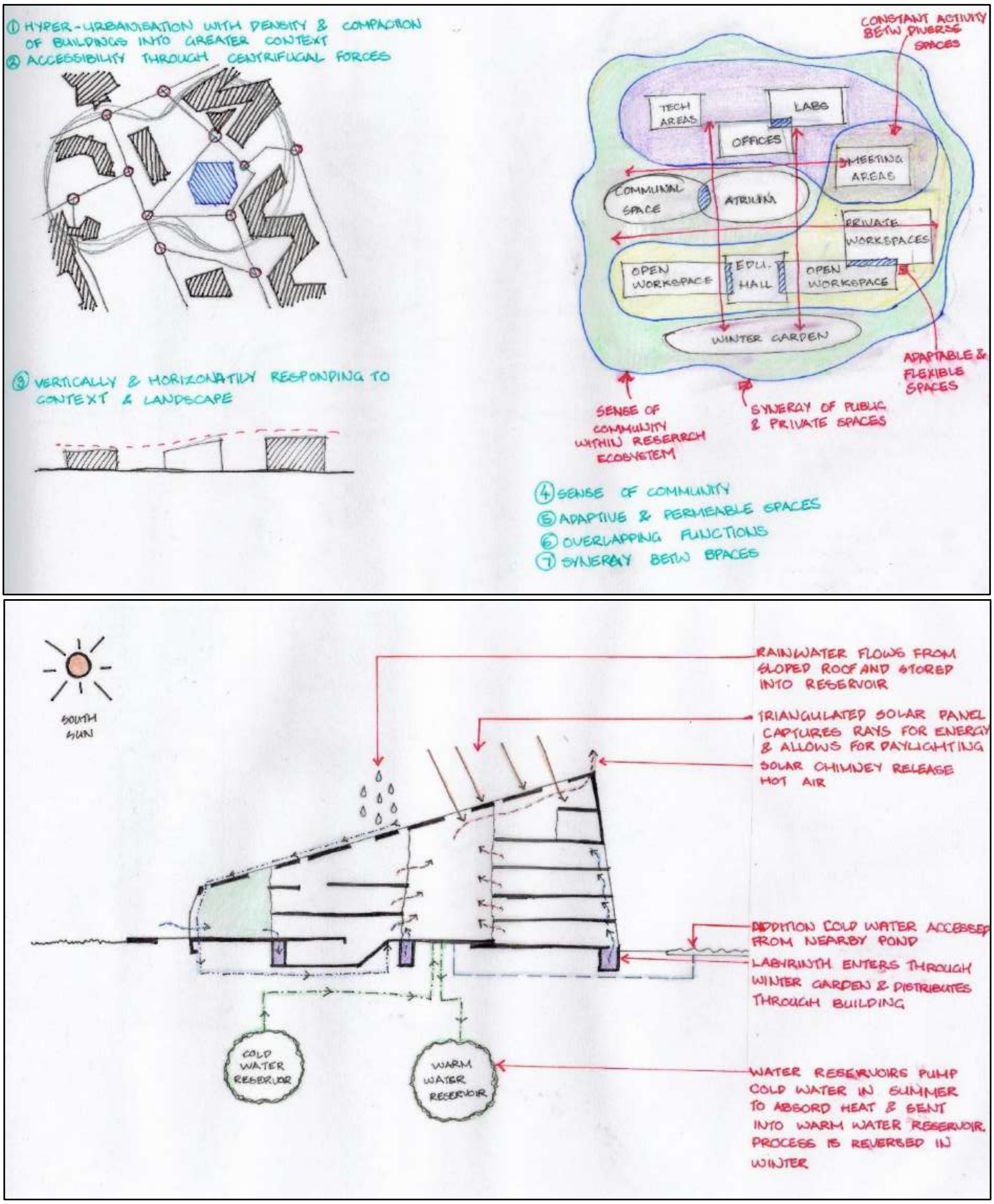


Figure 5.7: *These Diagrams of the Energy Academy Building depicting influences of hybridity and the sustainable solutions implemented throughout the building.*

Source: Author, 2021

5.3. COPENHILL / AMAGER BAKKE: COPENHAGEN, DENMARK

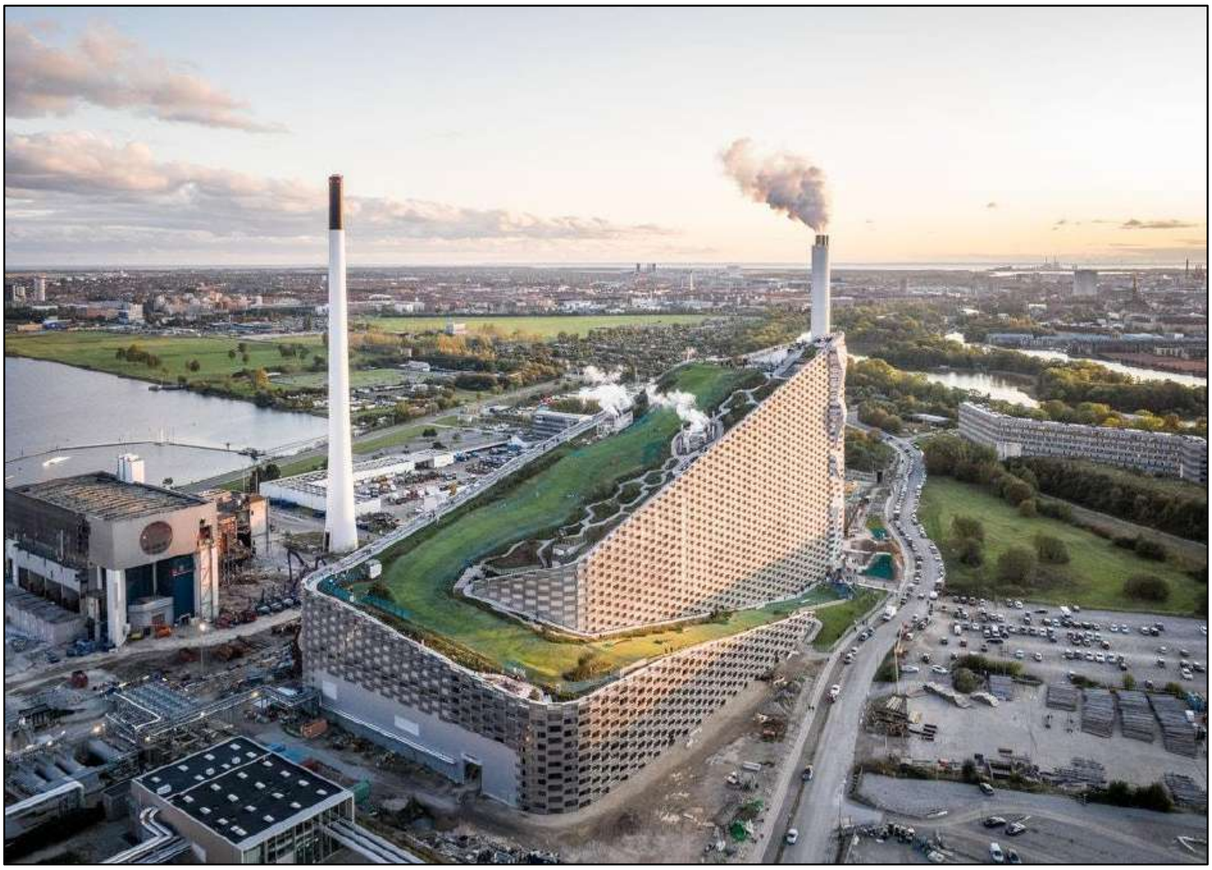


Figure 5.8: *The Copenhill, also known as Amager Bakke, in Copenhagen Netherlands set within the surrounding industrial context.*

Source: De Valence, 2019

5.3.1. Introduction

The Copenhill Waste-to-Energy Plant, also known as Amager Bakke, was designed by the Bjarke Ingels Group in 2019. This project has received numerous prestigious awards. There will be an exploration of the projects' unique approach to hedonistic sustainability and clean innovative architecture. Through analysing this precedent study and linking it to the literature, a developed understanding of the design approach can be obtained.

5.3.2. Waste-to-Energy Plant Objectives

The Copenhill Waste-to-Energy Plant, along with the development goals of Copenhagen, aims to be a carbon-neutral city by 2025. The Plant consists of a waste treatment and energy production facility, an urban recreational hub and an eco-educational centre. These functions create a balanced hybrid ecosystem that establishes social, environmental, and industrial cohesion.

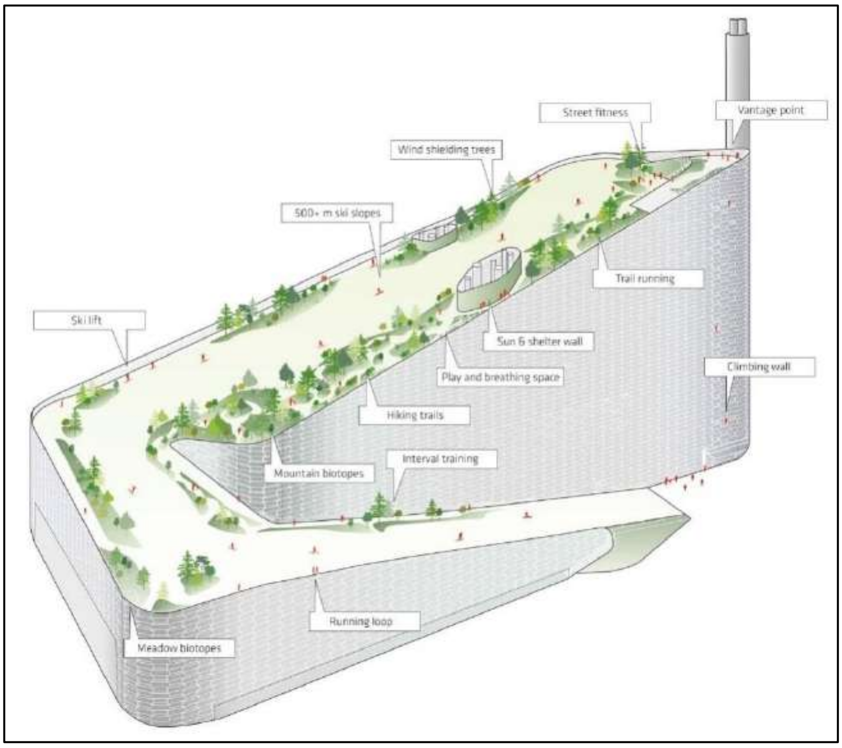


Figure 5.9: *This Diagram represents the roof layout and various activities.*

Source: Nelson, 2018

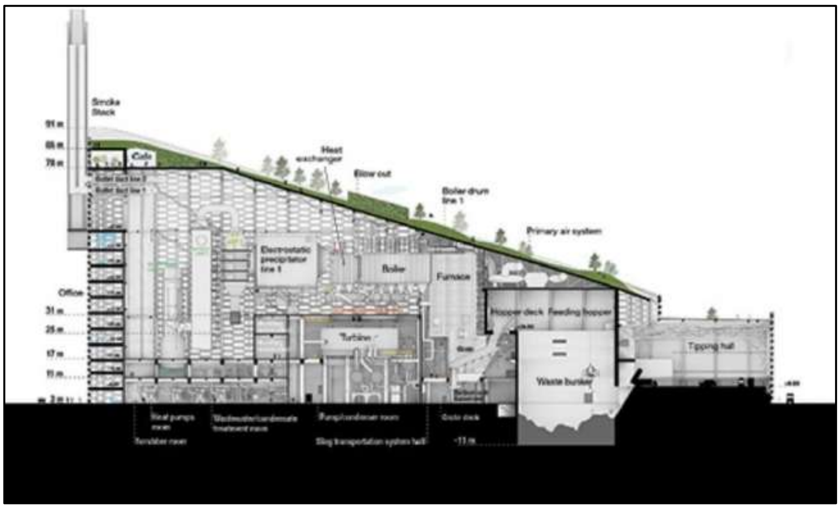


Figure 5.10: *This Section shows the internal spatial volumes of the Copenhill.*

Source: Arndt, Nordestgaard, 2020

Figure 5.11 (left): *This Picture shows the ski slope and public access of the hiking trails flanked by natural landscape. The picture also shows the aluminium and glass façade of the building envelope.*

Source: BIG, 2021

5.3.3. Theoretical and Conceptual Analysis

The existing context sits within an industrial waterfront, where the only form of social integration involved wakeboarding and go-kart racing activities. Fortunately for the industrial context of Copenhill, the area is not plagued with many biophysical and socio-economic challenges. However, simple green approaches uplift this industrial area making it a safe and pleasant place to be in. Not only does this Plant deal with renewable energy production, but it enhances the social quality of the area by including recreational skiing, hiking and rock-climbing activities. Hedonistic sustainability transforms this architecture into something that is socially dynamic and economically profitable. The sustainable principles applied are not an afterthought but included in the design development. Neither does infrastructure compromise sustainability.

The design development of Copenhill takes on several factors such as; the internal volumes of space is determined by the machinery needed in height order, the sloped rooftop is influenced by ventilation shafts and air-intakes, the man-made landscape is formed by an green synthetic-bristles ski terrain similar in length to an Olympic half-pipe with different gradients, the tallest artificial climbing wall on the longest vertical façade, a platter lift at the highest point accessible to the public that also provides a bird's-eye view of the flat cityscape, carpet lifts or glass lifts create a clear sightline into the facility's operation 24 hour systems, ten floors of the plant facilitate administrative spaces and an education centre for workshops and sustainable conferences, entertainment spaces like the rooftop bar and cross-fit areas invite social interaction, luscious natural terrain on the slope for hiking and trail running, a large green roof that addresses the micro-climate of the highest point as the biodiversity absorbs heat and minimised rainwater runoff. (BIG, 2021).

The waste incineration machinery, steam and turbines located beneath the slopes convert up to 440 000t of waste into clean energy for over 150 000 homes. The façade that wraps around the entire building envelope consists of 1.2m high x 3.3m wide aluminium bricks stacked and overlapping with glazed windows in-between to allow natural lighting to reach further into the Plant. Large openings on the southwest façade provide lighting into workspaces and administrative spaces.

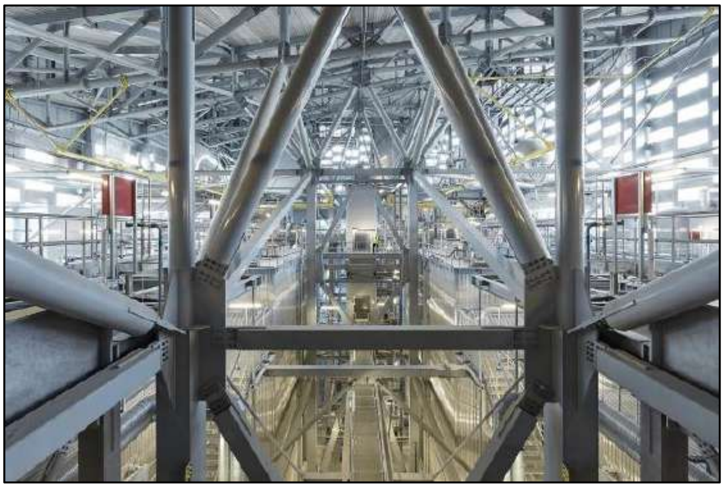
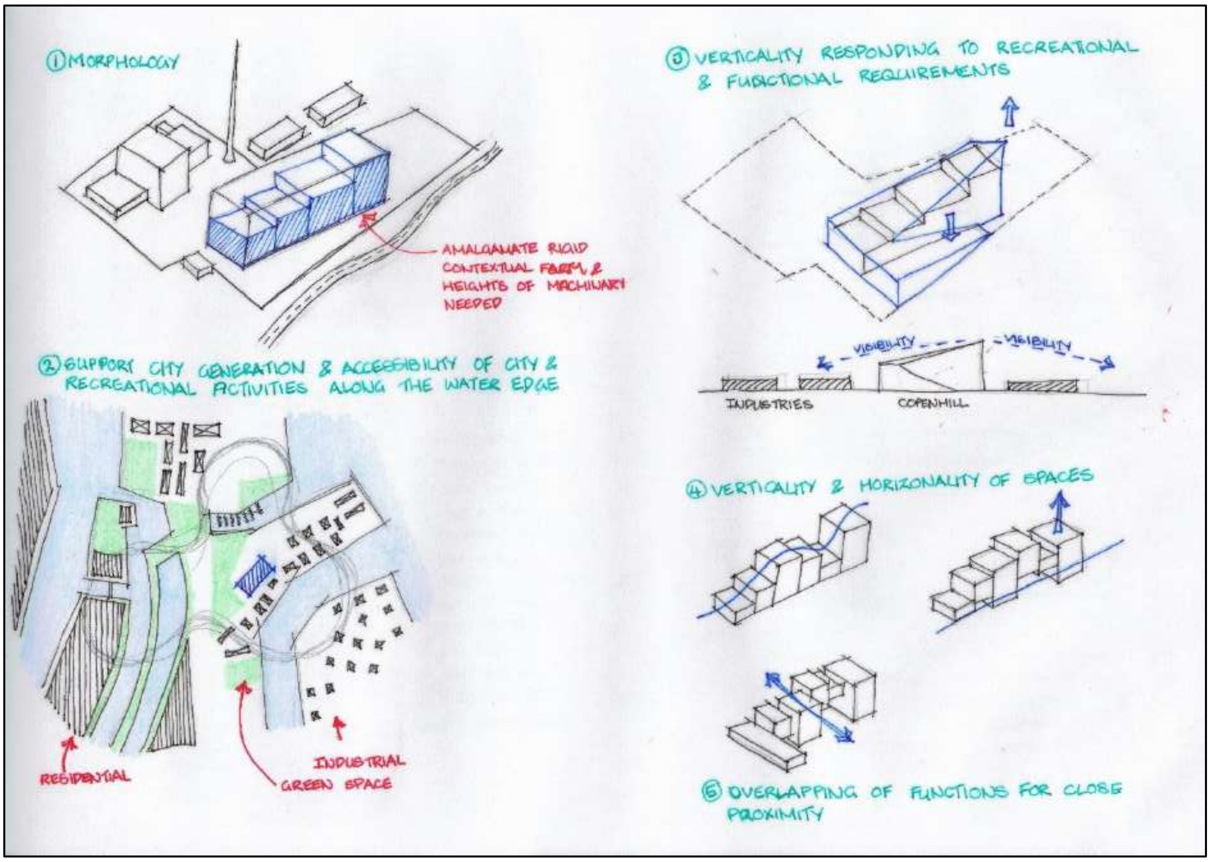


Figure 5.12: *This Picture shows the web-structure and spatial volume of the internal waste-to-energy plant.*

Source: BIG, 2021



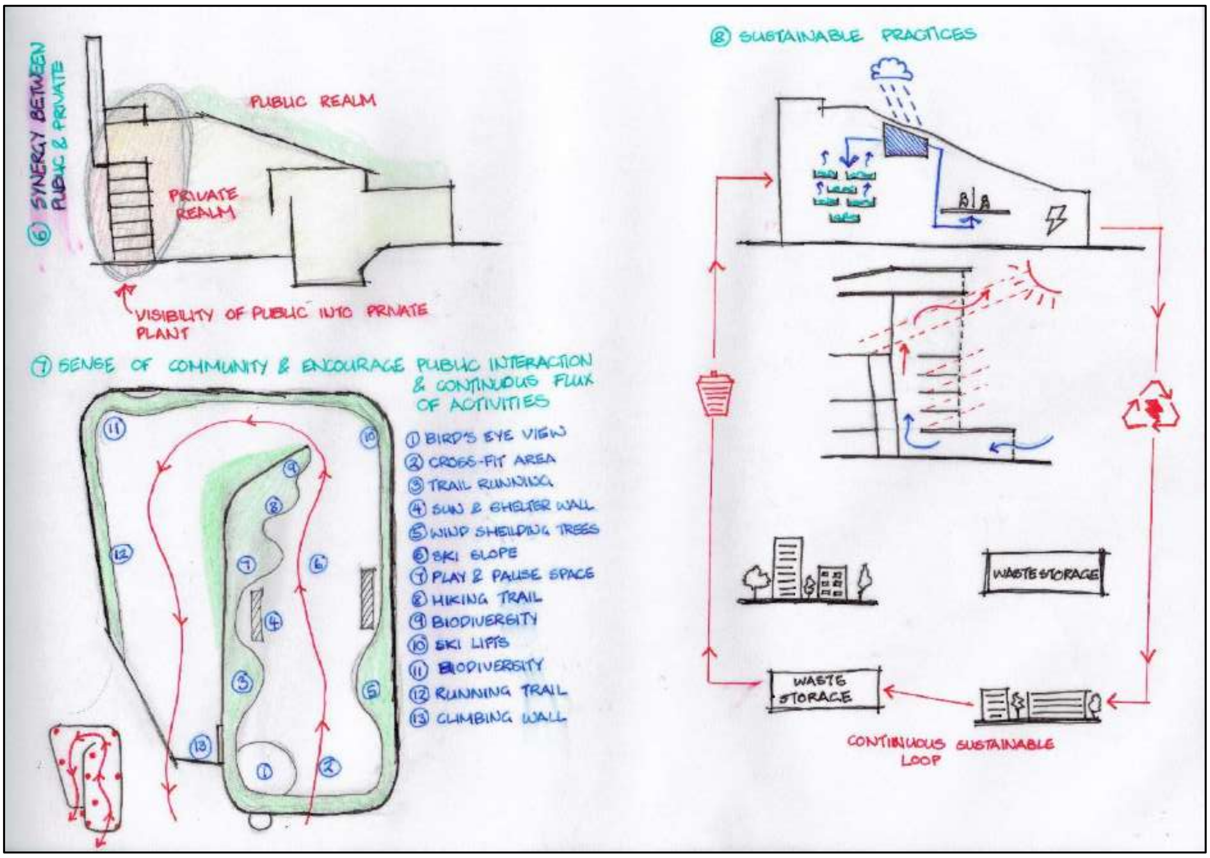


Figure 5.13: *These Diagrams of the Copenhill depicting influences of hybridity and the sustainable solutions implemented throughout the building.*

Source: Author, 2021

5.4. CONCLUSION

This chapter concludes the understanding of the Energy Academy Building and the Amager Bakke in response to the theoretical and conceptual framework of hedonistic sustainability and hybridity.

The Energy Academy conveys principles that would influence the architectural intervention envisioned by the researcher. These principles establish a hybrid research ecosystem of social collaboration, spatial well-being, and smart infrastructure that aids knowledge, research, and innovation. This can be envisioned through collaborative and inclusive spatial arrangements of educational and training spaces, work offices and laboratories, and socially interactive spaces. With sustainability in mind, there is an influence of optimising natural daylighting, manipulating ventilation, introducing innovative rainwater and solar harvesting, and adapting natural spaces within the built environment. These principles work together to create a hybrid ecosystem within the Energy Academy therefore, these principles will influence the architectural intervention.

The Copenhill Waste-to-Energy Plant conveys principles that would influence the architectural intervention envisioned by the researcher. These principles establish hybrid ecosystem of hedonistic sustainability and eco-education through social well-being, city upliftment and environmental consciousness. This can be envisioned through the morphology and materiality of the design within the industrial context, as the Durban Harbour is largely industrial, and the permeability of informative research spaces in conjunction with social ecological and interactive spaces. These principles work together to create a hybrid ecosystem within the Copenhill Waste-to-Energy Plant therefore, these principles will influence the architectural intervention by blurring the distinction between social upliftment and industrial constraint.

The analysis of these precedent studies can be used to create a sustainable architectural model that will create a public consciousness and education towards sustainable energy, in turn, alleviate the biophysical and socio-economic challenges of the Durban Harbour industrial area.

CHAPTER 6

CASE STUDY

6.1. INTRODUCTION

The case study that has been chosen will focus on a successful architectural model that combats renewable energy consumption which is ecologically conservative and implements sustainable energy practices within its design. Interviews and visual analysis with a local research facility will be conducted to gain an understanding of the research problem and solution. They will be analysed concerning the investigation of the literature review, theoretical and conceptual framework. The case study that will be investigated is the Biorefinery Industry Development Facility (BIDF) within the Council for Scientific and Industrial Research (CSIR) in KwaZulu-Natal. The case study will allow for direct observations on the architectural space, education, and implementation of sustainable energy.

6.2. THE BIOREFINERY INDUSTRY DEVELOPMENT FACILITY, CSIR, KWAZULU-NATAL, SOUTH AFRICA

Figure 6.1: *The Council for Scientific and Industrial Research main building set within the surrounding context of the University of KwaZulu-Natal, Durban*

Source: Author, 2021

***Figure 6.2:** The Biorefinery Industry Development Facility set within the CSIR in Durban.*

Source: Author, 2021

6.2.1. Introduction

The Council for Scientific and Industrial Research (CSIR) is a facility that focuses on multidisciplinary research and technological innovation with The Biorefinery Industry Development Facility (BIDF) being one of its many projects. Dr Basil Schonland, a leader of a group of scientists that developed South Africa's first radar system, is the founding president of the CSIR establishing it in 1945. Over the years the CSIR has made crucial discoveries in research and engineering. Amongst them is a focus on sustainable energy research. There will be an exploration of the BIDF's approach to sustainably reshaping research facilities to create an inclusive research ecosystem. Through analysing this case study and linking it to the literature, a developed understanding of the design approach can be obtained.

6.2.2. The CSIR Objectives

The CSIR as a whole focus on the key values of collaboration, improving the quality of life of society and research excellence (CSIR, 2021). The CSIR also has the renowned ability to gain international and regional investing for the research and development of energy solutions. With a dedication to sustainable energy research, the knowledge obtained is localised to the environment it is meant for to achieve energy security and establish cross-cutting approaches for a low carbon economy. For maximum optimisation of research is to be obtained, interconnected energy models such as hybrid energy systems are investigated, such as the BDIF. Hybrid systems are more likely to provide a frequent energy supply and energy storage also a significant focus when these innovative hybrid models are created. Research and investigation are done in interactive and collaborated groups to enable efficiency and increase social and work productivity.

6.2.3. Theoretical and Conceptual Analysis

The Biorefinery Industry Development Facility (BIDF), launched in Durban in 2018, is an example of a sustainable energy project being researched and tested. The BIDF focuses on the conversion of forestry and agro-processing biomass waste (wood chippings and waste paper) into energy (Averda, 2021). Analytical and pilot-testing research, evaluation and processing of technologies are accessible to multi-scale industry businesses. This initiative supports sustainable economic growth, innovative technology, social transformation and engagement. The BIDF building was design specifically for its use of energy research. The design layout consists of laboratory spaces for innovative prototype models to be designed and tested on the ground floor and research offices on the first floor. The next series of images will show a detailed layout of these spaces within the CSIR, along with the way people engage within the space.

Figure 6.3: *This is a chemical analysis laboratory that conducts specialised testing.*

Source: Author, 2021

Figure 6.4: *Researchers within the BIDF are allocated private spaces to conduct their analysis.*

Source: Author, 2021

Figure 6.5: *The CSIR main building administration office and average size office space for prominent researchers.*

Source: Author, 2021

Figure 6.6: *The boardroom that is adaptable to the users' needs of a lecture room with individual or an open plan space for gatherings*

Source: Author, 2021

Figure 6.7: *The BIDF research cubicles provide individual work to be conducted.*

Source: Author, 2021

Figure 6.8: *The laboratory allows for testing to be conducted and interactive collaboration.*

Source: Author, 2021

Figure 6.9: *This laboratory holds the industrial operational scale research and testing with larger equipment.*

Source: Author, 2021

Figure 6.10: *This storage space holds large machinery or prototype testing equipment before they are ready to be up-scaled for industrial use*

Source: Author, 2021

The main building holds a historic modular architecture that has been retrofitted to suit the needs of the occupants. The retrofitting of the main building and the modern layout of the BIDF building shows that the CSIR has taken a sustainable initiative to reshape its research facilities to improve productivity and infrastructure. Although these spaces are adequate for their use, most occupants do not conduct their research with fulfilling efficiency due to the discomfort of confinement within these spaces, and the restriction of physical engagement between people. This creates a slight sustainability imbalance within the research ecosystem.

The BDIF is situated within the CSIR, on the periphery of the University of KwaZulu-Natal premises. This allows for a cohesive link between the researchers and the University for interdisciplinary collaboration to take place and individual research to be conducted. Although the CSIR engages with institutional walkabouts and skilled professional lectures, a small canteen and break-away spaces within the premises minimises the social interaction between researchers and technicians. The small-scale offices serve practical use with artificial lighting and air-conditioning systems. Although, the private offices and research cubicles within the BIDF, feel uncomfortable and detached within the confined space that lacks natural lighting and outdoor views, all of which would stimulate their productivity and wellbeing. Open-plan offices are not provided for, even if some researchers prefer an open workspace environment that enables the easier exchange of intelligence and research. Most occupants work privately with only the conference and large laboratories used for collaboration and gathering. More storage space is needed for larger equipment to be invented and tested at a smaller scale to the actual industrial size so that data can be accurately gathered.

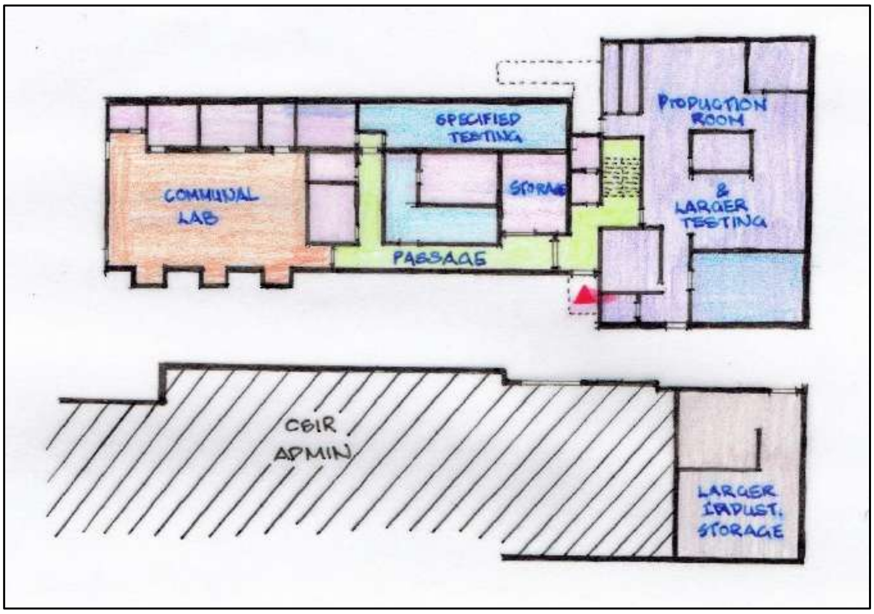


Figure 6.11: *This Sketch Plan shows the zones of spaces on the Ground Floor of the BIDF*

Source: Author, 2021

The hybridisation of spaces within the BIDF allows for working spaces to be easily accessible. The laboratories and conference rooms are accessible and adaptable to the user's needs, whether it is bench-based experiments, group of individual workspaces or informal stand-up meetings. The CSIR's involvement of universities and skilled professional engages the public as patrons of the research conducted through DIY community-based labs. The engagement of the public through live and interactive labs increases awareness of the challenges within the community and how the innovations created can be a solution to these challenges.

Smart infrastructure is implemented through digital lab equipment that responds directly to a shared database that all researchers have access to. These smart technologies are cost-effective and energy-efficient simplifying working environments. Gas outlets and oxygen levels are always monitored to create controlled working conditions within volatile laboratories. Sustainable approaches are used within the building, such as; LED lighting to reduce energy consumption, inverters are used within the air-conditioning systems. A shared database manages and stores research findings so that less time is spent on conventional labs and more time on collaborative research analysis. These systems allow for research findings to be based on real-time feedback. Unfortunately, this research is not available to the public due to its exclusivity and confidentiality.

The BIDF is a sustainable energy production facility with several informative principles that will be obtained for the dissertation architectural intervention. There are also spatial design shortcomings that need to be explored to create a desirable working environment and promote collaboration. These principles include;

- The laboratories and testing spaces are located on the ground floor for easier transportation of heavy machinery. The heavily secured storage spaces are situated near the laboratories.
  The research offices are located on the upper floor for privacy.
- There needs to be a variety of office spaces that encourage interaction and collaboration.
- The private offices need to be well lit and ventilated to increase work productivity.
- There need to be a well-defined lobby to accommodate guests, especially if large conferences and seminars take place.
- The conference room is adaptable to the user's needs, whether it is bench-based experiments, groups of individual workspaces or informal stand-up meetings.
- DIY community-based labs encourage universities and skilled professionals to engage with the public. Live and interactive labs promote engagement with the public.
- A shared database is used to managed research conducted and provide real-time feedback of results. However, research needs to be more publicly available.
- Gas outlets and oxygen levels are monitored to control the working conditions within volatile laboratories. LED lighting is used to reduce energy consumption.

6.3. CONCLUSION

This chapter concludes the understanding of the Biorefinery Industry Development Facility and CSIR in response to the theoretical and conceptual framework of sustainability and hybridity. The case study establishes a sustainable research ecosystem, influenced by a hybrid integrated system of social collaboration and well-being, spatial planning and smart infrastructure. There are challenges within this research ecosystem such as the lack of collaborative and dynamic interactive spaces, the need for pleasant working environments to stimulate productivity, along with the exclusivity of research. These challenges create a gap in addressing sustainability within the BIDF. The analysis of this case study can be used to create a sustainable architectural model that will create a public consciousness and education towards sustainable energy, in turn, alleviate the biophysical and socio-economic challenges of the Durban Harbour industrial area.

CHAPTER 7

ANALYSIS & DISCUSSION

7.1. INTRODUCTION

This chapter aims to explore the empirical findings based on the mixed methods approach collected from interviews and questionnaires that will be thematically analysed and graphically represented. These interviews and questionnaires will provide a greater understanding of the type of architectural response that can be implemented which will inform a sustainable response to the context.

7.2. ANALYSIS OF RESEARCH FINDINGS

The thematic analysis will follow the themes of; the current energy crisis, the biophysical and socio-economic challenges, and renewable energy development, education and society. Interviews were conducted with the Bluff Ward Councillor (Mr J. P. Prinsloo) and a Transnet Electrical Engineer (Mr R. Mkhize) to gain a closer perspective on the local biophysical and socio-economic challenges within the Durban Harbour. Interviews with the CSIR Principal Engineer (Mr C. Mushwana), the LTM Energy Director (Mr D. Pillay), and Dube Tradeport Agrizone Maintenance and Contracts Technician (Mr V. Naidoo) provided expertise on the energy crisis, renewable energy development in South Africa, and the effects of energy on society and architecture. Questionnaires were sampled through snowball referrals of 20 community members that have interacted with the Durban Harbour, the biophysical and socio-economic challenges they experience, and energy development.

7.2.1. Current Energy Crisis

The ongoing energy crisis is majority due to the government’s indecision on infrastructure for energy expansion, according to Mr C. Mushwana. This detrimental energy impact, has forced some industries and local businesses to engage in affordable renewable energy practices introduced by independent producers on a smaller scale. However, by infusing sustainable energy practices within higher energy demanding sectors will lessen the strain drastically on non-renewable energy demand. This has not been fully acknowledged due to arrogance towards individual needs rather than a holistic understanding, and due to the lack of awareness towards the benefits of energy conservation. Social awareness has progressed over the years as architects are leaning more towards sustainable design. Architecture has been impacted through cost-effective solutions, and Legislation that enforces compliance in sustainable design and construction.

According to the questionnaires, participants rely majority on telecommunication and internet access as people spend majority of time within a building for work or personal reasons as seen in FIGURE 7.1. The challenges caused by the energy crisis shown in FIGURE 7.2., has an effect on productivity levels as traveling and communication becomes difficult and business cannot run efficiency.

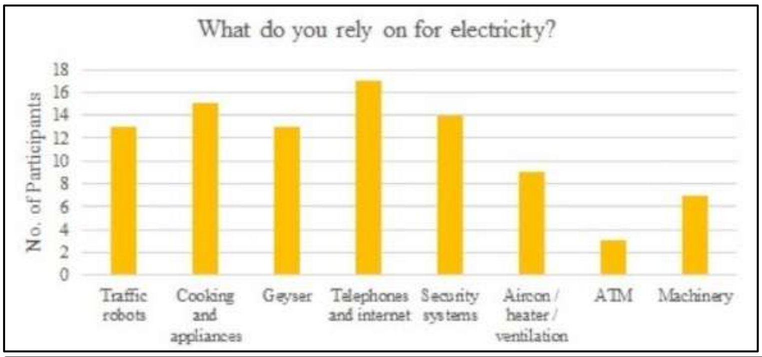


Figure 7.1: *The Diagram depicts what the participants rely on for electricity / energy*

Source: Author, 2021

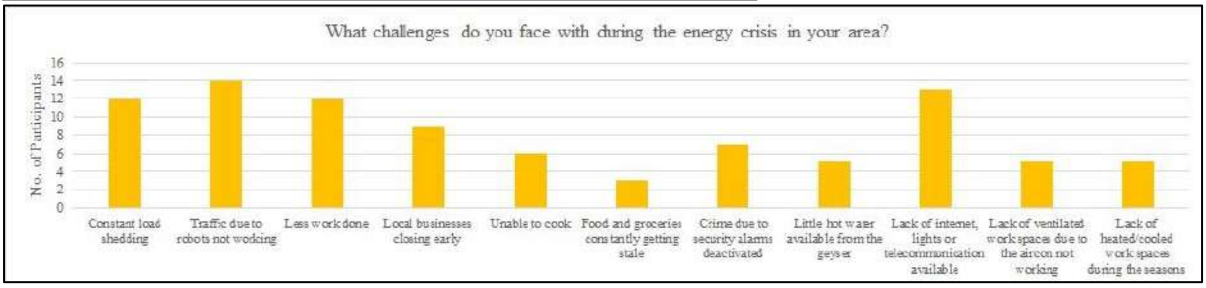


Figure 7.2: *This Diagram depicts the Challenges faced by the participants during the energy crisis*

Source: Author, 2021

7.2.2. Biophysical and Socio-Economic Challenges of the Durban Harbour

The research identifies that that Durban Harbour attracts people primarily through tourism, sport and recreation. The research was able to identify key challenges in FIGURE 7.3., that limits the participants from exploring the Durban Harbour. Safety and crime are key challenges due to the plight of urban decay and industrialisation taken place within the surrounding areas, the lack of outdoor lighting that enhance the visibility of spaces, and mismanaged upkeep of open spaces that encourage unseemly behaviour. The lack of outdoor seating amenities prevents people from unwinding and discourage social interaction. The restriction of areas from Transnet, municipality and port authorities, limit the number of access people has to the Durban Harbour.

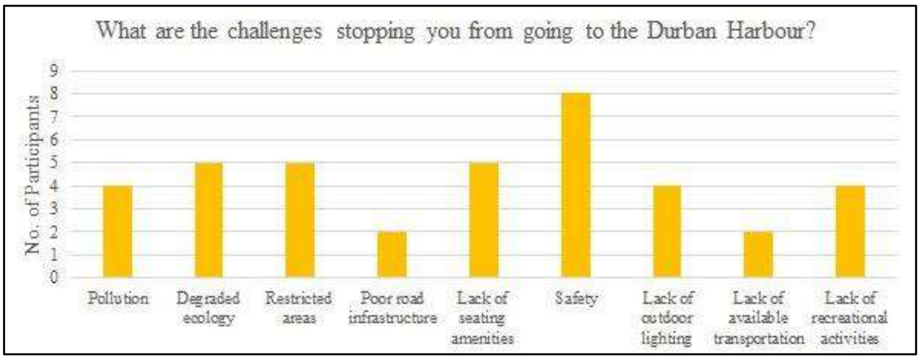


Figure 7.3: *The Diagram depicts the challenges preventing the participants from accessing the Durban Harbour.*

Source: Author, 2021

The research identifies the transportation sector as playing a vital role in the accessibility and development of the Durban Harbour. There are key challenges that hinder this, such as traffic convergence between public transportation and heavy-load transportation and poor road infrastructure that acts as a social deterrent. To promote accessibility and interest to the Durban Harbour, the transportation sector would need to develop efficient inter-modal transportation, sanction roadway design and infrastructure that demarcate different transportation zones and promotes pedestrian safety.

Along with transportation, the research identifies the environmental sector having detrimental effects and influence on society. The key environmental challenges that contribute towards the social development and sustainability stems from the pollution through illegal dumping upriver, and industrial spillage and misuse. To promote environmental conservation and desirable recreational spaces, pollution mitigation and ecological rehabilitation is needed, along with encouraging industrial incentives for environmentally-conscious practices, and penalties for spillages.

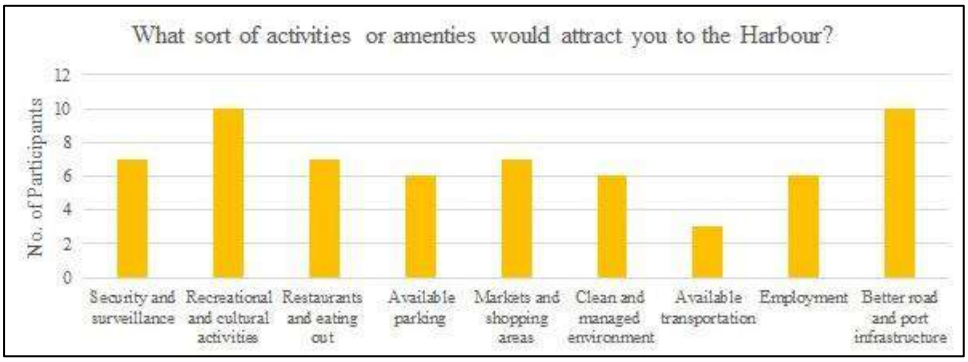


Figure 7.4: *The Diagram depicts the type of activities and amenities that will attract the public to the Durban Harbour.*

Source: Author, 2021

The research gathered establishes that 75% of the participants agree to explore the Durban Harbour frequently if it were to be redeveloped and more publicly inclusive. With the 15% being indecisive, all have come to a common ground on the type of activities and amenities that could be introduced to attract the public to the Durban Harbour as seen in FIGURE 7.4. This will encourage social interaction and local economic development. Improving road and port infrastructure, and parking spaces will promote employment opportunities, and provide easy and efficient accessibility. Natural and visible surveillance will ensure safety. Clean and managed environments will aid in public engagement to the ecology and create awareness.

7.2.3. Renewable Energy Development, Education and Society

According to the research findings, South Africa faces many challenges of renewable energy development, such as; upfront capital costs, poor workmanship, the loss of faith and apathy, and the lack of awareness of innovation and technological advancement.

The data gathered through the questionnaires gauge that 60% of the participants conserve energy at least once or more times a day through several means at home or the workplace. The most practised energy-saving and cost-effective method, for 55% of the participants, is the use of low-energy lighting and switching off unnecessary lighting and electronics when not in use. The design of spaces at home and work maximises natural daylighting rather than the need for artificial lighting. There are only a few residents that utilise solar power for heating and lighting. The use of an air-conditioning unit and heater is subjected to seasonal change, therefore only 25% of participants use it economically. Energy-efficient equipment is utilised with participants that work within the area. Those participants who have practising energy saving within their homes and place of work have largely experienced cost savings, especially within their utility bills. By applying these small practices in their daily lives depicted in FIGURE 7.5., they have subconsciously become aware of the benefits of energy-saving as seen in FIGURE 7.6.

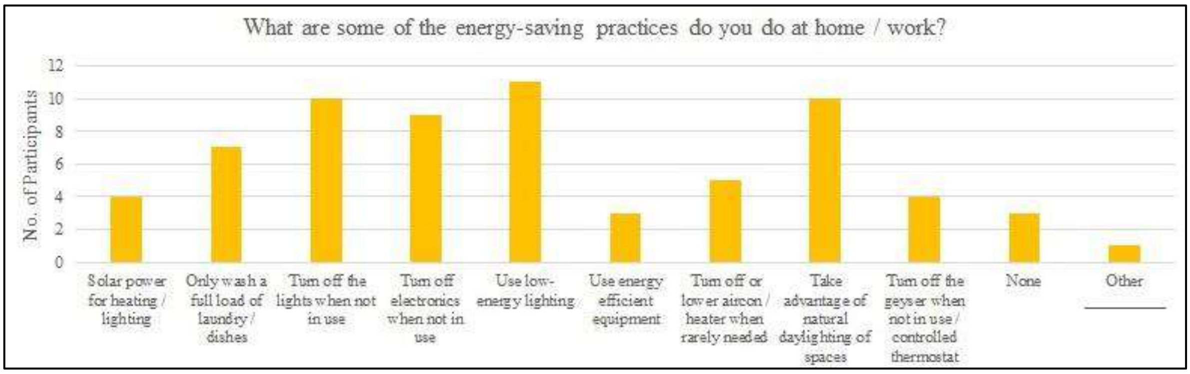


Figure 7.5: *This Diagram depicts some of the energy-saving practices done by the participants. Other explained as Gas power at their place of work.*

Source: Author, 2021

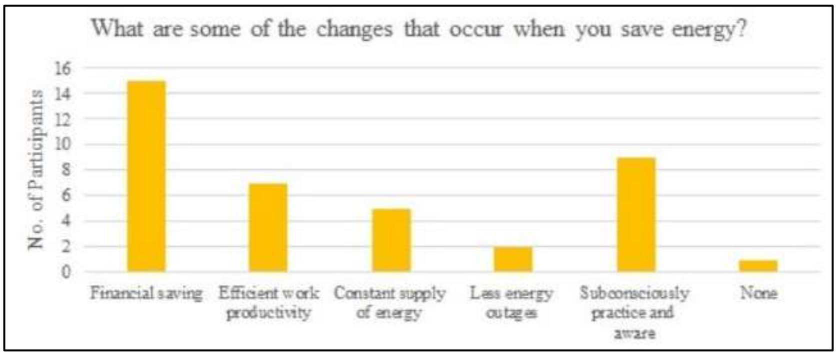


Figure 7.6: *The Diagram depicts benefits faced by the participants who practice energy -saving.*

Source: Author, 2021

Largely, those that do not practice energy efficiency accept that their lack of knowledge on the matter hinders their need to be energy efficient. This may be due to their busy livelihoods and schedules throughout the day, whereby a small task of energy-saving might seem tedious. There is a 25% of participants that find some of these energy-efficient solutions to not be affordable. This may be from the lack of knowledge on cost-effective solutions.

With many private organisations and industries having to focus on sustainable energy production to fulfil their energy demands, the private sector is able to compete in the global market, contribute to the green economic development of the country, and achieve energy efficiency standards through municipal regulations set in place within the built environment. Thus, leaving the public sector in a slow progression towards on alternative energy strategies and the challenge of private companies having exclusive access to their research rather than being publicly inclusive. This hinders public education and awareness. Seemingly, Mr C. Mushwana expresses that "The future of energy sustainability, in South Africa, lies in the link between electricity, biofuels for transportation, and industrial heating production. Although renewable energy paves the way for a sustainable future, it might not be able to bridge the gap in the amount of energy that the country needs". In addition, society may seem complacent about sustainability due to the lacking of understanding and knowledge therefore, education and awareness are vital to progression. Not only to communicate the benefits of renewable energy but to empower sustainable skills development, educate society about energy self-sufficiency, and gain a sense of social responsibility by reducing one's carbon footprint.

This can be resolved through a holistic research approach towards renewable energy and how it relates to the context and not just individual systems. Such as hybrid systems. Whereby on a local scale, hybrid systems can generate a relevant capacity of energy that is cost-effective. Hybrid energy projects prove to be more reliable when they complement each other's constraints, rather than individual systems, and storage systems are vital during peak demand. Along with efficient renewable energy generation, is the necessity of energy storage. Lithium-Ion batteries are a primary example explained by Mr. V. Naidoo, as they have a larger lifespan, and are capacity and sizing efficient for energy storage.

The data gathered through the questionnaires indicated that majority of the participants suggest that an education and research facility on sustainable energy will benefit their community or workplaces, as energy efficiency will improve productivity at home and work because there will be less concern for outages and more cost-efficiency. Many agreed to explore the opinion of participating in training and education on sustainable energy if it were offered to the public. The participants feel that education and awareness towards sustainable energy is a universal concern, and it would broaden one's perspective on how it could be advantageous in their daily lives, and in turn, mitigate many of the biophysical and socio-economic challenges within the area. An education and research facility will succeed because people are always willing to learn new ideas and explore new avenues. However, an education facility will need to accommodate other means of attracting the public that is not just academic. This could encourage employment opportunities and skills development.

There were research key characteristics identified by the interviews that will assist in establishing a successful architectural intervention that promotes renewable energy research and awareness. Within architecture, energy conservation needs to be met from the bottom-up and the initial stage of design hence, engaging with the public at the start of the project is significant to encourage employment and skills development. Research can create a positive impact if the public can view real-time performance on pilot projects and innovation hubs, which will encourage them adapt these practices into their livelihoods and working environment. This can be explored through smart and sustainable energy practices at the input phase, rather than focus on the output produced. Smart infrastructure is crucial for data collection to be academically and publicly available. The international company, Sunny Web Portal, is an ideal example of a public-accessible shared database that monitors solar energy units that are installed, and the information is used to improve the units or replaced them for better performance. An inclusion of clean public spaces and green spaces will increase social well-being and work productivity. This will encourage shared research and collaboration. The efficiency between public accessibility and a partnership between the government and private sector will then follow through with these projects. The futurity of this architectural intervention will encourage other government renewable energy projects to be brought forward and enforced.

The research determines that the establishment of a successful architectural intervention will need to be initiated by private organisations in conjunction with academic institutes to educate the public on with the benefits of energy efficiency and sustainability, whilst maintain the continuity of the project and providing real-time feedback on sustainable energy innovations.

7.3. CONCLUSION

This chapter concludes that through the empirical findings based on the mixed methods approach collected from the interviews and questionnaires, the researcher can understand how the literature and theoretical framework - energy development and sustainability - has impacted South Africa as a whole and the Durban community, as discussed in Chapter 3.2.1 and 3.2.2. These chapters explored how the social participation, economic efficiency, ecological conservation and bottom-up approach of governance has contributed to the city's transformative growth in the residential, industrial, local authority and transportation sectors. These findings serve as a transformative architectural solution towards renewable energy and sustainable development within the context of Durban.

Architecture, within the conceptual framework of hybridity and hedonistic sustainability, will play a catalytic role in achieved this through; establishing a publicly inclusive research and education facility, municipal involvement, social awareness and energy consciousness, innovative feasibility and hybrid energy production. In turn, architecture will establish a balance by introducing conscious-sustainable design solutions to increase the social quality of life and improve human enjoyment, whilst catering for the energy demand in a sustainable manner.

CHAPTER 8

CONCLUSIONS & RECOMMENDATIONS

8.1. INTRODUCTION

This chapter concludes the fundamental approaches that will be taken from the primary and secondary research findings towards the research problem statement. These conclusions will form a basis of recommendations that will develop an appropriate architectural response to the research aim and objectives.

8.2. CONCLUSIONS

The problem identified within the research scope deals with the strain of energy consumption within the industrial context of the Durban Harbour, the inaccessibility of innovative research towards renewable energy and appropriate sustainable architecture, and the lack of social consciousness that contribute to the biophysical and socio-economic challenges within the area. This affects the transformative progress of sustainable development within the city and social awareness towards renewable energy.

8.2.1. Addressing the Key Questions

1. What are the contextual implications of energy development within the environmental, social, and economic systems of the Durban Harbour?

The primary research in *Chapters 2 and 3*, and the secondary research analysis have achieved the researcher's objective of studying the contextual implications of energy development within the environmental, social, and economic systems of the Durban Harbour.

Although the adoption of creating an inclusive green economy, a city or community can grow self-sufficiently and sustainably. However, the transformative approach of sustainable development and green economy within the context of Durban has not been fully successful. The evidence is depicted in the biophysical and socio-economic challenges experienced by the community in the secondary research analysis. Biophysical and socio-economic issues within the industrial area of the Durban Harbour are aided by poor planning, the absence of management from the municipality, the lack of technological advancement and social capital.

With goals already set in place within governance, there are still setbacks that keep sustainable development from progressing. The built environment is considerate towards energy efficiency and sustainable design through legislation and behavioural changes. Many private organisations and industries have focused on sustainable energy production to fulfil their energy demands, compete individually in the global market, contribute to the green economic development of the country, and achieve energy efficiency standards through municipal regulations set in place within the built environment. Unfortunately, many of these actors (such as government, stakeholders, businesses, researchers, and civil society) within governance withhold their research to renewable development from the public due to confidentiality and the lack of management. If these actors or organisations were to introduce incentives, or conduct their business in an energy-efficient manner and instil cost prepositions when delivering that energy, including publicly involved, then other businesses will be encouraged to emulate their progress and the public would be interested in applying their strategies.

Social investment and participation within energy development are minimal. Through the secondary analysis, society acknowledges the effects of the energy crisis and can consider solutions, but it stops there. Unfortunately, as a society, we become complacent about sustainability due to the lacking of understanding and awareness. Education on sustainability can be showcased at a simple scale for the public to understand and later implement, not only to communicate the benefits of renewable energy, but to encourage skills development and employment, and enhance social accountability towards their community. With Durban igniting the need for environmental interventions that protect the ecology and manage waste and pollution that emanate from the city, society is guided towards environmental awareness and their responsibility towards it. Green space has a high probability of social well-being and work productivity.

By focusing on Durban's sustainable development, there needs to be a focus on creating a successful transformative approach through economic influence and funding, social initiative and awareness, ecological consciousness and resource availability, and management through governance. By achieving these core concepts, the city will be able to prosper by mitigating environmental exploitation, enhancing the social quality of life, and educating the public on the futurity of resources, in turn uplifting the economic growth.

2. How can sustainable architecture be used as an appropriate response towards renewable energy and alleviate the biophysical and socio-economic challenges of the Durban Harbour?

The primary research in *Chapters 3, 4,* and in the precedent studies, as well as in the secondary research analysis has achieved the researcher's objective to explore a sustainable architectural model of a renewable energy research facility that is responsive to the local context, appropriate towards renewable energy development, and the alleviation of biophysical and socio-economic challenges within the local context.

The theoretical framework of hedonistic sustainability within the Durban Harbour and surrounding context acts as an ecosystem that integrates social participation, energy consumption, economic profitability, and ecological awareness. Whereby the architecture will establish a balance by introducing conscious-sustainable design solutions to increase the social quality of life and improve human enjoyment, whilst catering for the energy demand in a sustainable manner. The conceptual framework of hybridity will play a significant role in the morphology of the natural landscape to an infrastructural coastline that responds to the urban scale. The urban context of the Durban Harbour being accountable for the development of its' biophysical and socio-economic systems. Architecture and nature can be amalgamated into a self-sustaining habitat that reintroduces diverse interdependency between people and industry to overcome the challenges of urban sprawl, non-renewable energy demand and ecological depletion within the Durban Harbour.

The precedent studies create a clear understanding of how a sustainable architectural model can connect public consciousness, social collaboration, spatial well-being, and smart infrastructure that aids knowledge, research, and innovation. With a sustainable design and structure in mind, the design can be adaptable to future needs. An innovative architectural model can embody hybrid qualities of function, space, and infrastructure. Not only to stand as a physical landmark but uplift the cityscape, the social well-being of the occupants and public, enhance ecological consciousness, in turn, alleviate the biophysical and socio-economic challenges of the Durban Harbour industrial area.

An appropriate architectural model can connect social integration and innovative infrastructure through a reformed research facility. This model will provide social consciousness and educate the community on the futurity of renewable energy development, whilst alleviating many biophysical and socio-economic challenges of the area.

3. How can sustainable architecture be used as a tool to promote education and social consciousness and create an interdependency on hybrid sustainable energy?

The primary research in *Chapters 2 and 3,* the case study and the secondary research analysis have achieved the researcher's objective to promote education and social consciousness towards hybrid sustainable energy solution through an architectural model.

Education, involvement and infrastructure are important for sustainability to progress within the public realm. Involvement can include employment and skills development. Smart infrastructure is crucial for data collection to be academically and publicly available. The research looks at a holistic approach towards renewable energy and how it responds to the community and industries. By studying the possible renewable sources available on the coast of the Durban Harbour, strategies can be investigated and implemented. Through the second analysis, society will be motivated to part-take in energy efficiency research and activities if they were publicly inclusive.

The case study creates a clear understanding of how a successful research ecosystem is influenced by a hybrid integrated system of people, technology, and spatial planning. The gap within this research ecosystem is the lack of collaborative and dynamic interactive spaces, the need for pleasant working environments to stimulate productivity, along with the exclusivity of research. By focusing on collaboration, flexibility and accessibility, researchers can share knowledge of research to all in turn creating innovative technology based on these findings. This can then be available to the community and industries to implement. Just by improving infrastructure, spatial planning and architecture, the hybrid principles can be contributed to the community's quality of life and further positively impact the city in a hedonistic sustainable way.

8.2.2. Confirming the Assumption

The research hypothesis states - *The development of a renewable energy research facility will educate the public on the futurity of sustainable energy and the benefits of implementing hybrid renewable energy innovations within their community. This intervention will provide excess energy supply to the municipal power grid during peak demands, and in turn resolve the biophysical and socio-economic challenges of the area.*

The researcher's objectives;

1. To investigate the contextual implications of energy development within the environmental, social, and economic systems of the Durban Harbour.

2. To explore a sustainable architectural model of a renewable energy research facility that is responsive to the local context and alleviate the biophysical and socio-economic challenges of the local context.

3. To promote education and social consciousness towards hybrid sustainable energy through an architectural model.

Through analysis of the primary and secondary analysis, the researcher can achieve the objectives set in place and confirm the assumption of the research topic. By creating an appropriate architectural model, through a renewable energy research facility, there will be a focus on research and educational component to create social consciousness towards the sustainable energy challenges of the Durban Harbour and allow for the hybrid renewable innovations to be researched and implemented within the Durban Harbour, whilst contributing to the municipal power grid. This architectural model will in turn be responsive to mitigating the biophysical and socio-economic challenges of the Durban Harbour.

Additionally, the futurity of this architectural model will encourage other regions to establish similar interventions beneficial to that specific region.

8.3. RECOMMENDATIONS

The recommendations intend on addressing the research findings, from the primary and secondary research gathered, that embody the fundamental principles of the theoretical and conceptual framework and formulate a clear architectural response towards a renewable energy research facility on the Durban Harbour. These principles will be applied to accomplish the research aim and objectives.

8.3.1. Urban Design Framework

Location: The key characteristics in the architectural design approach needs to consider the relationship between the industrial context and proposed development. The site will need to be located within the industrial zone southwest of the Durban Harbour, near the harbour mouth. This site will maximise the potential for tidal power and wind power, have clear visibility along with the Durban CBD, and have easy access by the community members near the Durban Harbour and surrounding areas.

Hyper-urbanisation and support of Urban regeneration: By redeveloping and improving urban planning, the community has access to mixed-use developments, integrating several existing buildings into the density within the urban framework, and compact appropriate activities and resources that will respond to the needs of the occupants. These activities and forms of engagement will create new connections to the city and sprawled areas within the industries, and ignite the city's character.

Accessibility through Centrifugal Forces: Links between the community and harbour will draw people in freely and create a dialogue between spaces. The road infrastructure needs to be inclusive to accommodate larger vehicles, public transportation routes, and enhance pedestrian walkability. More public transportation (bus and water taxi routes) needs to be designated for the public and commuters to easily access the site. The industries will be able to stitch to the urban fabric by the inclusion of activities, transportation routes and green spaces. Regeneration of the water edge by reintroducing the mangroves and green spaces, and public amenities need to be considered in the urban framework to entice the public to the site.

8.3.2. Design Approach

Morphology and sculpting the land: The architectural design form and site is seen as a hybrid ecosystem; therefore, a morphology approach should be taken, which amalgamates the rigid planning of the industrial area to an organic inscription of the water edge.

Vertically and Horizontality: Although the neighbouring industries are low-lying, the architectural design needs to stand as a landmark to the city to draw in awareness visibility and functionally. To minimise the carbon footprint, maximise solar and wind power collection, the development would need to be expressed vertically. The apex of the building will be accessible to the public for cityscape views and the activities within the site.

Spatial Organisation: The research facility will act as an ecosystem for education, research and innovation. The organisation of adaptive and permeable spaces that are flexible to the user's future needs. The occupants can circulate through porose spaces with clear sightlines. The organisation of interconnect working spaces that are flexible to ease the flow between people and research equipment. Spaces will be adaptable to different forms of research. The structural grids need to allow for a multitude of easily interchangeable functions.

A synergy between public and private spaces enhances the dynamism of the site. The dynamism of social spaces will promote wellbeing and productivity, and allow the occupants to connect with the environment. Hedonistic sustainability encourages interaction between the pubic and occupants, the density of interactive spaces and overlapping functions diversify experiences and create a sense of community.

Functions: A continuous flux of activities within the design and surrounding context will create constant activity through proximity, that will intensify modern spaces and the functions will keep the site alive.

Collaborative workspaces include; administrative offices, research offices, open-plan layout labs, group and individual workspaces, bench-based experiment labs, industrial labs, informal stand-up meeting spaces, semi-private stations, unplugged quiet spaces, conference and meeting rooms, lecture theatres, educational rooms, library, auditorium, and storage spaces. Social interactive spaces include; break-out spaces and communal cafeterias.

Public interactive spaces will attract the public and increase awareness of the challenges within the community and how the innovations created can be a solution to these challenges. These include; DIY community-based labs and maker spaces, training and mentorship spaces, university and pop-up research parks, work-bench spaces, live labs within the city, public gathering spaces, open-view labs, exhibition spaces. Public recreational activities enhance the hedonistic sustainability of spaces that are socially dynamic and economically profitable.

Smart Infrastructure: Reconfigurable infrastructure to services plug and play features so that all have access to digital systems wherever they work in smart-tech labs, wireless communication systems, digital lab equipment that responds directly to a shared database, high-capacity cloud storage technology for data processing and storage.

Sustainable Design Approach: Architectural principles need to consider rainwater harvesting, smart energy management, energy-efficient LED lighting, atrium spaces for daylighting to access internal spaces, solar chimneys to naturally release air, waste management, green spaces within the building to naturally cool the air quality, and sustainable building materials used. Efficient transportation systems allow for the movement of people and technology.

Renewable Energy: Renewable energy generation will be inclusive in the urban framework. Energy storage spaces for the general of renewable energy. The building form will be orientated to maximise the surface area for solar energy. The façade and roof of the built form will be equipped with innovative solar panels to maximise solar harvesting. Energy efficiency interventions (solar, wind and tidal) will be conducted on the roofs of the surrounding context, along the street and water edge.

Figure 8.1: *Renewable Energy Research Facility Logo*

Source: Author, 2021

All of these principles will collectively form a sustainable architectural approach towards energy; through a renewable energy research facility that is responsive to the context of the Durban Harbour.

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APPENDICES

INTERVIEW: BLUFF WARD COUNCILLOR

The research will be conducted through a semi-structured interview with a key informant to gain an understanding on the research they have conducted and how it will relate to the challenges at hand. This interview is open to any relevant information that would be interesting to discuss. This interview is conducted with Mr J.P. Prinsloo (Bluff Ward Councillor).

My name is Ashmika Ramklass and I am currently a Master's if Architecture Student at the University of KwaZulu-Natal. My dissertation topic is "A Sustainable Architectural Approach towards Energy: Through a Renewable Energy Research Facility on the Durban Harbour". I would like to thank you in advance for participating in this research process. I have a couple of questions to ask however we may treat this as more of a discussion of your experience and expert knowledge of the area. The interview will relate to the challenges of the industrial and residential sector, with regard to energy development and the Umhlatuzana River.

How long have you been working within this community?
What made you decide on taking up this position?
What is your relation to the area? • **Do you live here, and if so, for how long?**
Have you been to the Umhlatuzana River canal at the harbour? • **What would be your reasoning for visiting or not visiting this area?**

What is your opinion of the Umhlatuzana River canal situated within Bayhead?
What is your understanding on the link between population increase, urban sprawl and energy consumption? • **What are the advantages of these impacts within the area?** • **What are the disadvantages of these impacts within the area?**

What is the relationship between the industrial sector and residential sector? • **How have these sectors impacted the Umhlatuzana River in a positive way?** • **How have these sectors impacted the Umhlatuzana River in a negative way?**
Why is there a need for the conservation of the Umhlatuzana River?
How do you think the economy and social well-being can be affected by renewable energy alternatives as compared to ordinary energy sources?
How would society benefit to the accessibility and education of alternative renewable energy and ecological conservation?
What are your thoughts on the government policies on re-integrating the public into the Durban Harbour Precinct? • **Do you think a public intervention will fail or improve the area?** • **How do you think the area will be impacted by a public space that educate and trains people on renewable energy alternatives?**
How will this public and education facility contribute to the infrastructure of the area? • **What do you think will be the long-term benefits for this intervention?**

• **Would you happen to recommend anyone that could assist in my research? I would kindly provide you with my contact details.**

INTERVIEW: TRANSNET ENGINEERING

The research will be conducted through a semi-structured interview with a key informant within the industries that currently reside within the Durban Harbour and have any interaction with the Harbour on a daily basis. This interview is open to any relevant information that would be interesting to discuss. This interview is conducted with Mr Richard Mkhize (Transnet Engineering).

My name is Ashmika Ramklass and I am currently a Master's if Architecture Student at the University of KwaZulu-Natal. My dissertation topic is "A Sustainable Architectural Approach towards Energy: Through a Renewable Energy Research Facility on the Durban Harbour". I would like to thank you in advance for participating in this research process. I have a couple of questions to ask however we may treat this as more of a discussion of your experience and expert knowledge of the area. The interview will relate to the facility and its relationship to the Bayhead area and the Umhlatuzana River, energy development and renewable energy practices.

What is your current position in this facility? • **How long have you been working with this facility?**
Do you reside or work in close proximity to the facility? • **How long does it take to commute?** • **Do you have any idea how long this company has resided in this area?**

What is your understanding on the relationship between the local residents and this company? • **What are the positive impacts with this relationship?** • **What are the negative impacts with this relationship?**
What is your understanding on the relationship between the ecology of the Umhlatuzana River and this company? • **What are the positive and beneficial impacts with this relationship?** • **What are the negative impacts with this relationship? This may be accidental impacts.**
What are your thoughts on the ongoing energy crisis in South Africa? • **How has the energy crisis affected this company?** • **How has energy usage affected your relationship to the environment and the local residents?**

What are the primary components in your company that require a high energy demand?
Does this company solely rely on the energy grid supplied by the government or does the company part-take in any renewable energy practices? • **If so, then what renewable energy practices are implemented in this facility?** • **If not, what are your thoughts on implementing these practices to benefit this facility future productivity?**
What is your opinion on the availability of educational resources to highlight the plight of energy consumption and ecosystem depletion, faced within your industry?
How would the proposal of a renewable energy education facility in the area be an advantage or disadvantage to this facility?
How often do you visit this area for leisure activities? • **What is your reasoning for visiting this area for anything besides commuting?**
Do you have any concerns on the social quality of work life within this facility, with regard to the facility being based in an industrial zone? • **How would an improvement on public space affect this facility?**
Where do you see this company going in the future? • **If it carries on the way it is?** • **If the company implements sustainable practices, more employees are educated in these practices the public space around the facility is greatly improved, and the river stays untouched by urban impacts?**

Would you happen to recommend anyone that could assist in my research? I would kindly provide you with my contact details.

INTERVIEW: LTM ENERGY & CSIR

The research will be conducted through a semi-structured interview with a key informant to gain an understanding on their expertise and how it will relate to the research at hand. This interview is open to any relevant information that would be interesting to discuss. This interview is conducted with Mr Vijen Naidoo (Dube Tradeport Agrizone), Mr Crescent Mushwana (CSIR), and Mr Dhevan Pillay (LTM).

My name is Ashmika Ramklass and I am currently a Master's if Architecture Student at the University of KwaZulu-Natal. My dissertation topic is "A Sustainable Architectural Approach towards Energy: Through a Renewable Energy Research Facility on the Durban Harbour". I would like to thank you in advance for participating in this research process. I have a couple of questions to ask however we may treat this as more of a discussion of your experience and expert knowledge of the area. The interview will relate to the energy crisis in South Africa, energy efficiency and sustainable design, education and research as a tool, and the challenges of renewable energy development in South Africa.

What does your current role entail at LTM Energy? • **How long have you been working here?**

What are your thoughts on the ongoing energy crisis in South Africa?
From your experience, which sector (residential, transportation, industrial or commercial) requires the largest energy demand in South Africa and why?
Why type of affects has you seen within the society and architecture due to the energy crisis?
What are the challenges of renewable energy development in South Africa right now? • **Why do you think it is so important for South Africa to be moving towards renewable energy projects?**
Why do you think innovative sustainable research is greatly unavailable or inaccessible to the public? • **How could this research facility be more publicly inclusive?**

What type of funding is greatly needed for renewable energy projects and research to progress?
Who do you think needs to be more aware on the development of sustainable projects and why?
How could the company influence society to become more reliant on renewable energy?
Why would a renewable energy facility and research availability be imperative in the advancement of sustainable energy?
What kind of changes have you seen within the society, economy and architecture on renewable energy practices?

Would you happen to recommend anyone that could assist in my research? I would kindly provide you with my contact details.

QUESTIONNAIRE: COMMUNITY MEMEBERS

The research will be conducted through snowball group questionnaire with community members that currently reside within close proximity to the river course and/or have a direct interaction with the river on a daily basis. The research will be conducted to gain an understanding on the research they have conducted and how it will relate to the challenges at hand. This questionnaire is open to any relevant information that would be interesting to discuss.

My name is Ashmika Ramklass and I am currently a Master's if Architecture Student at the University of KwaZulu-Natal. My dissertation topic is "A Sustainable Architectural Approach towards Energy: Through a Renewable Energy Research Facility on the Durban Harbour". I would like to thank you in advance for participating in this research process. I have a couple of questions to ask however we may treat this as more of a discussion of your experience and expert knowledge of the area. The questionnaire will relate to energy saving practices, and the challenges of energy development between the industries, community and natural environment.

What is your reason for going to the Durban Harbour area?			
☐ Reside	☐ Work	☐ Leisure	
How long have you been living or working here?			
☐ -1 year	☐ 1-3 years	☐ +3 years	☐ Other ___________

Are you able to have access to the Durban Harbour along the Bluff?		
☐ Yes	☐ Partial	☐ No
If so, what do you do there?		
☐ Work in the industries	☐ Transportation of goods	☐ Photography
☐ Visit the Bayhead Heritage site	☐ Private yacht club	☐ Other ___________
If not, what is challenges are stopping you from going there?		
☐ Pollution	☐ Degraded ecology	☐ Restricted areas
☐ Poor road infrastructure	☐ Lack of seating amenities	☐ Safety
☐ Lack of outdoor lighting	☐ Lack of available transportation	
☐ Lack of recreational activities	☐ Other ___________	

What challenges do you face with transportation within the Durban Harbour area?	
☐ Traffic	☐ Lack of various public transportation
☐ Poor road infrastructure	☐ Air pollution
☐ None	☐ Other ___________

What improvements in transportation can be taken?	
☐ Improve road infrastructure	☐ Introduce different public transportations
☐ Widen roads	☐ Demarcate roads for different uses
☐ Other ___________	

What challenges do you face with the environment within the Durban Harbour area?	
☐ Flooding upriver	☐ Quarrying and over-fishing
☐ Illegal dumping	☐ Smell, waste and water pollution
☐ Lack of recreational space	☐ Inaccessibility to the river and mangroves
☐ Other ___________	

What environmental initiatives can be taken?	
☐ Environmental heritage sites	☐ Litter recycling
☐ River and bay clean-ups	☐ Prosecute companies for spillages
☐ Protected areas with no fishing or yachting	
☐ Educate and promote ecological conservation	
☐ Provide alternative waste collection for informal settlements	
☐ Other ___________	

What challenges do you face with due to the energy crisis in your area?	
☐ Constant load shedding	☐ Traffic due to robots not working
☐ Less work done	☐ Local businesses closing early
☐ Unable to cook	☐ Food and groceries constantly getting stale
☐ Crime due to security alarms deactivated	
☐ Little hot water available from the geyser	
☐ Lack of internet, lights or telecommunication available	
☐ Lack of ventilated work spaces due to the aircon not working	
☐ Lack of heated/cooled work spaces during the seasons	
☐ None	☐ Other ___________

How often do you experience power outages during load shedding in your area?	
☐ Once or more a day	☐ Once or Twice a week
☐ Never	☐ Other ___________

What do you rely on for electricity?	
☐ Traffic robots	☐ Cooking and appliances
☐ Geyser	☐ Telephones and internet
☐ Security systems	☐ Aircon / heater / ventilation
☐ ATM	☐ Machinery
☐ Other ___________	

What are some of the energy-saving practices do you do at home or at work?	
☐ Solar power for heating / lighting	☐ Only wash a full load of laundry / dishes
☐ Turn of the lights when not in use	☐ Turn off electronics when not in use
☐ Use low-energy lighting	☐ Use energy efficient equipment
☐ Turn off or lower aircon / heater when rarely needed	
☐ Take advantage of natural daylighting of spaces	
☐ Turn off the geyser when not in use / controlled thermostat	
☐ None	☐ Other ___________
How often do you conserve energy?	
☐ Once or more a day	☐ Once or Twice a week
☐ Never	☐ Other ___________
What are some of the changes that occur when you use energy saving practices?	
☐ Financial saving	☐ Efficient work productivity
☐ Constant supply of energy	☐ Less energy outages
☐ Subconsciously practice and aware	☐ None
☐ Other ___________	
If not, what is preventing you from implementing these practices?	
☐ Not affordable	☐ Lack of knowledge on this information
☐ Lack of time	☐ Theft
☐ None	☐ Other ___________
_______	

If the Durban Harbour, along the Bluff, were to be developed and open to the public, would you go?	
☐ Yes ☐ Partial ☐ No	
If not, what sort of activities or amenities would attract you to this area?	
☐ Security and surveillance	☐ Recreational and cultural activities
☐ Restaurants and eating out	☐ Available parking
☐ Markets and shopping areas	☐ Clean and managed environment
☐ Available transportation	☐ Employment
☐ Better road and port infrastructure	
☐ Other ___________	

In your opinion, would an education and research facility on sustainable energy would benefit your community or work place?
☐ Yes ☐ Partial ☐ No
Explain ___________
If there were training and education offered to the public, would you explore it?
☐ Yes ☐ Partial ☐ No

What type of sustainable energy methods do you think would benefit your community or work place?	
☐ Energy conservation	☐ Use sustainable materials in construction
☐ Renewable energy use	☐ Practice low-impact design of spaces and structures
☐ Water conservation	☐ Other ___________

How do you think energy efficiency could help improve your work productivity?	
☐ Pleasant heated / cooled spaces	☐ More work done
☐ No power outage concern	☐ Pleasant social spaces
☐ Well-designed work spaces	☐ Efficient advanced technologies available
☐ Less money spent on additional ventilated / heating / cooling systems	
☐ Other ___________	

Would you happen to recommend anyone that could assist in my research? I would kindly provide you with my contact details.

11 August 2022

Ashmika Ramklass (213506761)
School of Built Environment & Development Studies
Howard College Campus

Dear A Ramklass,

Protocol reference number: HSSREC/00003718/2021
Project title: A sustainable architectural approach towards energy: Through a renewable energy research facility on the Durban Harbour

Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 06 December 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 11 August 2023.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

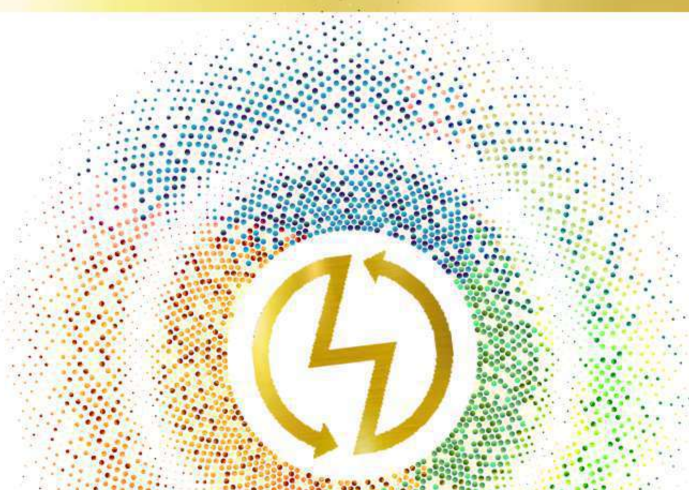
[redacted]

Professor Dipane Hlalele (Chair)

/ms

PROBLEM STATEMENT-AIM

An **architectural response** through **education** and **awareness** towards the **challenges** of **sustainable energy development** on the **Durban Harbour**, as well as a **mechanism** that will **foster** the **production** of **hybrid renewable energy**

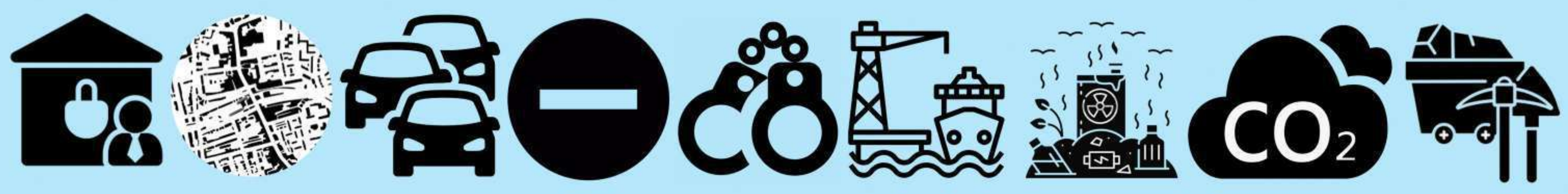


KEY QUESTION

How can a renewable energy **research facility** act as a **sustainable** architectural **response** to **energy** in the **Durban Harbour**?

OBJECTIVES

- **Investigate** the **contextual implications** of energy development within the **environmental, social and economic systems** of the **durban harbour**.



- **Explore** a sustainable **architectural model** of a renewable energy research facility that is **responsive to the local context** and alleviate the biophysical and socio-economic challenges of the local context.

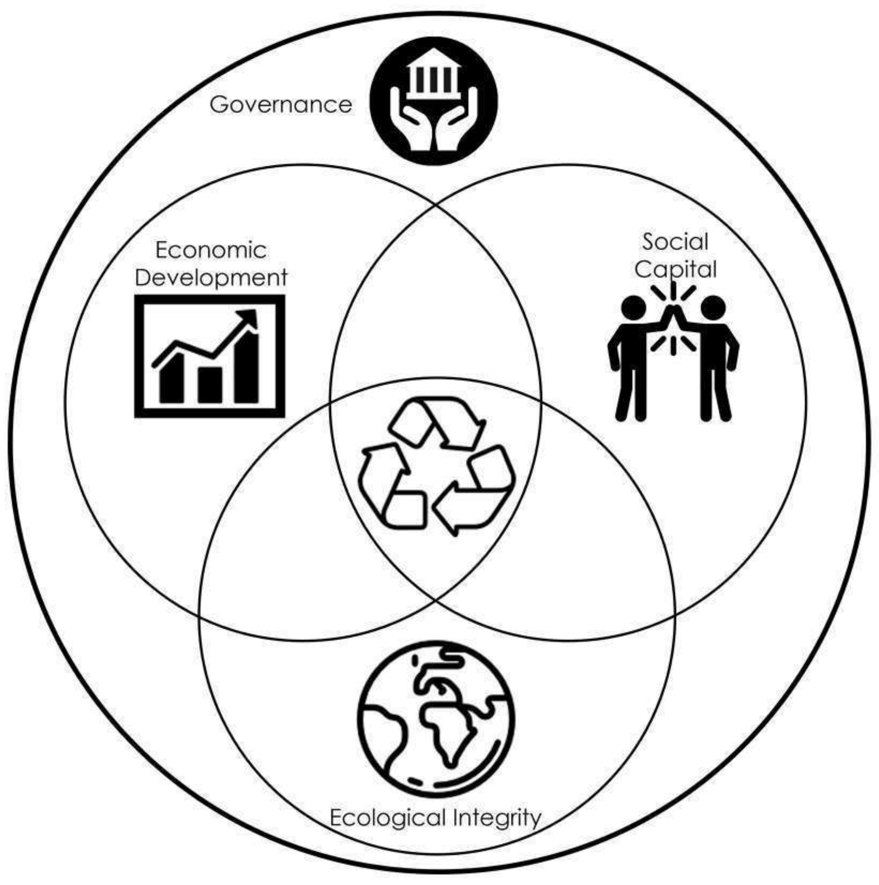
Hybridity
Architecture and Nature will amalgamate urban fabric into a self-sustaining habitat to reintroduce interdependency between people and industries to overcome urban degradation and resource demand

Hedonistic Sustainability
Architecture will balance conscious-design solutions to increase quality of urban life

Precedent Study
Architecture will stand as a public landmark to uplift cityscape, social wellbeing and renewable energy consciousness

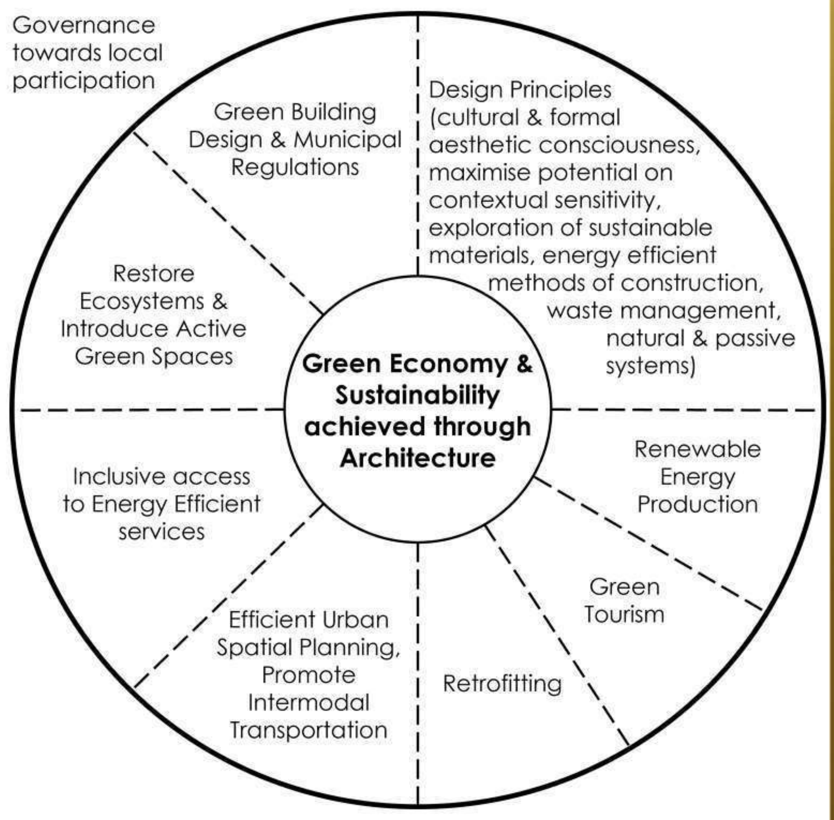
- **Promote education & social consciousness** towards hybrid sustainable energy through an architectural model.

SUSTAINABLE DEVELEOPMENT & GREEN ECONOMY

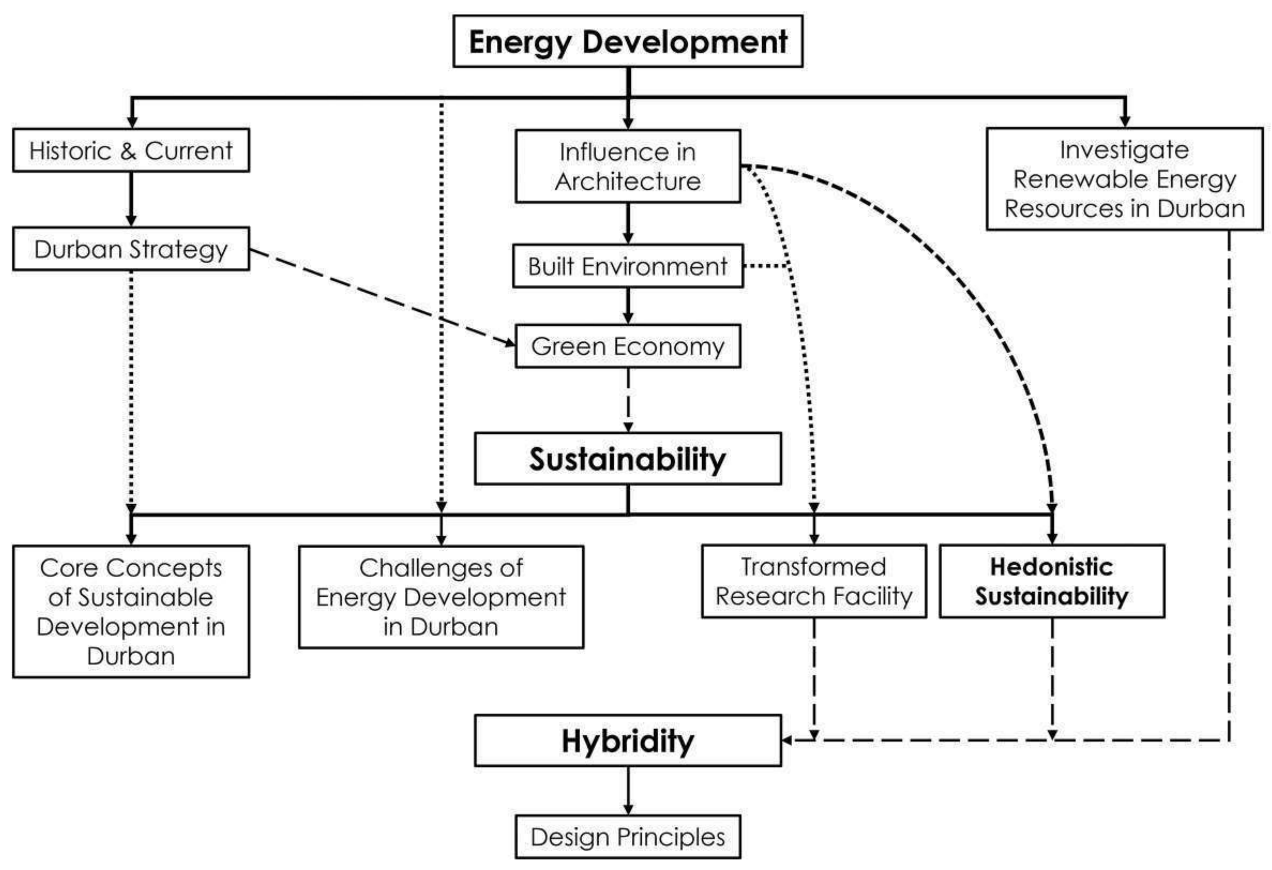


Brundtland Report Sustainable Development Principles

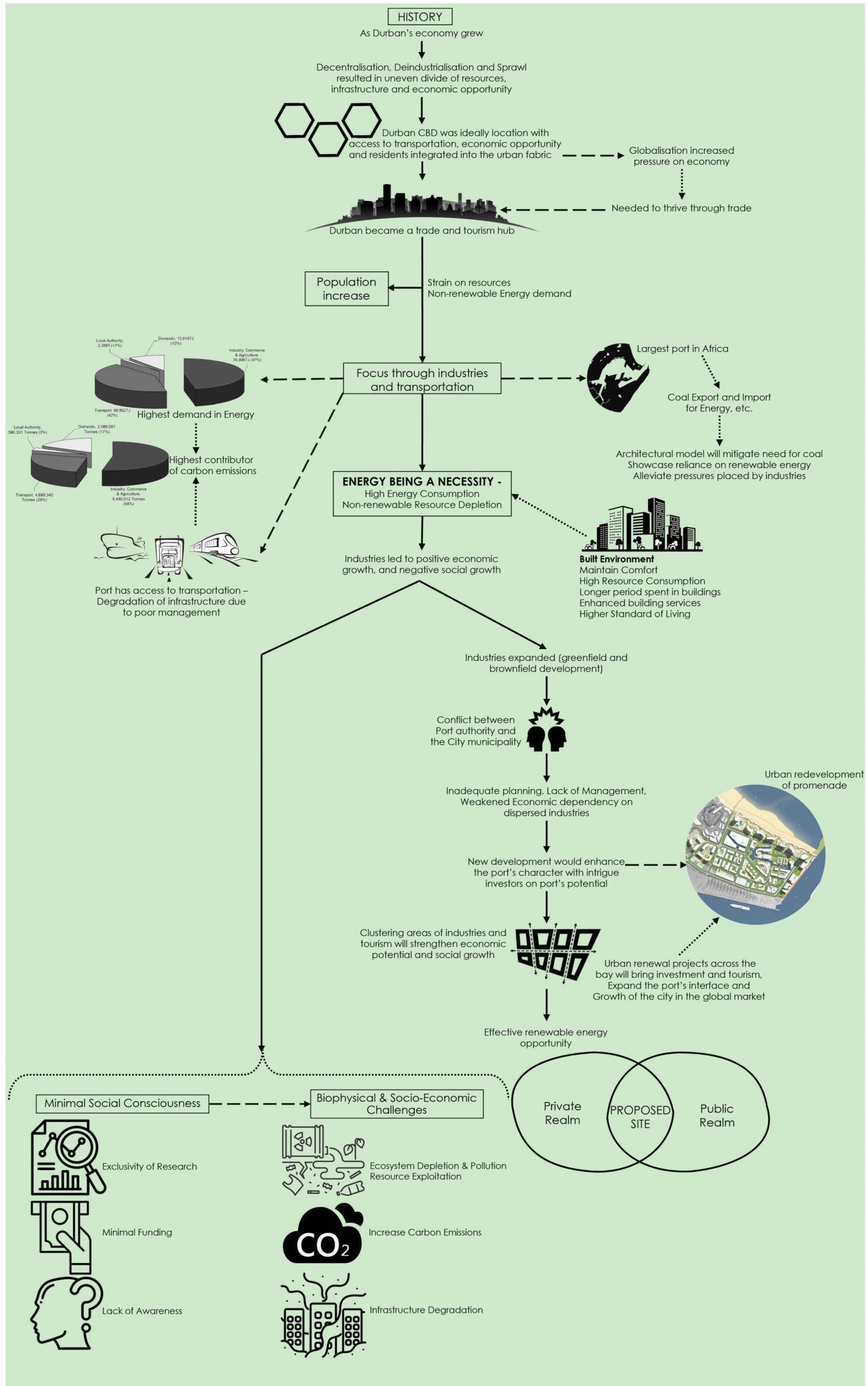
- Responsive policymaking to decrease resource demand
- Equal social development
- Sensitive production of resources within ecosystem carrying capacity
- Global alliance for initiatives
- Innovative technology to improve utility of resources
- Governance towards local participation



STRUCTURE OF DISSERTATION

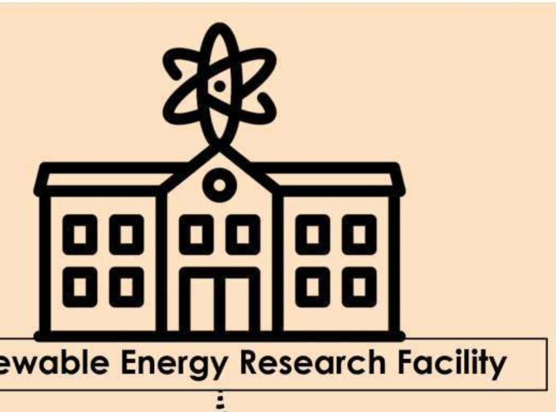


WHY?



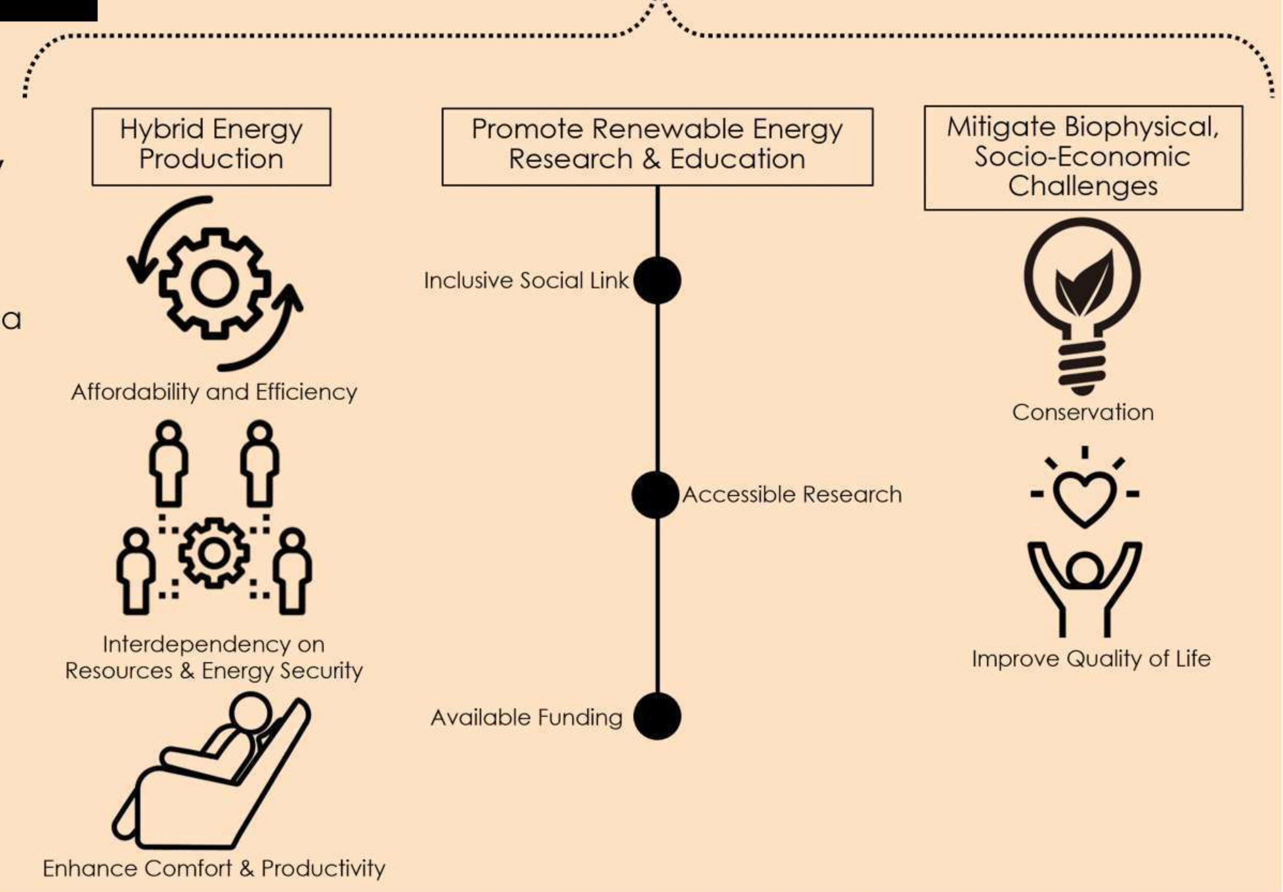
WHAT?

An architectural model will create an **social consciousness** towards the **sustainable energy challenges** of the **Durban Harbour** industrial zone, whilst addressing **biophysical and socio-economic challenges** of the area, through the theorectical & conceptual framework analysis of **sustainable development, hedonistic sustainability & hybridity**

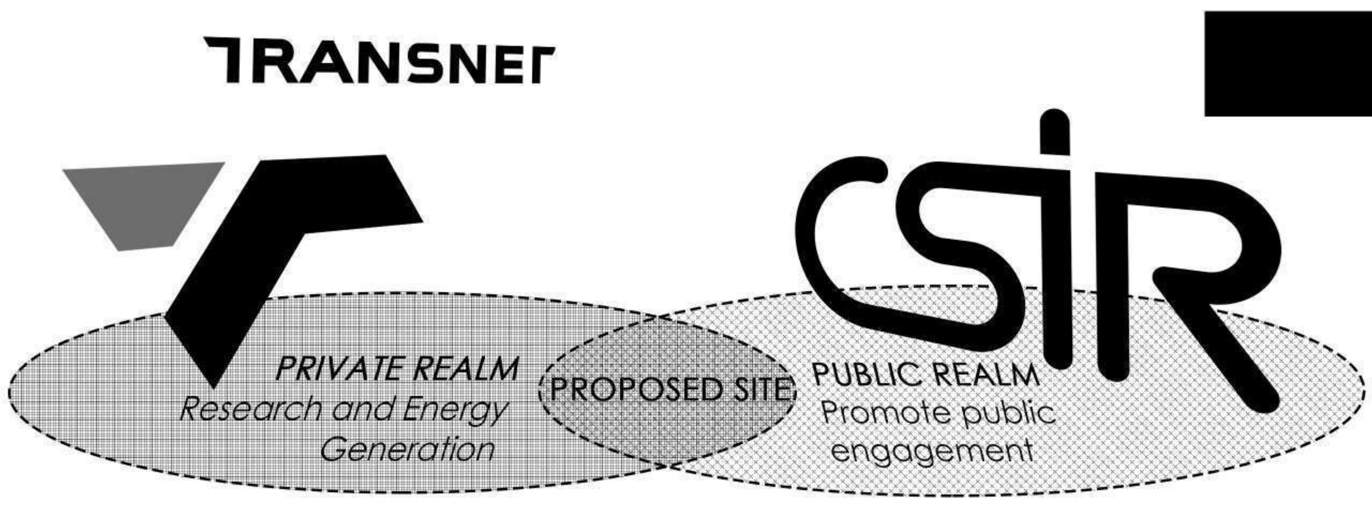


HOW?

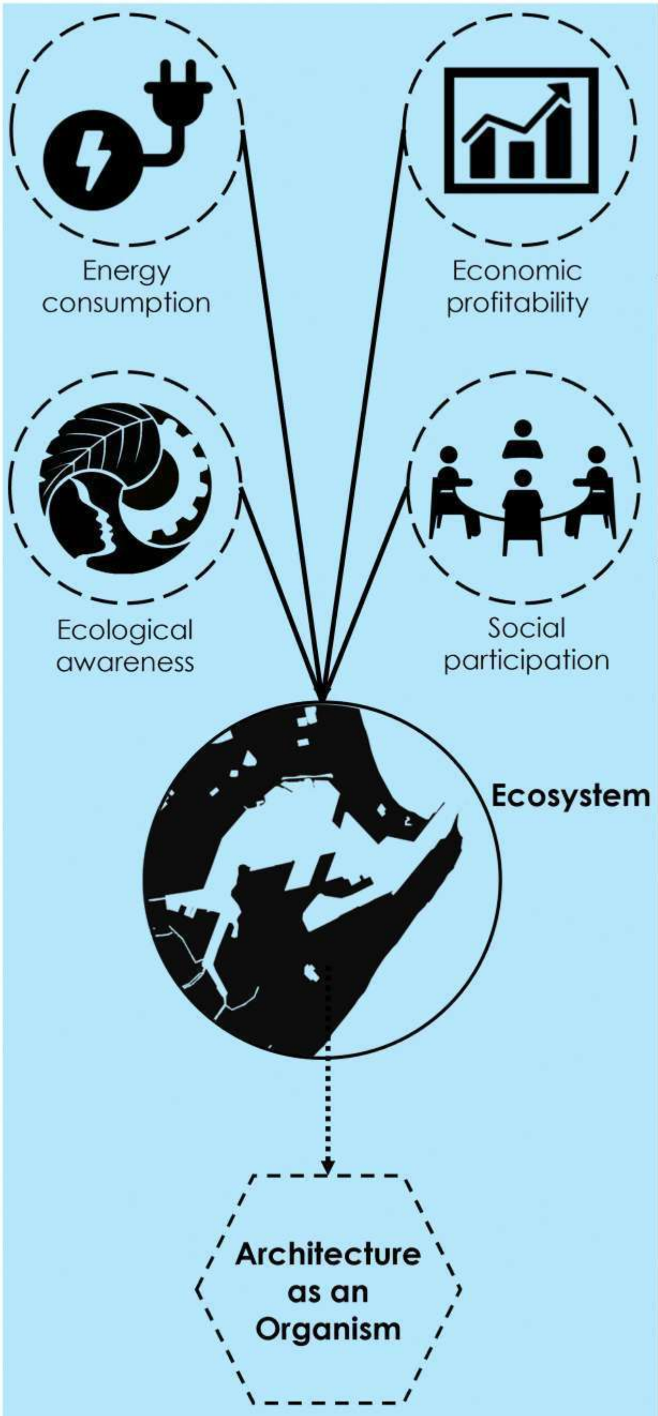
This model will promote **sustainable energy research** and education that is **publicly inclusive** with the implementation of **hybrid sustainable energy** that can contribute to the industrial area of the Durban Harbour and **mitigate biophysical and socio-economic challenges.**



WHO?



HEDONISTIC SUSTAINABILITY



Balance solutions for the energy demand in a sustainable manner whilst improving human enjoyment

PRINCIPLES
- Synergy of art and science
- Create sustainable solutions to challenges
- Playful to enhance the quality of the space

HEDONISTIC SUSTAINABILITY WITHIN A REFORMED RESEARCH FACILITY

Hybrid integration of social collaboration, digital infrastructure & spatial planning to enhance quality of life and impact the urban fabric in a hedonistic way,

Adopting a transformed research facility, social integration and innovative infrastructure can create a sustainable architectural model.
This model will provide a social consciousness and educate the community on the futurity of renewable energy development, whilst alleviating many biophysical and socio-economic challenges of the area.

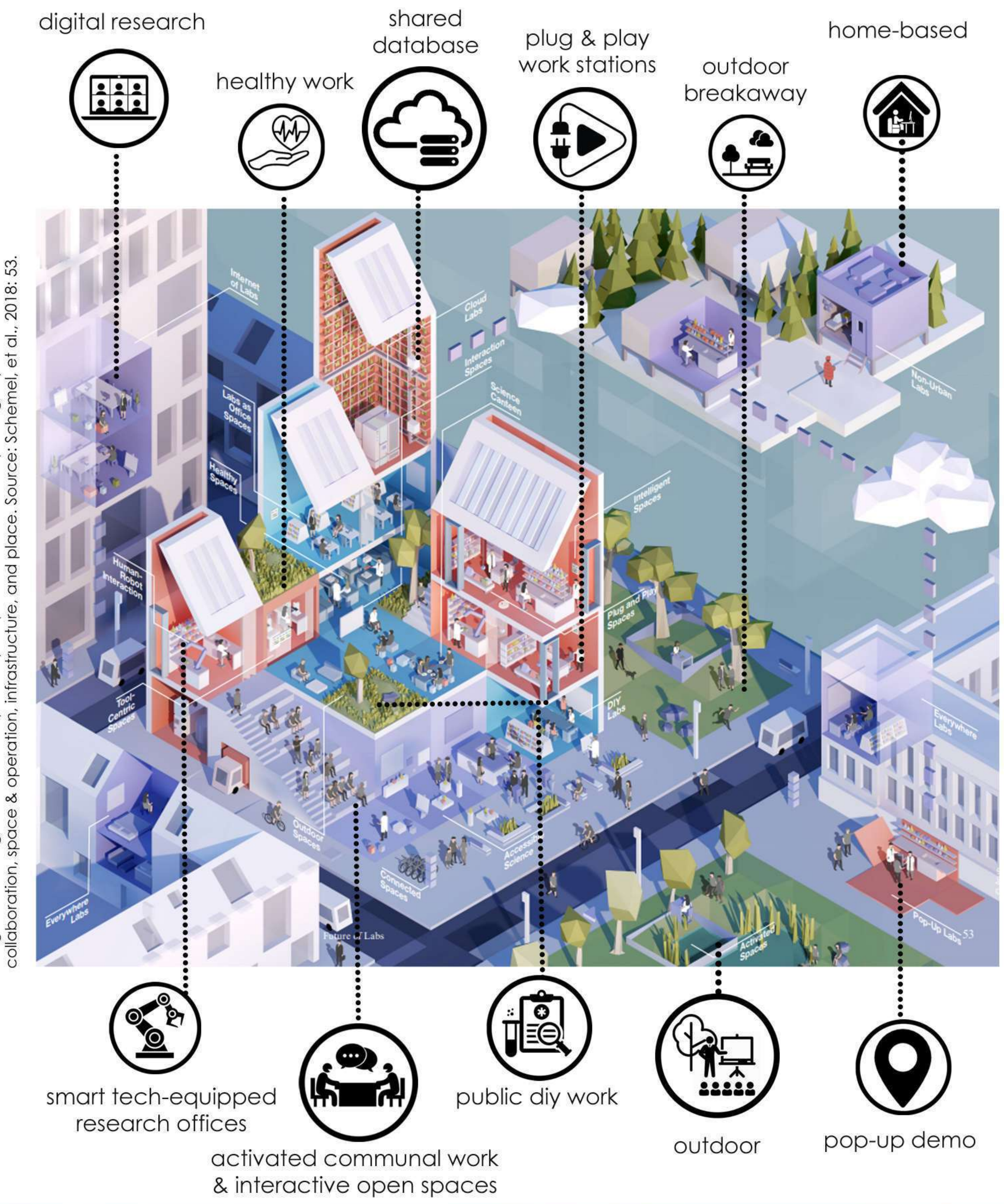
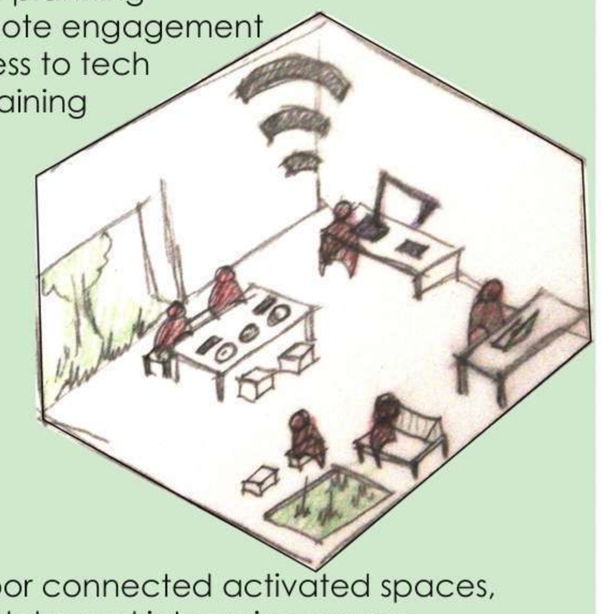
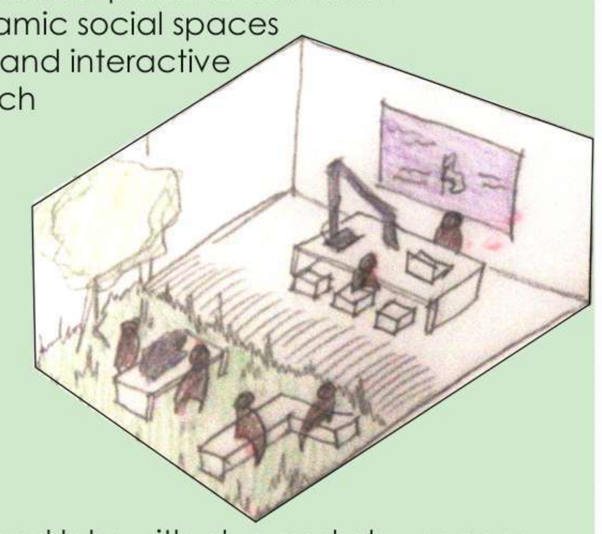


Diagram showing Research Ecosystem by Arup Future Labs encompassing key drivers of social collaboration, space & operation, infrastructure, and place. Source: Schemel, et al. 2018: 53.

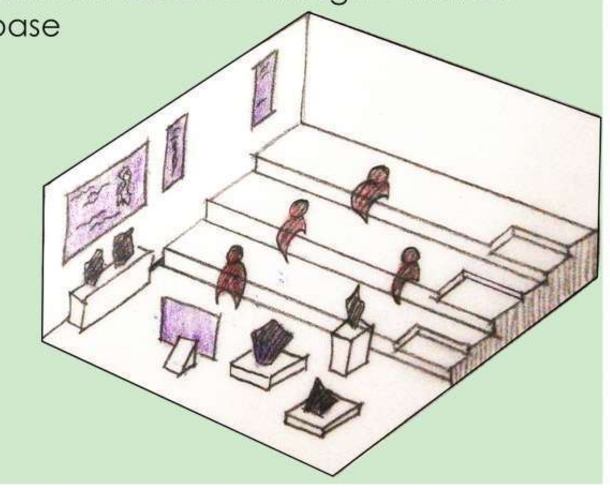
Accessible tech spaces & communal research spaces
- Flexible & adaptable working spaces - hybrid spatial planning
- Promote engagement
- Access to tech and training



Outdoor connected activated spaces, digital labs and interacive spaces
- DIY labs for public involvement
- Dynamic social spaces
- Live and interactive research

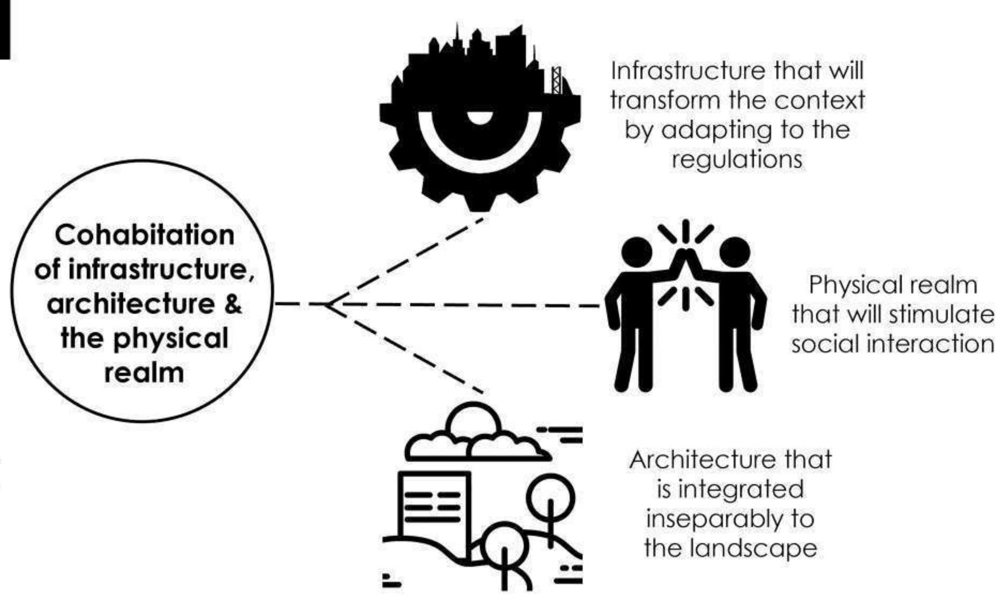


Equipped labs with plug and play spaces
- Smart labs with flexible spaces to different research to take place
- Live and interactive research
- Communal research through a shared database

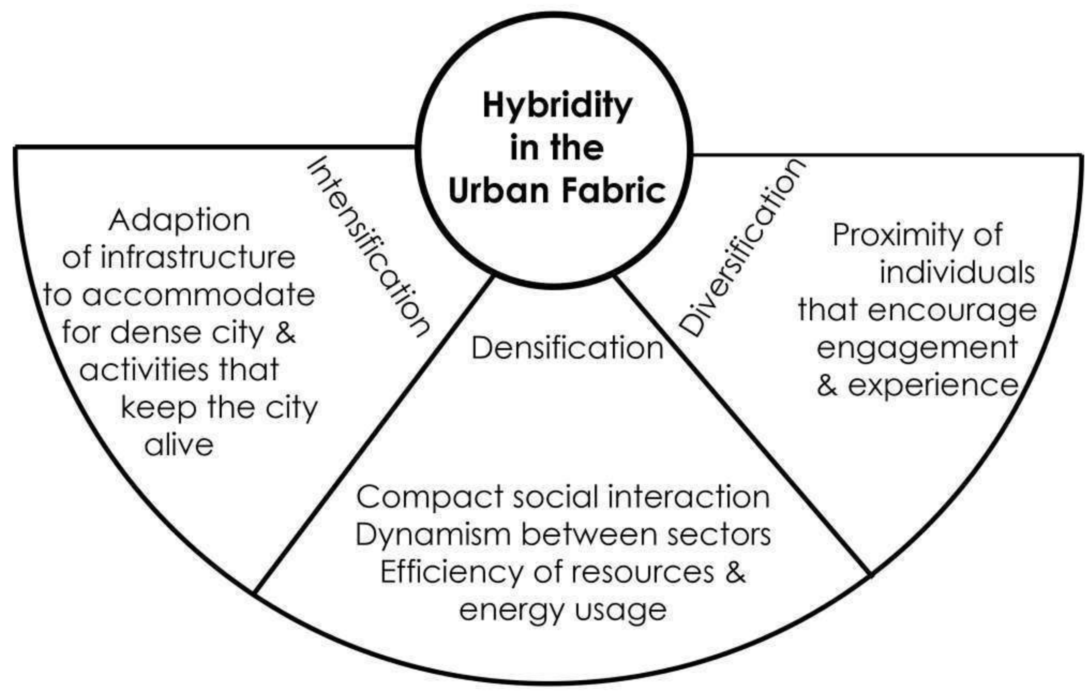


HYBRIDITY

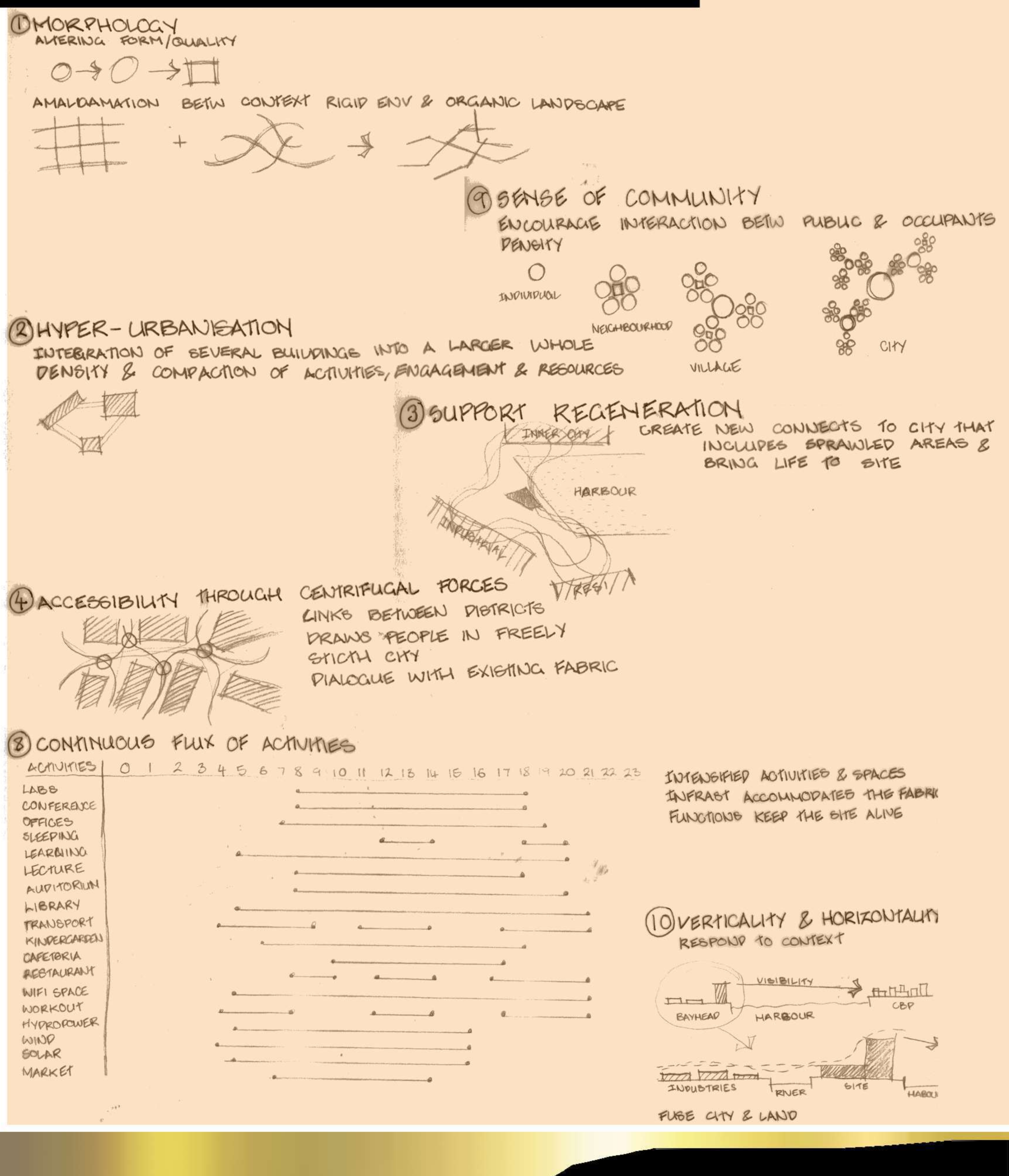
PRINCIPLES
- Self-sustaining habitat
- Reintroduce interdependency between people, industry & energy
- Overcome challenges of industrial sprawl, non-renewable energy consumption & ecological depltion within the Durban Harbour.



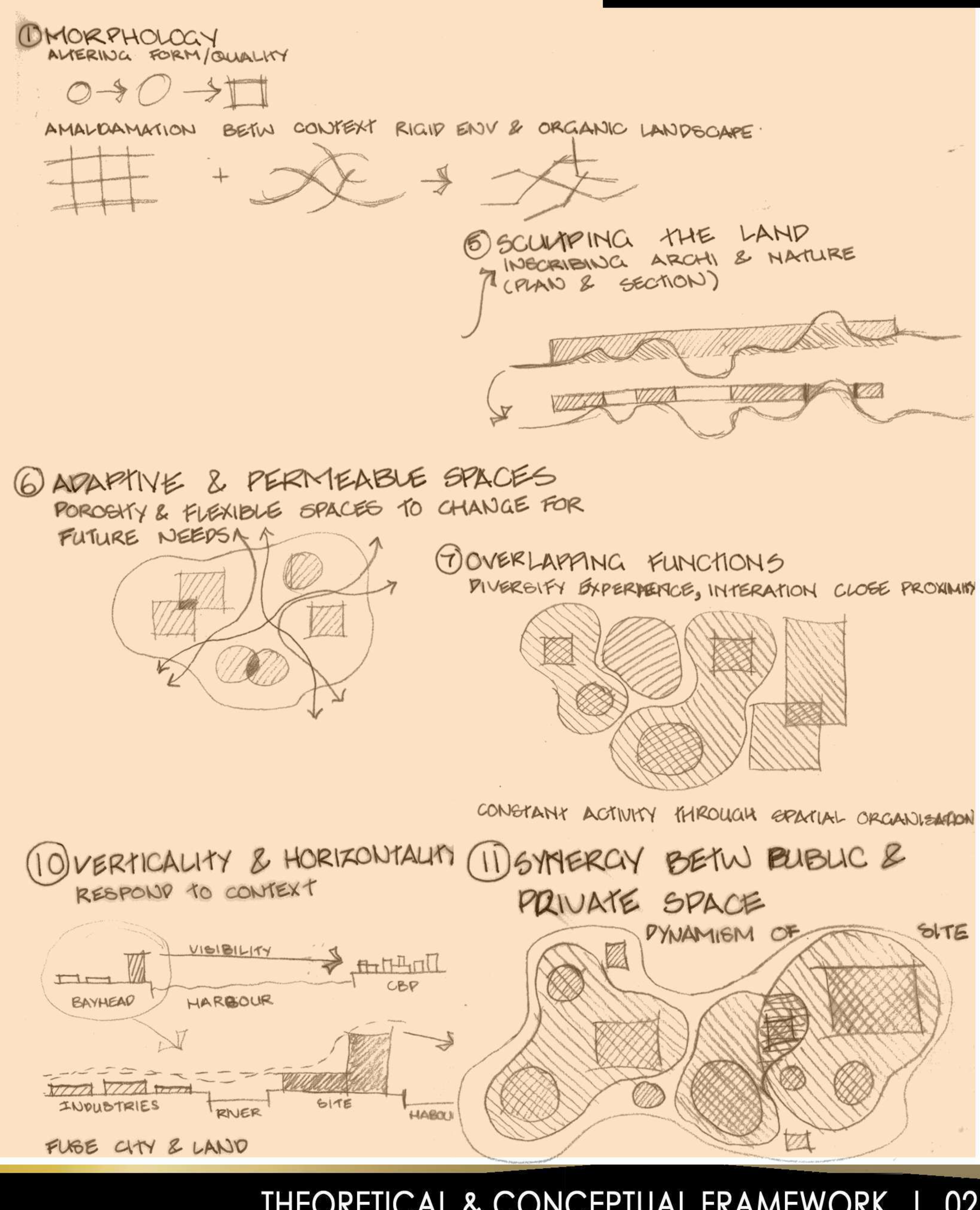
Systems will **work together** providing a **reliable** source of energy, contributing to the energy grid and showcasing **innovative technologies** and **education** first-hand. The **futurity** of this hybrid system is that this architectural model can be recreated with **public conciousness** as it **maximises the potential of the region** it is located in.



HYBRIDITY DESIGN DRIVERS WITHIN THE URBAN FRAMEWORK



HYBRIDITY DESIGN PRINCIPLES



ASHMIKA RAMKLASS_213506761

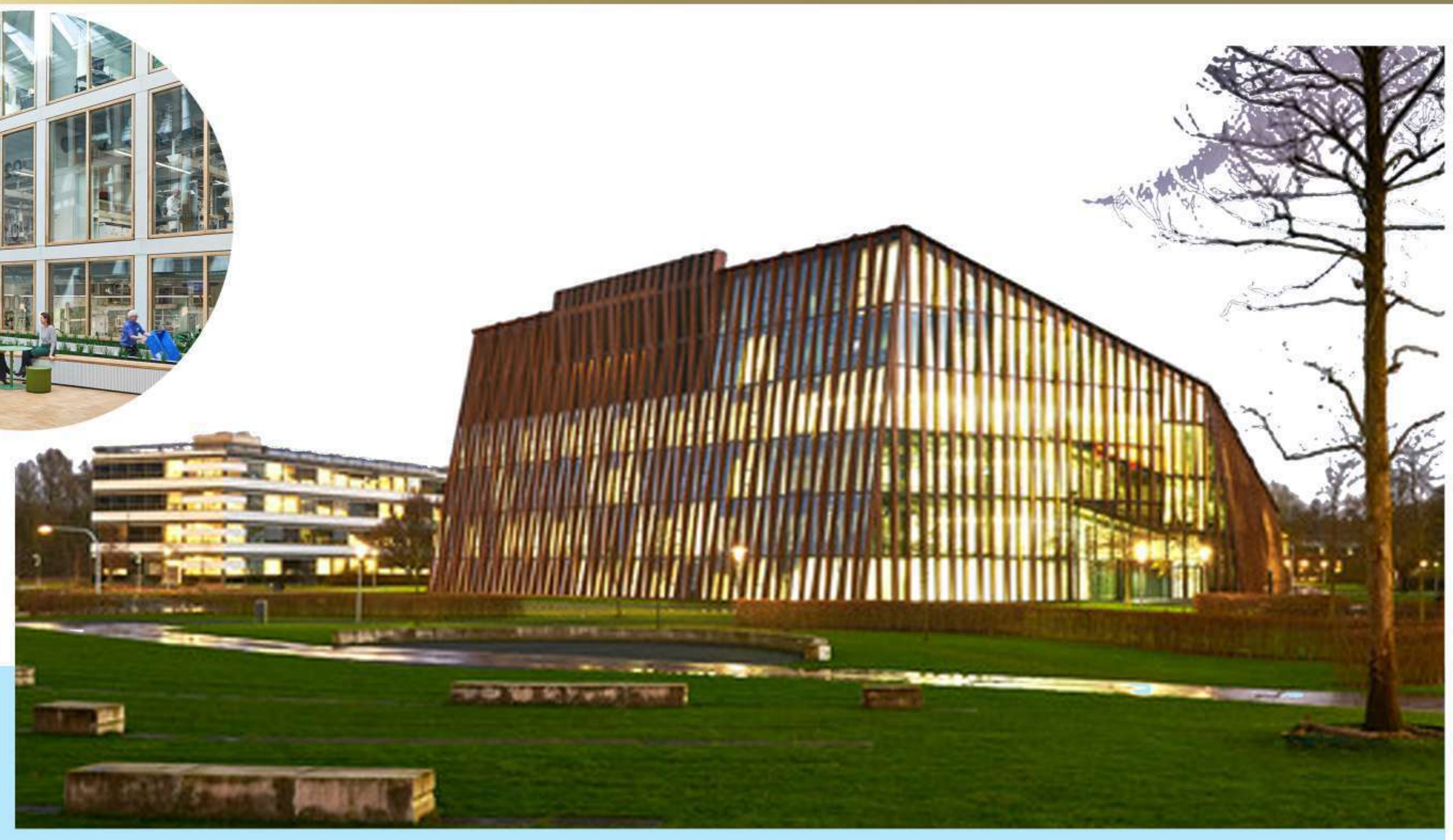
ENERGY ACADEMY EUROPE BUILDING: GRONINGEN, NETHERLANDS

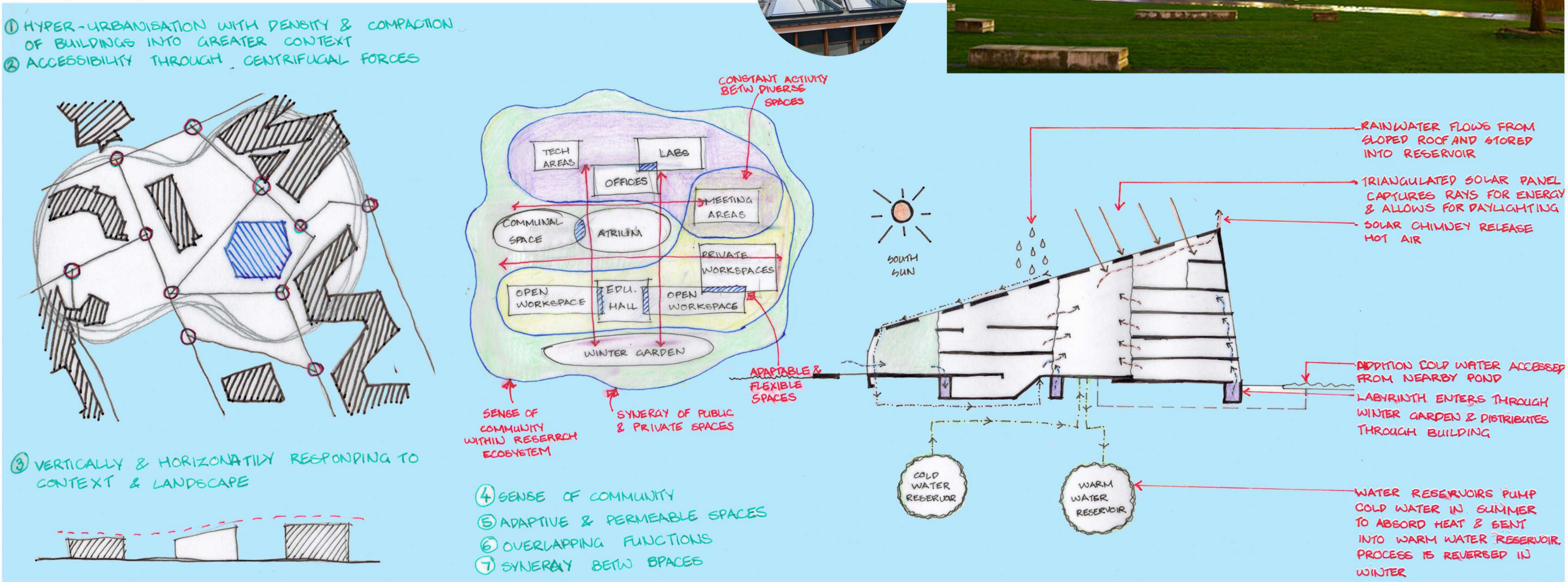
These principles establish a **hybrid research ecosystem** of **social collaboration**, **spatial well-being**, and **smart infrastructure** that aids knowledge, research, and innovation.

This can be envisioned through:
- **Collaborative and inclusive** spatial arrangements of educational and training spaces, work offices and laboratories.
- Socially **interactive** spaces.

With sustainability in mind, there is an influence of:
- Optimising **natural daylighting**
- Manipulating **ventilation**
- Introducing **innovative** rainwater and solar **harvesting**
- Adapting **natural spaces** within the built environment.



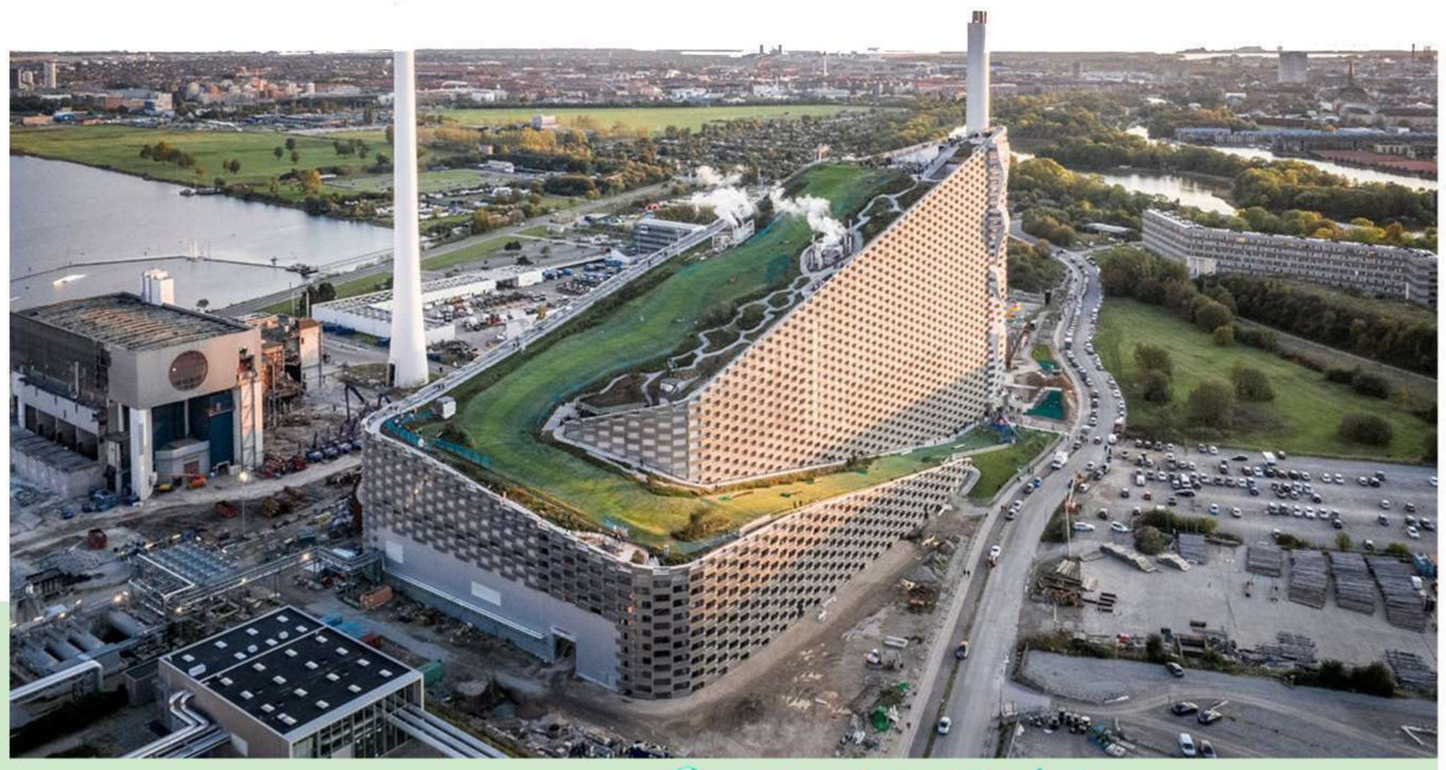


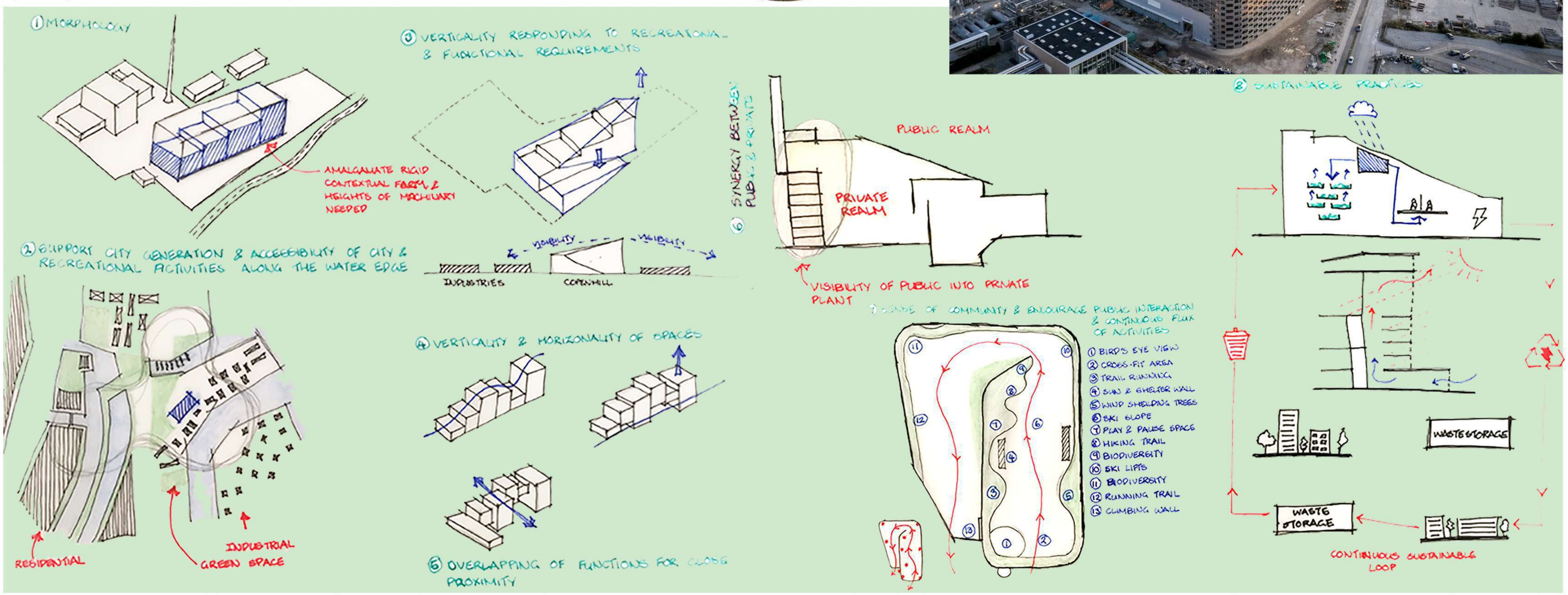
COPENHILL / AMAGER BAKKE: COPENHAGEN, DENMARK

These principles establish **hybrid ecosystem** of **hedonistic sustainability** and eco-education through **social well-being**, **city upliftment** and **environmental consciousness**.

This can be envisioned through:
- **Morphology and materiality** of the design within the industrial context, as the Durban Harbour is largely industrial.
- **Permeability** of informative research spaces in conjunction with social ecological and interactive spaces.

These principles work together to create a hybrid ecosystem within the Copenhill Waste-to-Energy Plant therefore, these principles will influence the architectural intervention by blurring the distinction between **social upliftment and industrial constraint**.

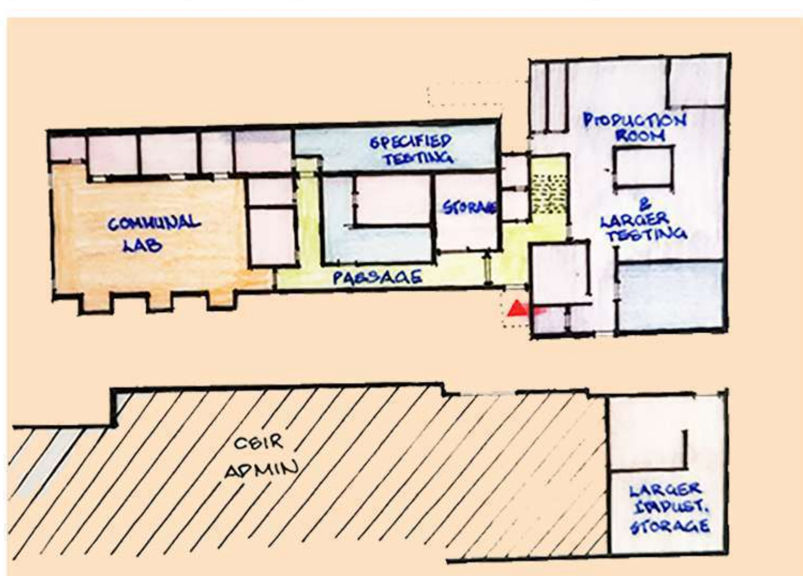





THE BIOREFINERY INDUSTRY DEVELOPMENT FACILITY, CSIR, KWAZULU-NATAL, SOUTH AFRICA

The BIDF establishes a sustainable research ecosystem, influenced by a hybrid integrated system of social collaboration and well-being, spatial planning and smart infrastructure.

There are **challenges** within this research ecosystem such as the **lack of collaborative** and dynamic **interactive spaces**, the need for pleasant working environments to **stimulate productivity**, along with the **exclusivity of research**.



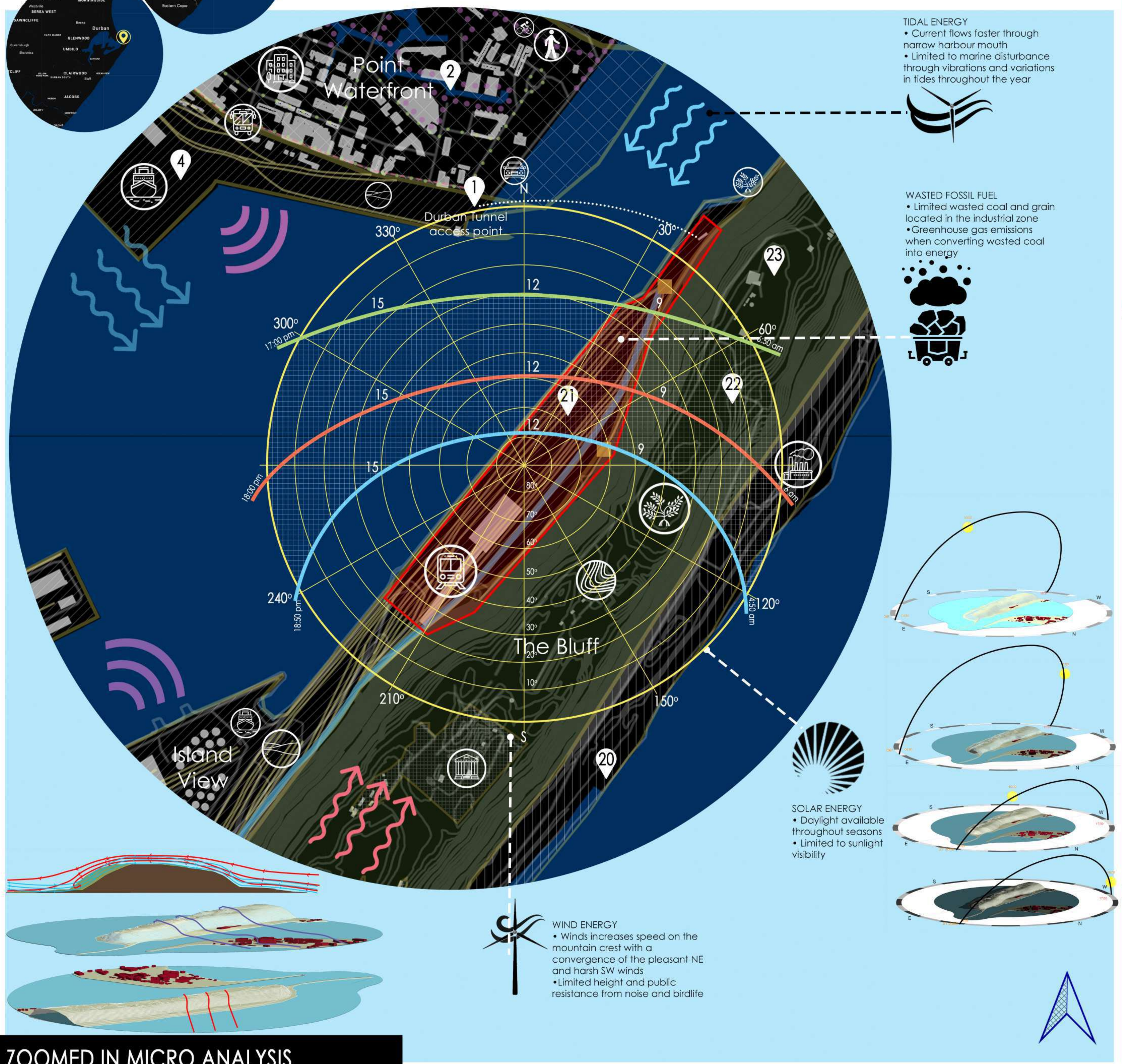





MACRO LOCALITY & SWOT ANALYSIS

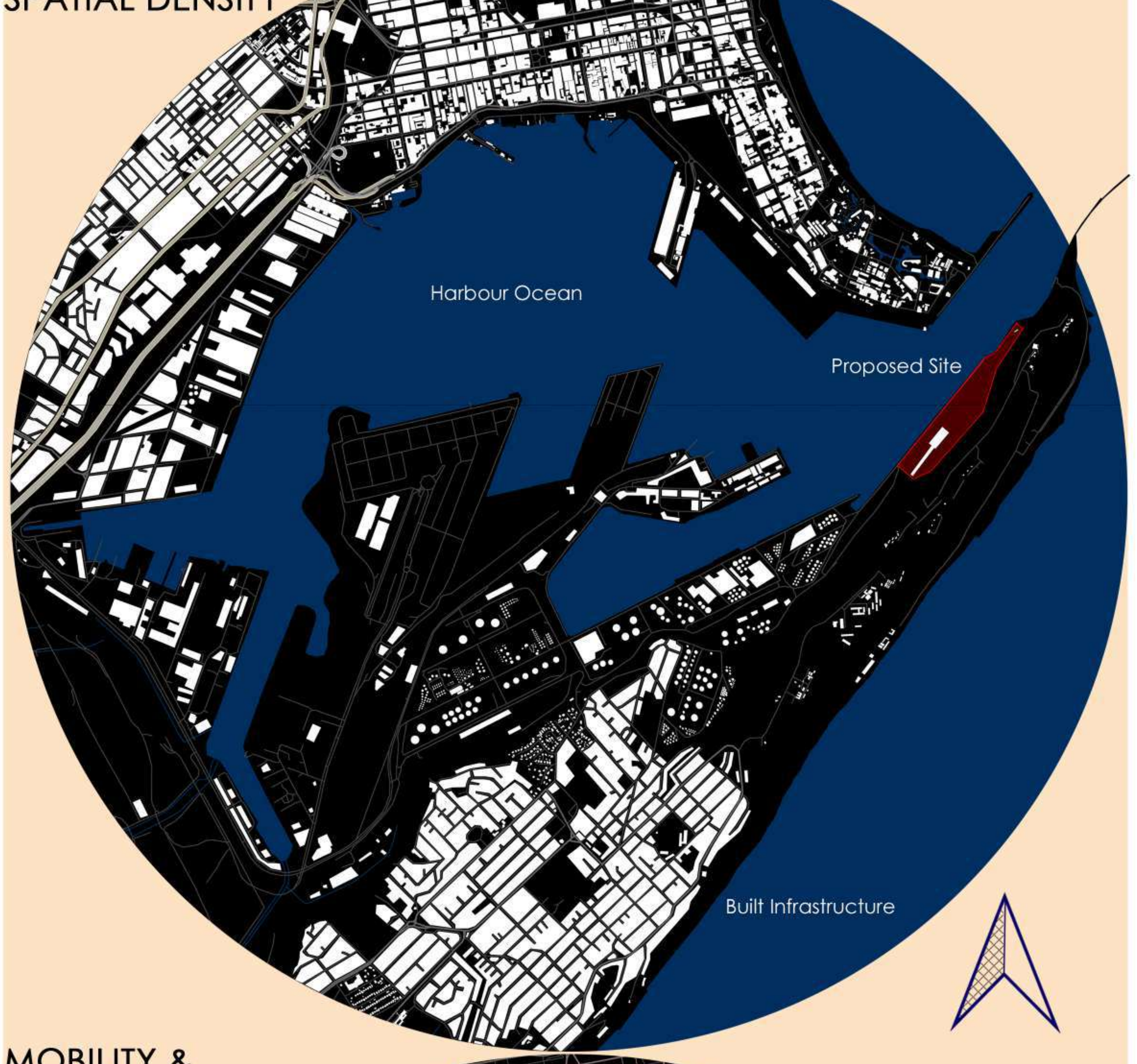
PROPOSED SITE SWOT ANALYSIS

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• Located between a Private and Public Realm • Access to Renewable Resources • Visibility of interest from Durban CBD and Promenade • Next to Coal Terminal that exports and Imports coal for Energy, etc.	• Restricted Area – Health and Safety Risks • Subject to Industrial and Transport degradation • Lack of Ecological preservation • Lack of Public Access	• Cooperation between Transnet Port Authority and City • Introduce Public Linkages • Renewable Energy Innovations to contribute to the industries • Renewable Energy produced will decrease relance on Coal • Encourage Green Tourism through trade, controlled tours through industries to view Renewable Energy Innovations and Open Breakaway spaces • Introduce clustered land-uses to maximise potential and needs - employment and safety • Improve Harbour interface – Attract investors and increase in trade and tourism	• Health and Safety Risks • Privatisation of Port will slow development • Public access through the industries

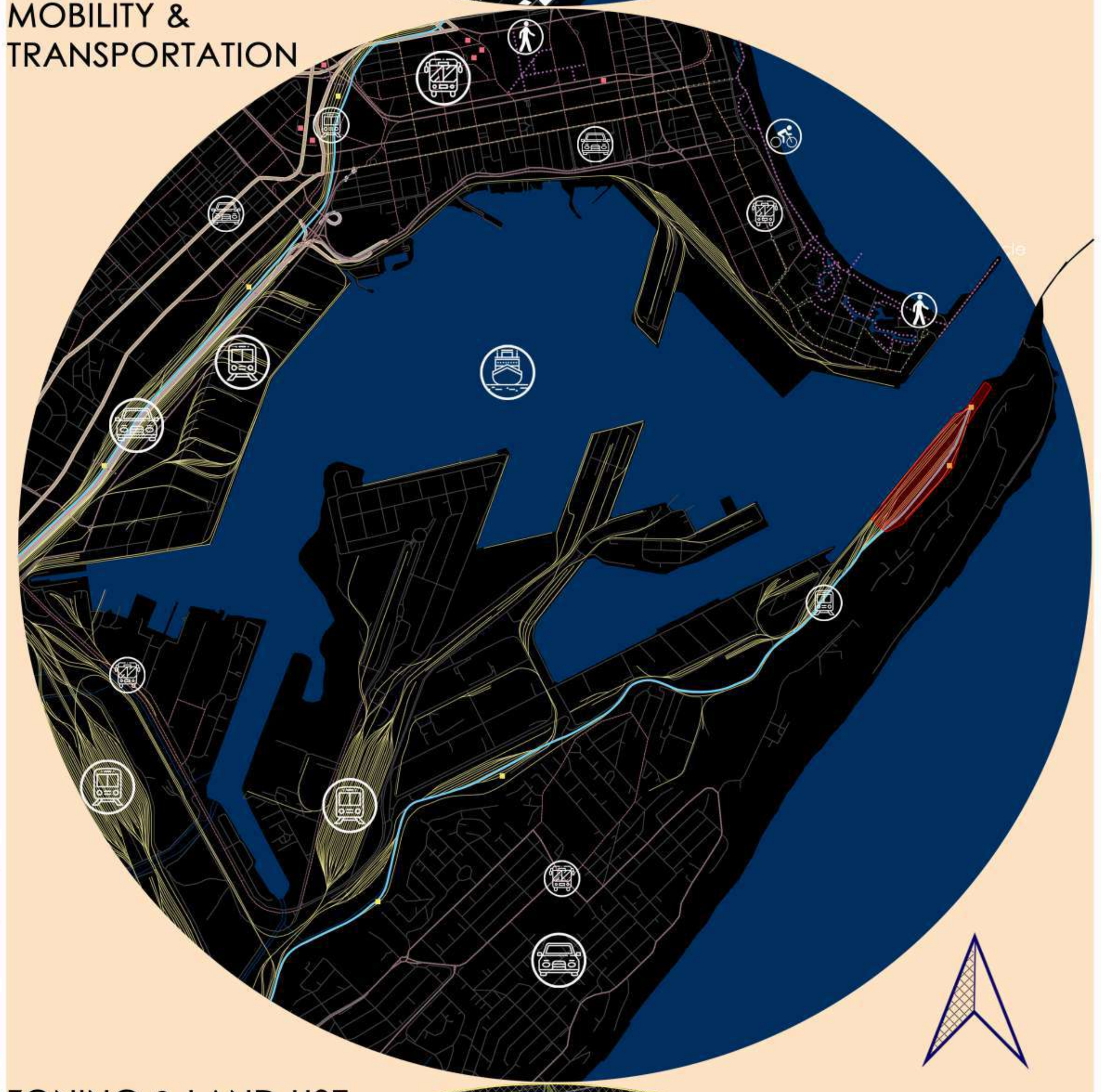


ZOOMED IN MICRO ANALYSIS

FIGURE GROUND & SPATIAL DENSITY



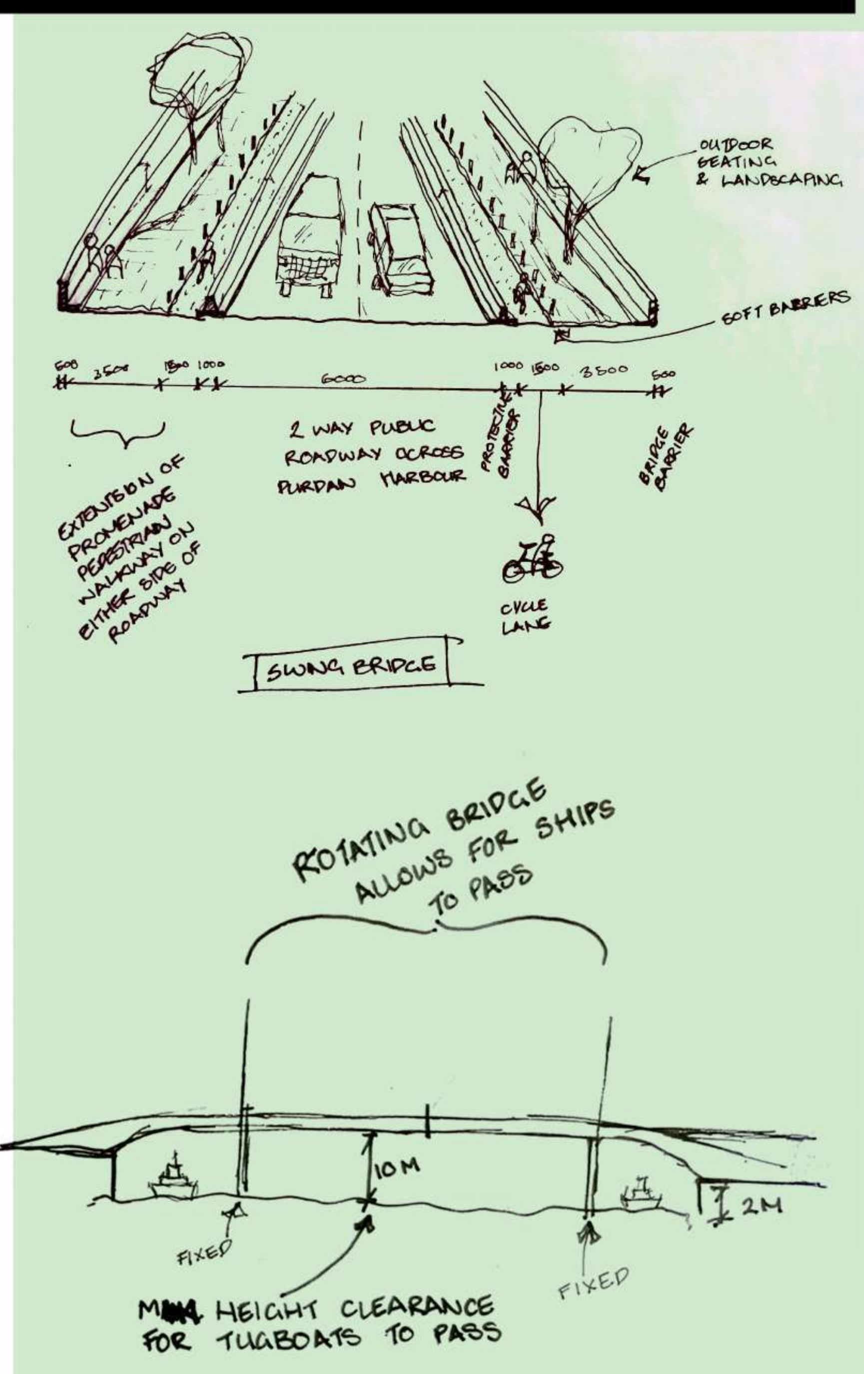
MOBILITY & TRANSPORTATION

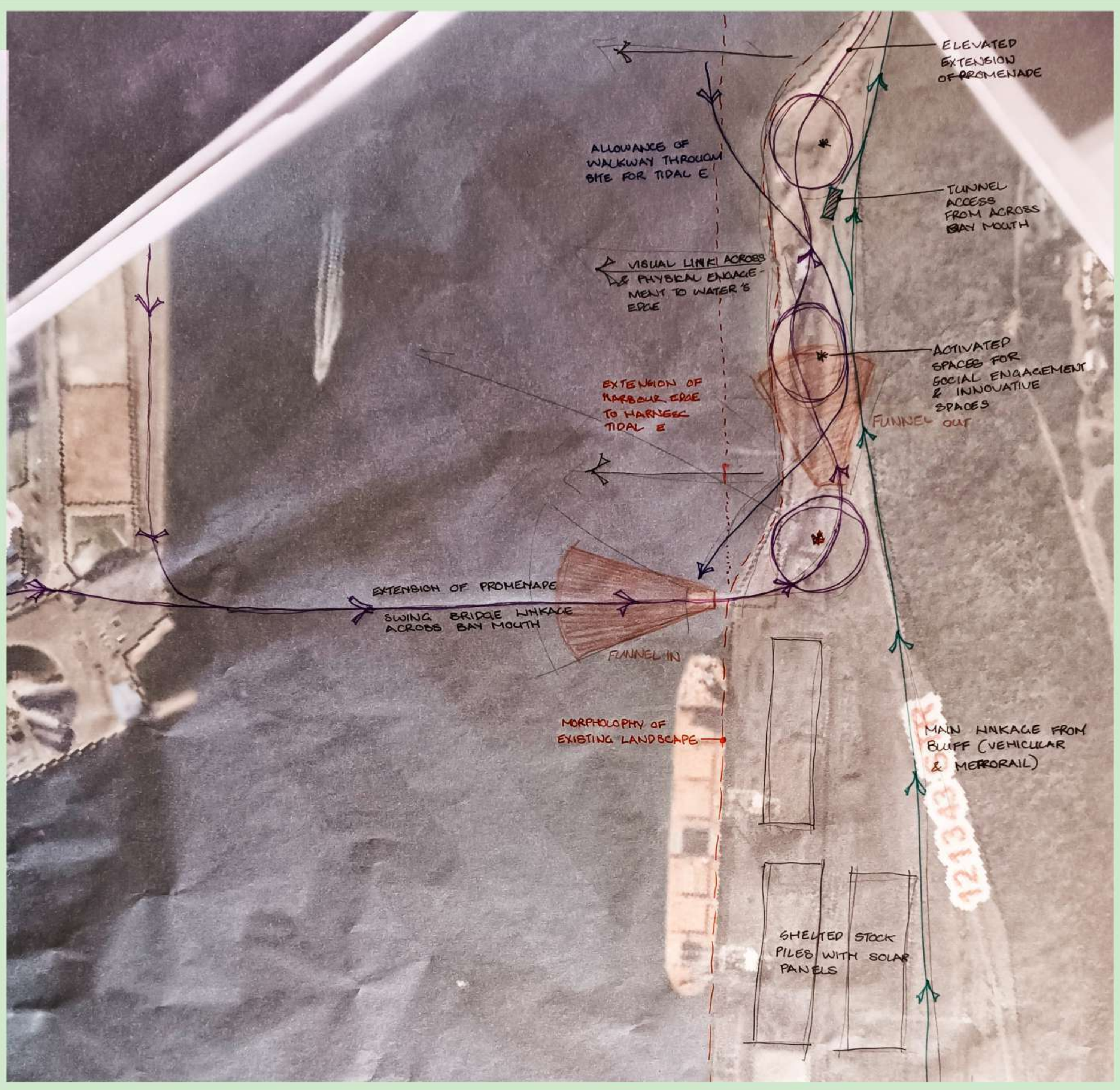


ZONING & LAND-USE

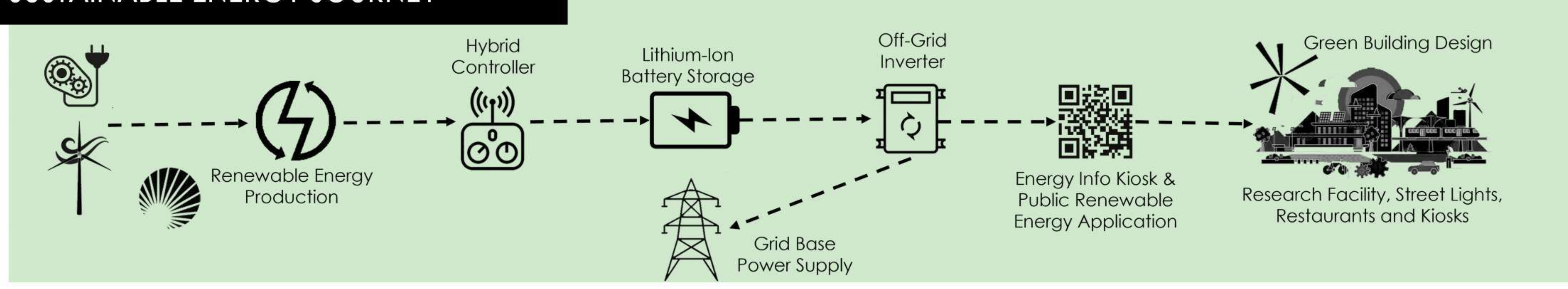
POINTS OF INTEREST

MACRO URBAN DESIGN DEVELOPMENT



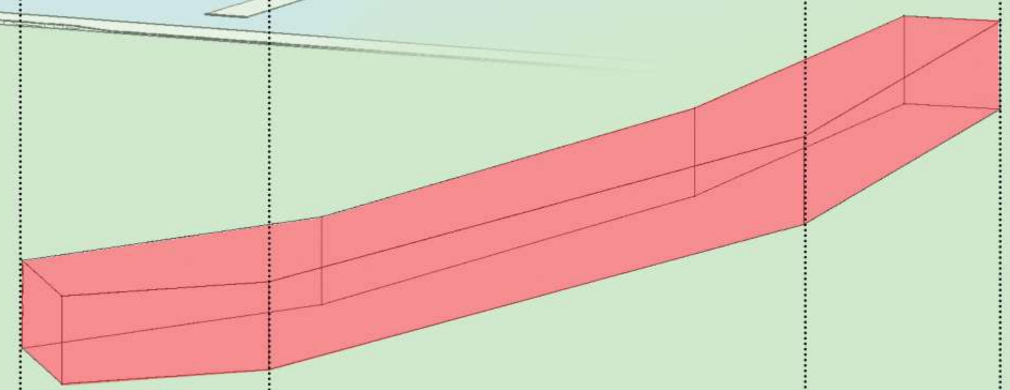


SUSTAINABLE ENERGY JOURNEY

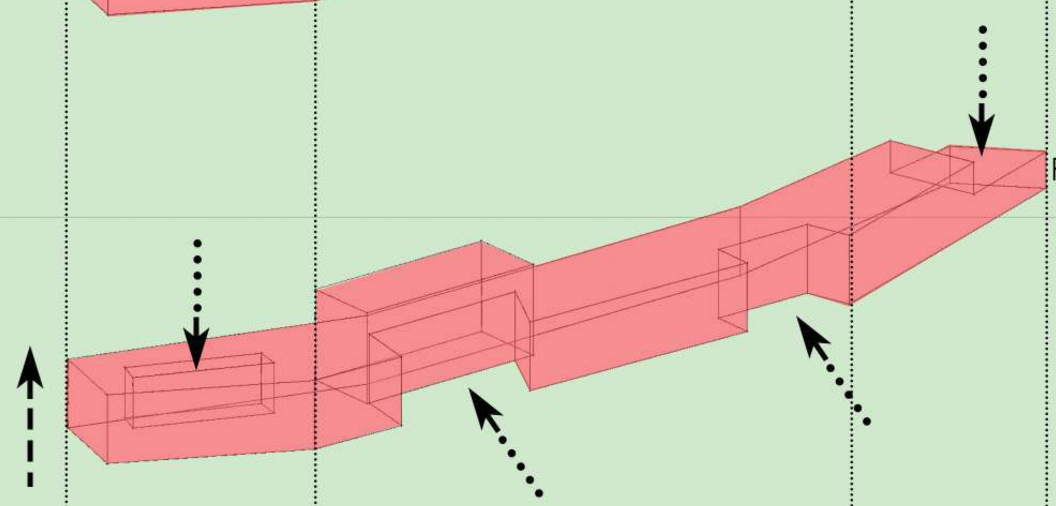


DESIGN DEVELOPMENT MASSING

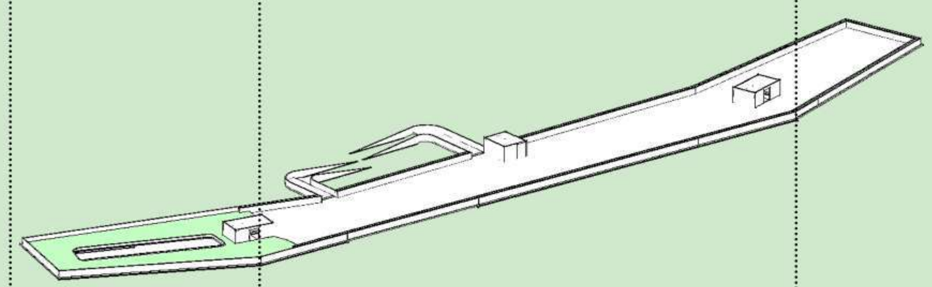
01 Free flowing form derivedfrom the movement of people through the urban design
Height of form suitable to low lying surrounding context



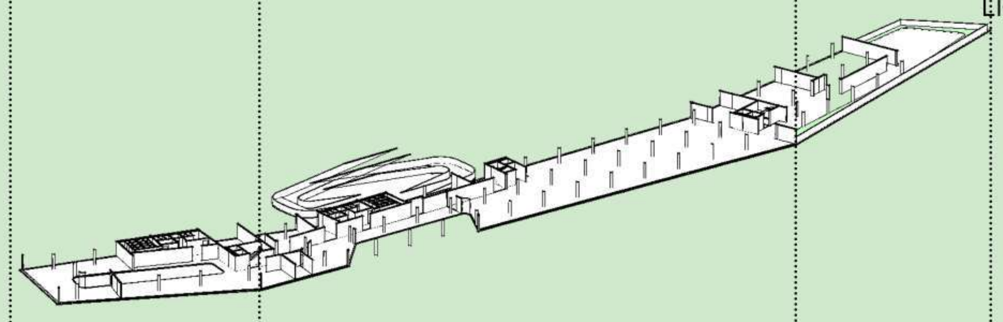
02 Angle facades to repond to the morphology of the industrial zone



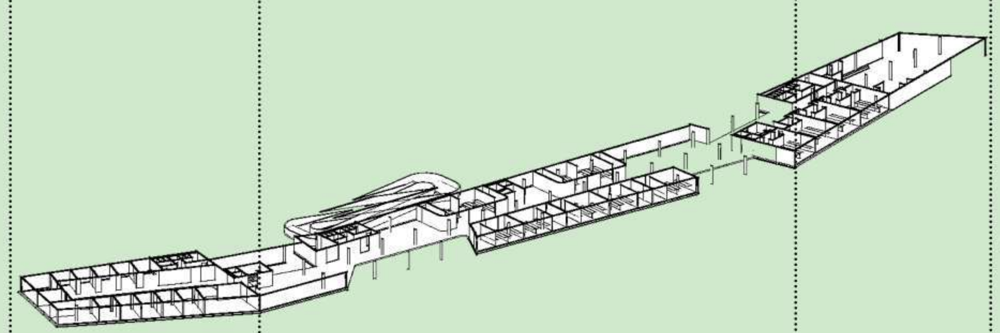
03 Recess and depress planes to maximise passive design (natural lighting & ventilation)
Form elevated of the ground to allow for a free flowing public realm



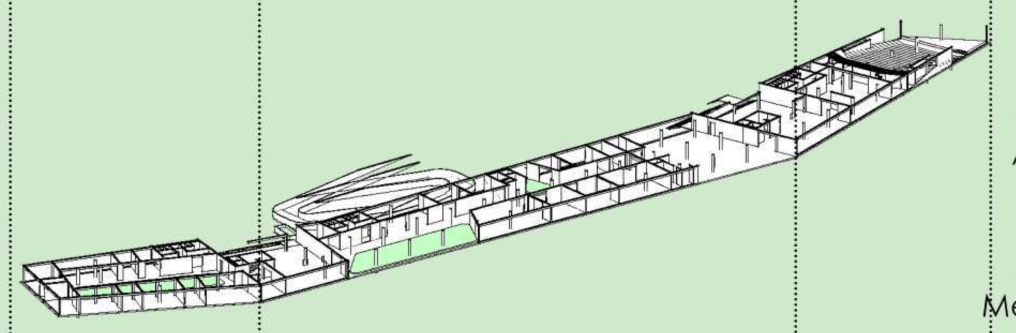
04 Roof Floor
Parking & Roof Garden



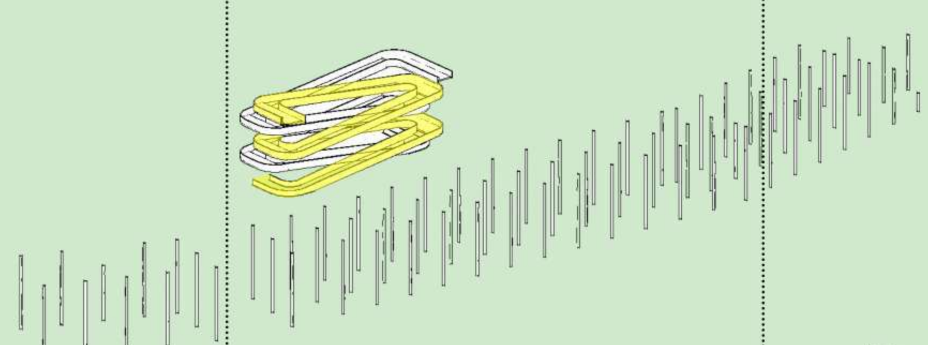
05 Third Floor
Recreational Area & Gym
Ablutions, Staff Offices & Storage
Light Manufacturing Workshop & Outdoor Testing Area
Security & Server Room
Water Storage & Filtration
Energy / Battery Storage
HVAC & Mechanical Room



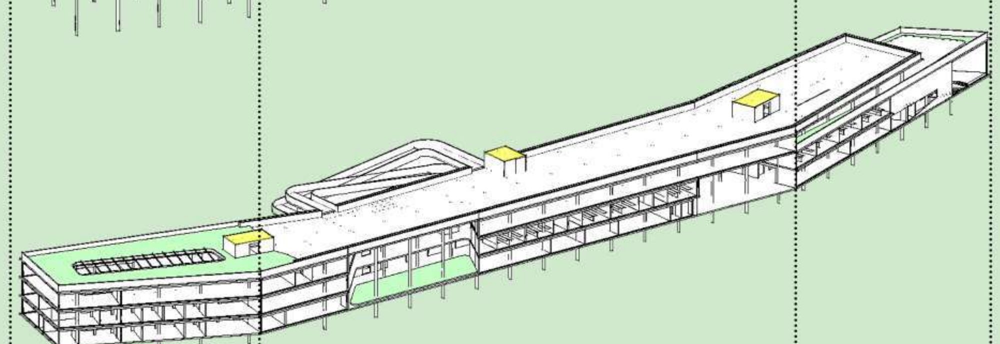
06 Second Floor
Management & Private Offices, Conference Rooms
Connected spaces
Plug & Play
Collaborative Labs, Small scale labs & Specialised Labs



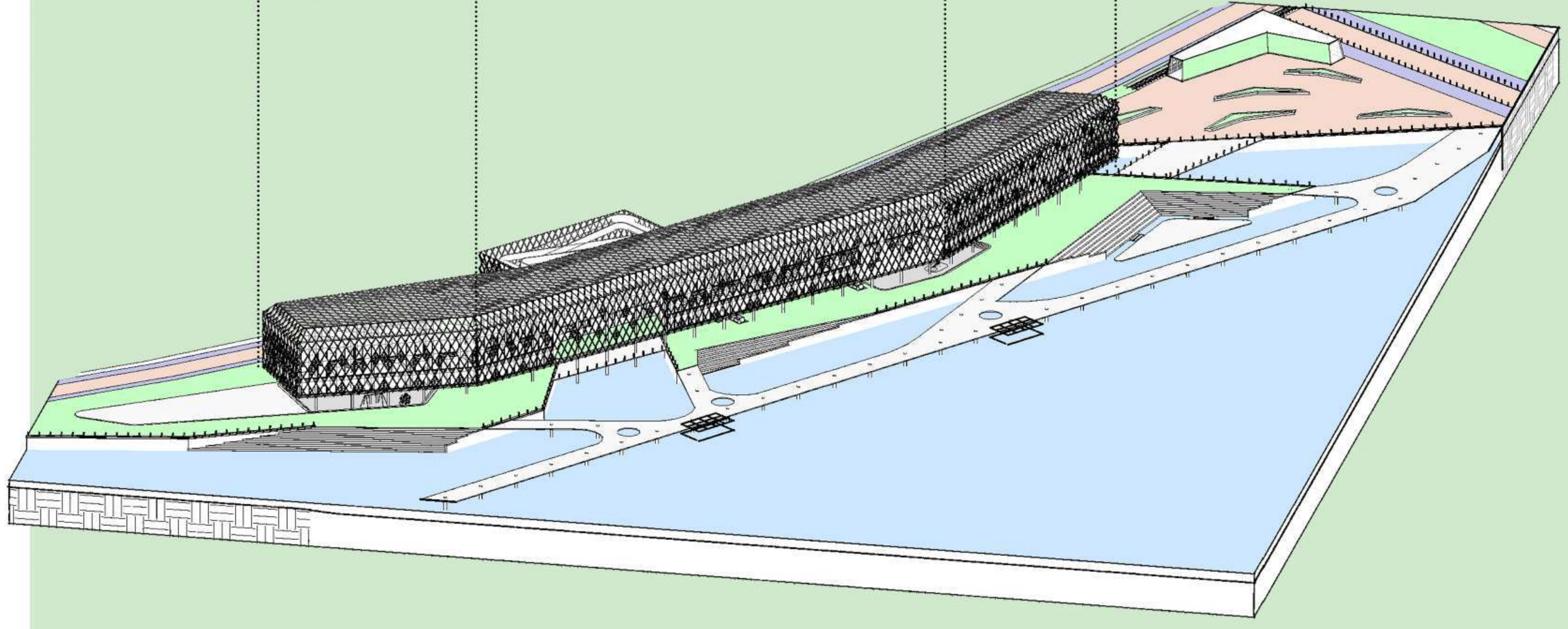
07 First Floor
Entrance & Security
Auditorium & Foyer
Exhibition Space & Food Bar
Adaptable Lecture Rooms & Workshops
Study Space & Canteen
Collaborative Office Space,
Meeting & Conference Rooms
Indoor Garden space



08 Ramped Vehicular Access to Roof Parking
8x8m Column Grid Systemt

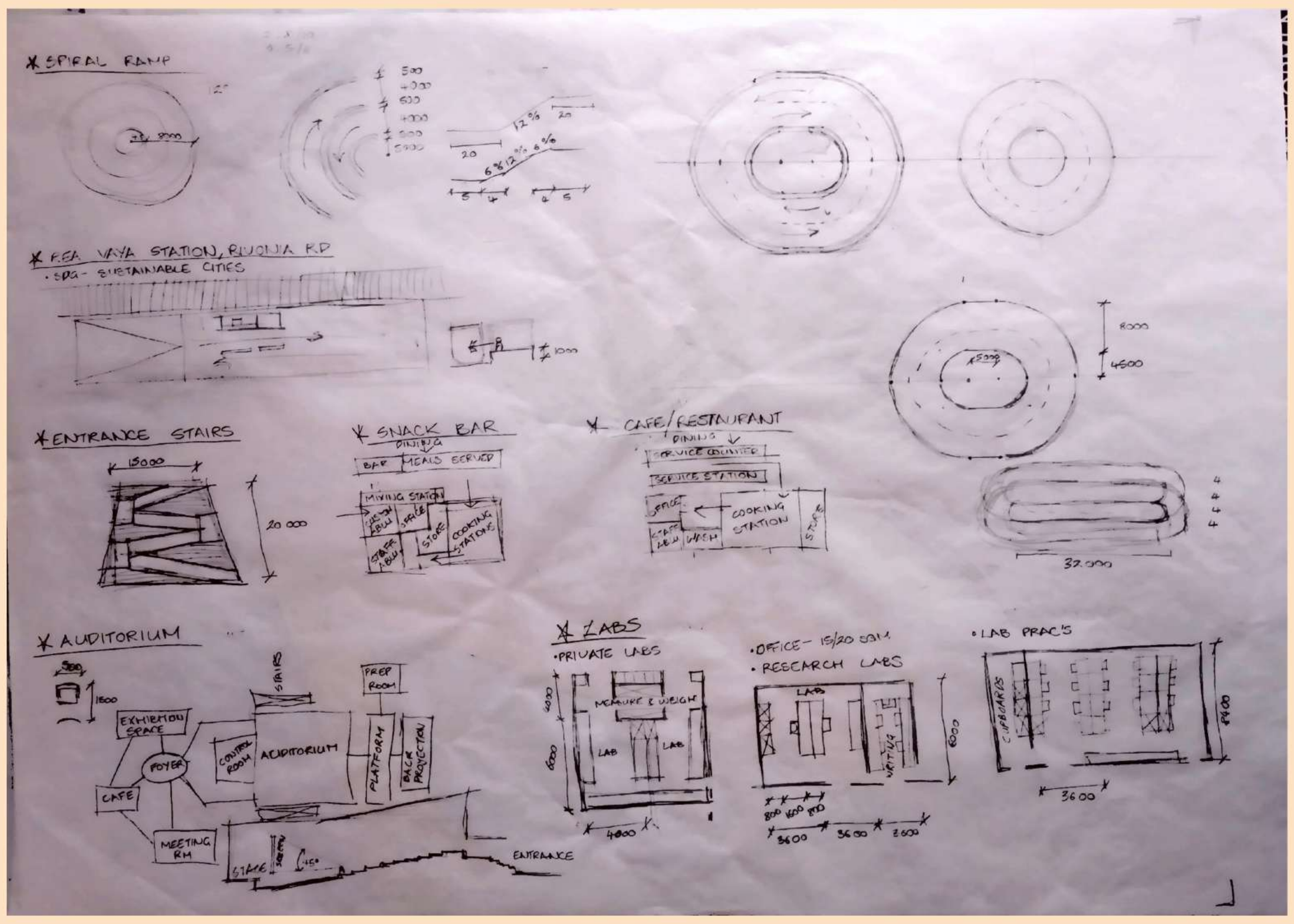


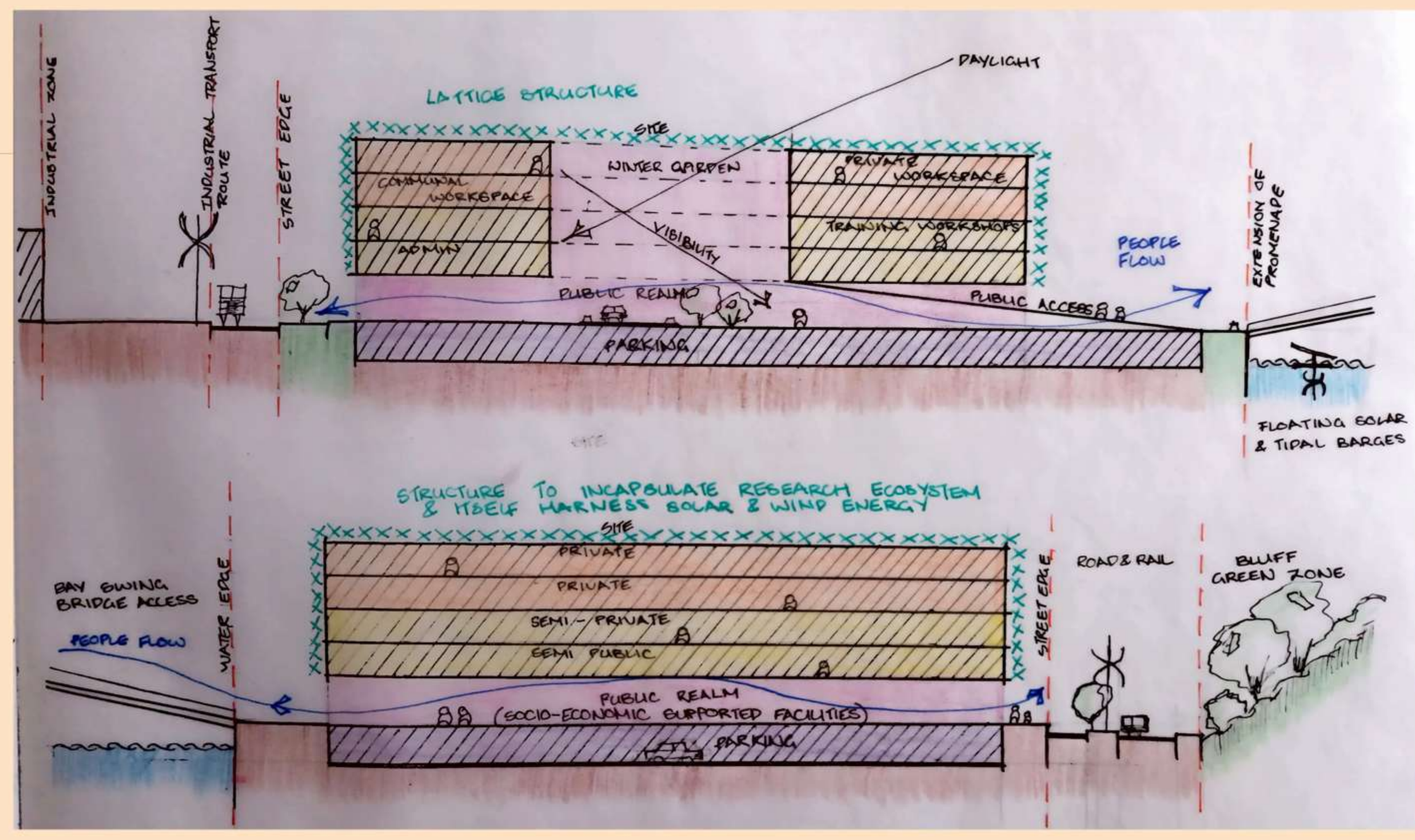
09 Floor & Column Construction System with Core Circulations Spaces

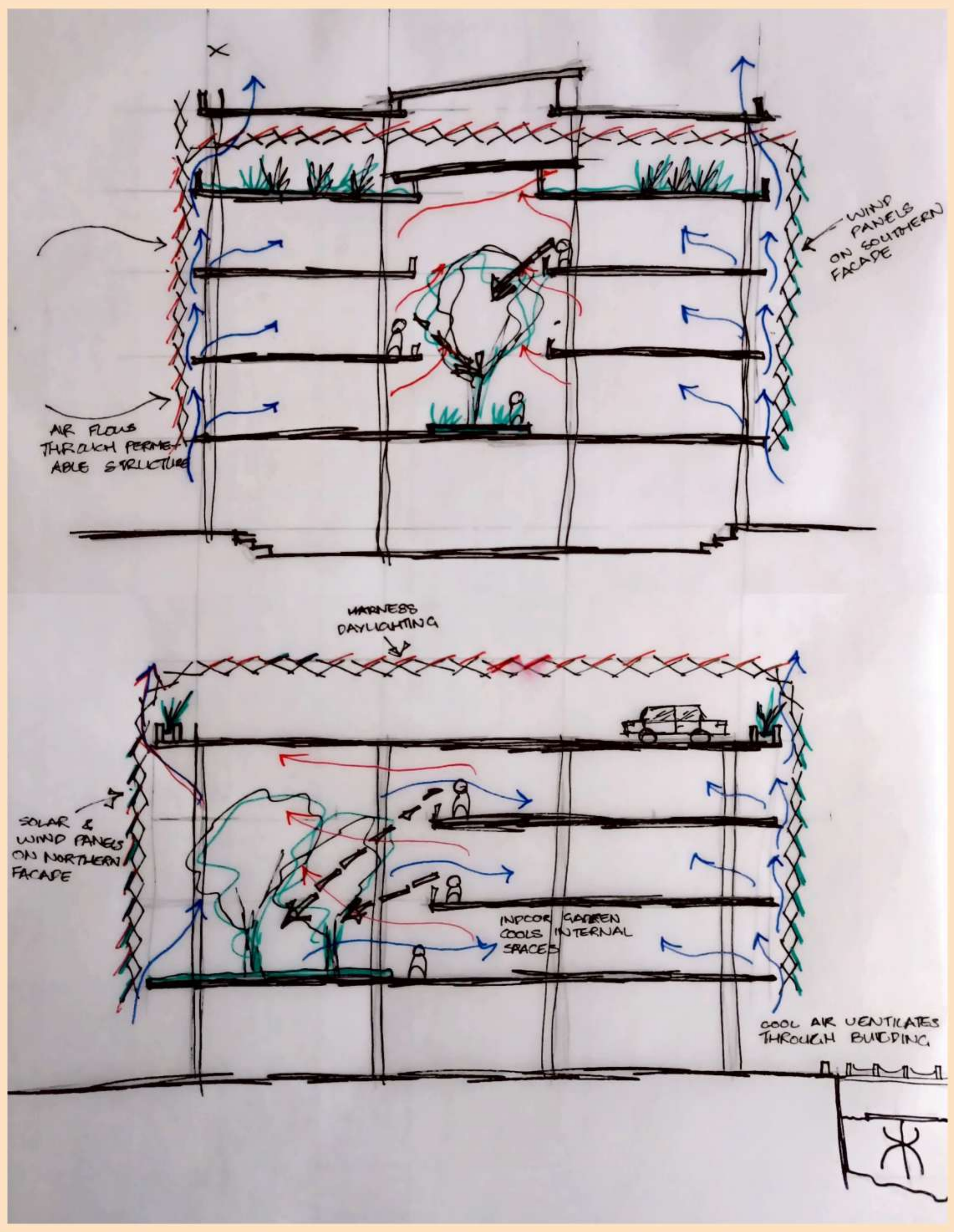


10 Lattice Structure to envelope the ecosystem of the research facility & to harness rRenewable Energy

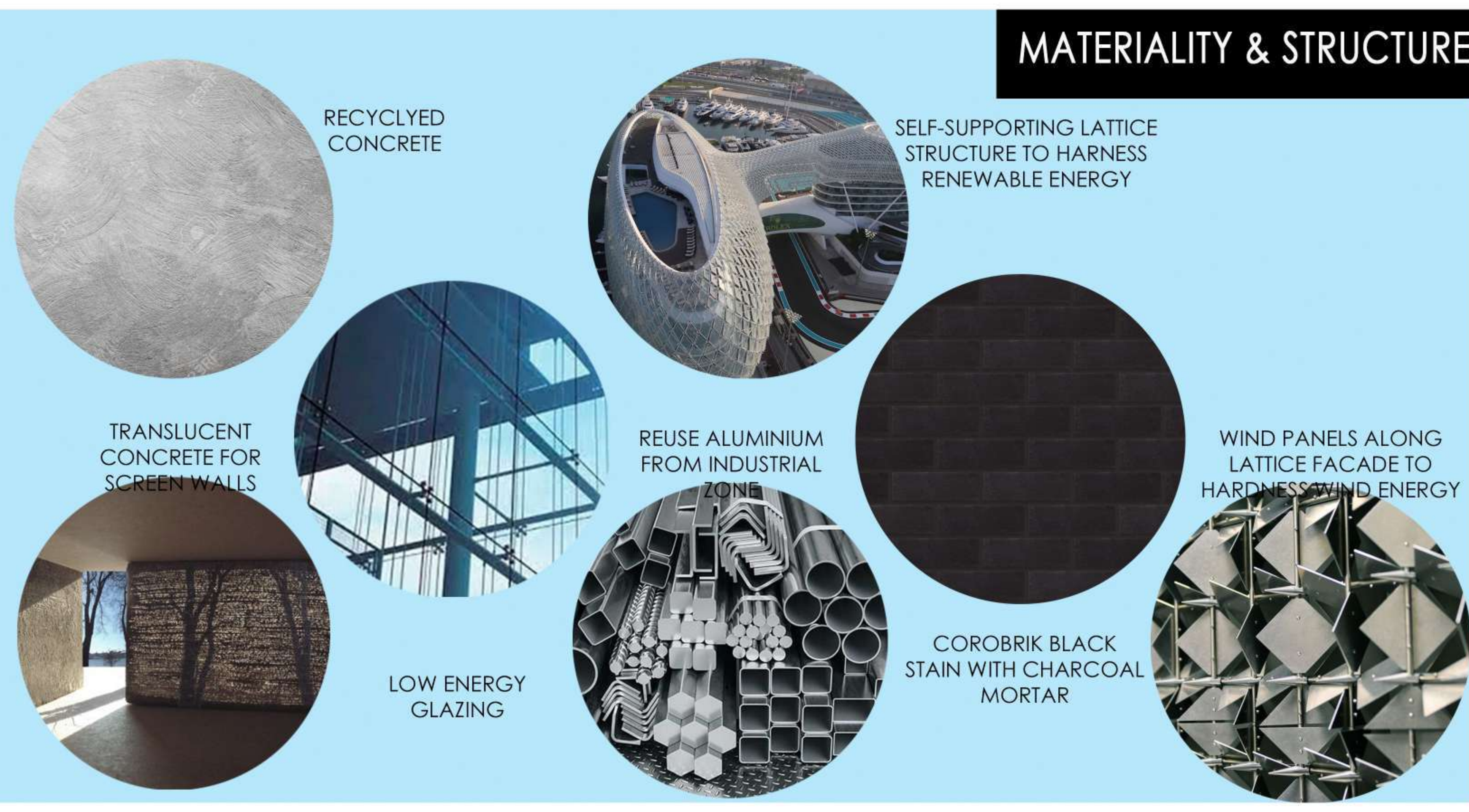
DESIGN PROCESS







MATERIALITY & STRUCTURE



MACRO URBAN DESIGN DEVELOPMENT | SCALE 1:2000

USERS

DESIGN DRIVERS WITHIN URBAN & BUILDING FRAMEWORK

URBAN

Intensify activties to keep city alive:
- Support Regeneration
- Continuous Flux of Activities

Densify & Compaction of social interaction, & Efficient use of Resources:
- Hyper-Urbanisation

Diversify engagement & experience:
- Sense of Community

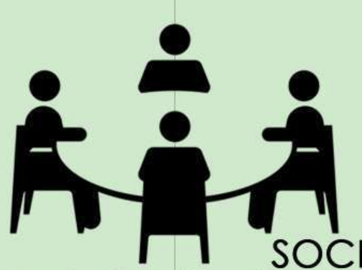
Linkage draws people freely into site, creating a blurring the distinction between social upliftment and industrial constriants:
- Access

Amalgamate industrial fabric & natural flow of people
- **Morphology**
- Verticality & Horizonality

ARCHITECTURE

Mechanism that **fosters Renewable Energy** for Research, Industry & Urban:
- Smart Infrastructure
- Optimise Passive & Active Design

SOCIO-EDUCATION



SOCIO-ECONOMIC

Interactive & Inclusive Spatial Organisation for Educational & Training Spaces:

Trade & Market Zones to **support** Research Funding

Restore Ecology within Industrial Fabric

MACRO URBAN DESIGN LEGEND

1	Proposed Site of Building
2	Extension of Promenade and New Swing Bridge across Harbour Mouth for Public Access.
3	Efficient Road & Rail Access from Bluff.
4	Solar and Wind Energy harnessed through Street Lighting.
5	Efficient Silos to store Minerals.
6	Dry Bulk to be sheltered from elements and protect biophysical environment. Sheltered with reused materials from Harbour. Solar panels on roof to be used within Coal Terminal.
7	Metrorail Train Stop
8	Tidal Turbines along the Ocean Deck to harness tidal energy

6 Efficient bulk dry storage through silo's & solar enhanced sheltered structures

5 Accommodation of multimodal transportation with wind turbines attached to street lighting

MESO URBAN DESIGN DEVELOPMENT | SCALE 1:500

ASHMIKA RAMKLASS_213506761

GROUND FLOOR PLAN | SCALE 1:250

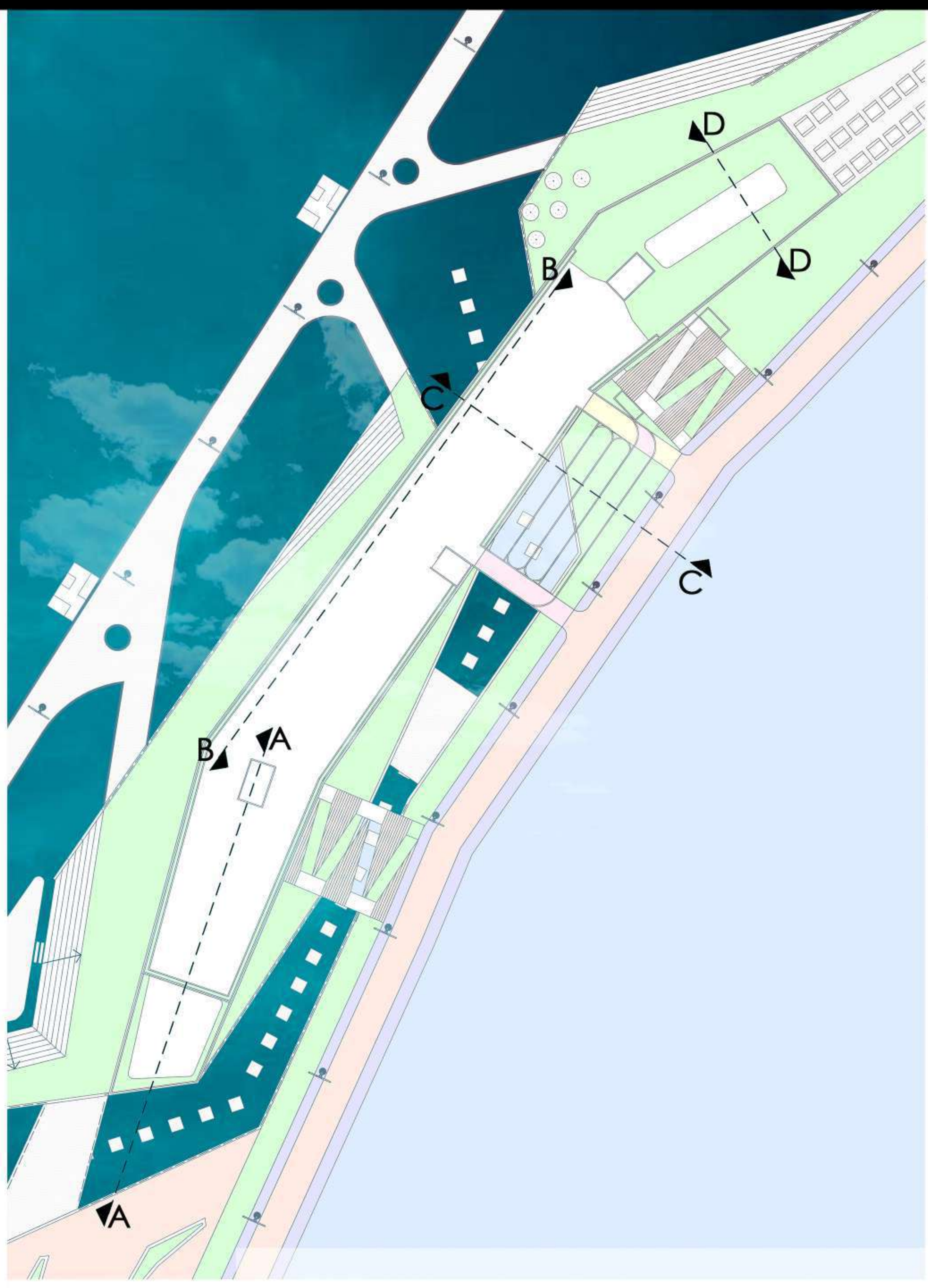
FIRST FLOOR PLAN | SCALE 1:250

SECOND FLOOR PLAN | SCALE 1:250

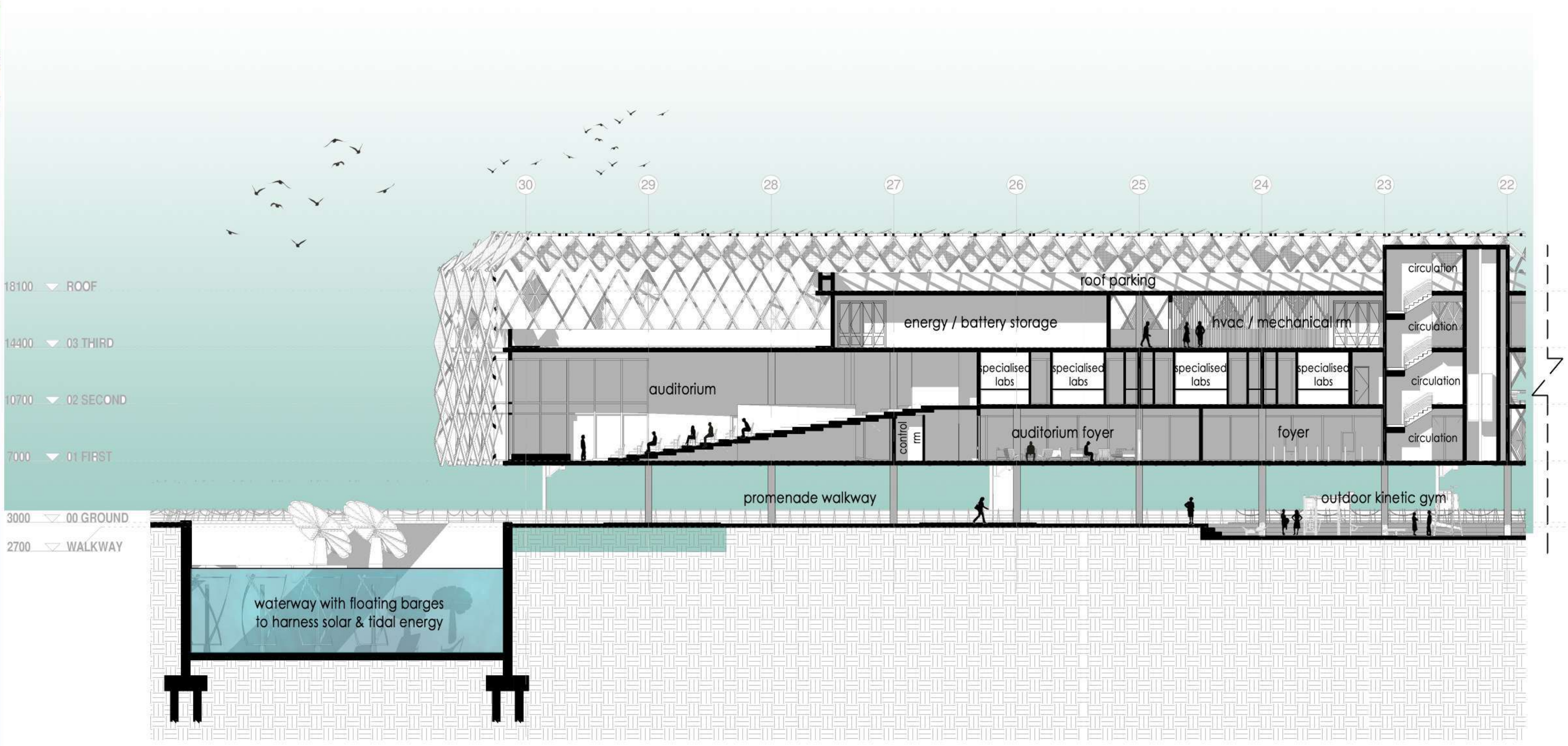
THIRD FLOOR PLAN | SCALE 1:250

ROOF FLOOR PLAN | SCALE 1:250

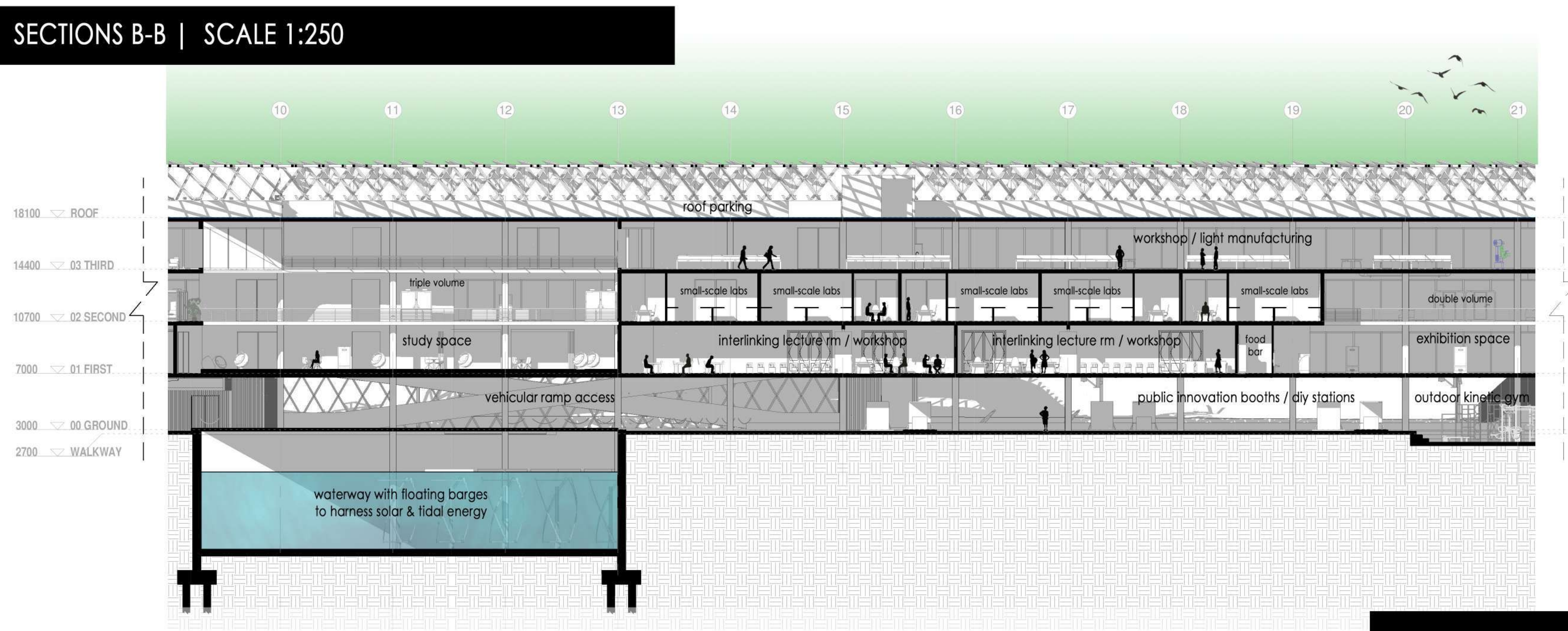
SECTIONS PLAN | SCALE 1:250



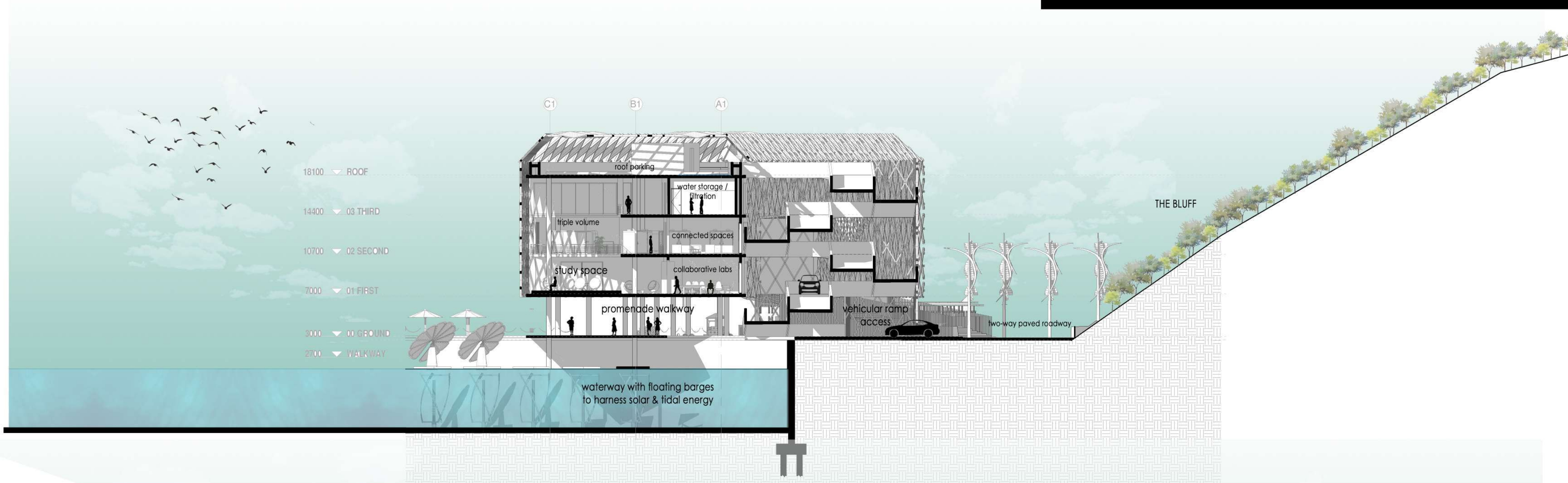
SECTIONS A-A | SCALE 1:250

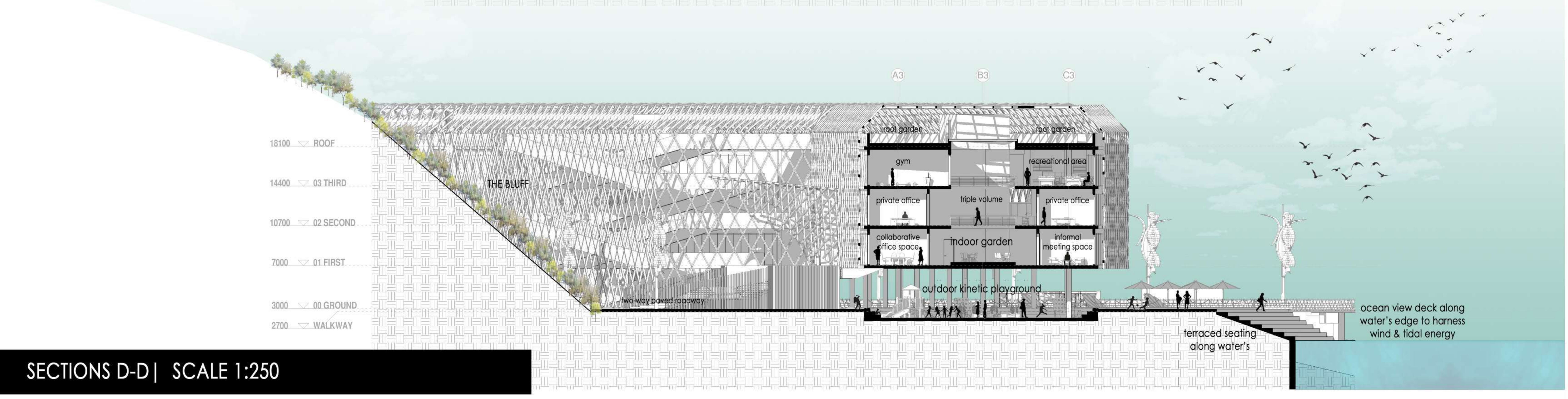


SECTIONS B-B | SCALE 1:250



SECTIONS C-C | SCALE 1:250

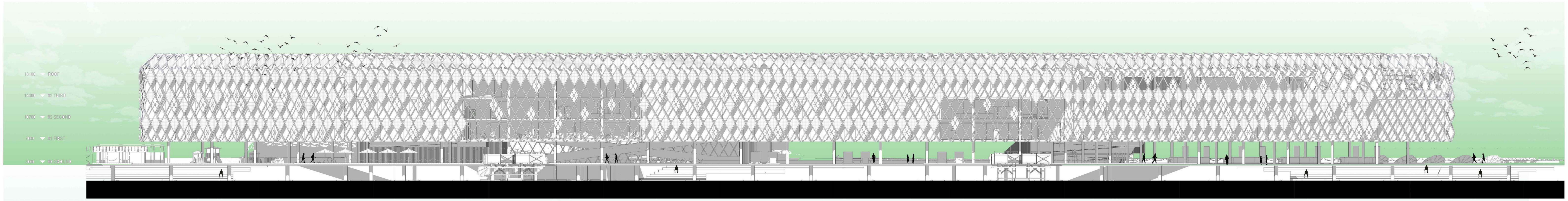




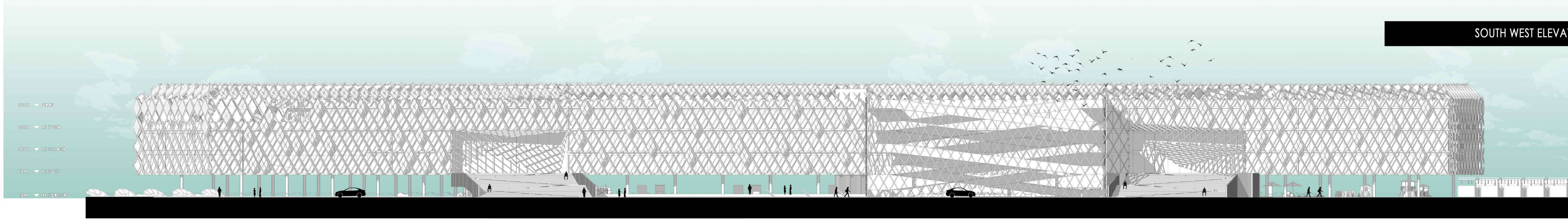
SECTIONS D-D | SCALE 1:250

ASHMIKA RAMKLASS_213506761

NORTH EAST ELEVATION | SCALE 1:250

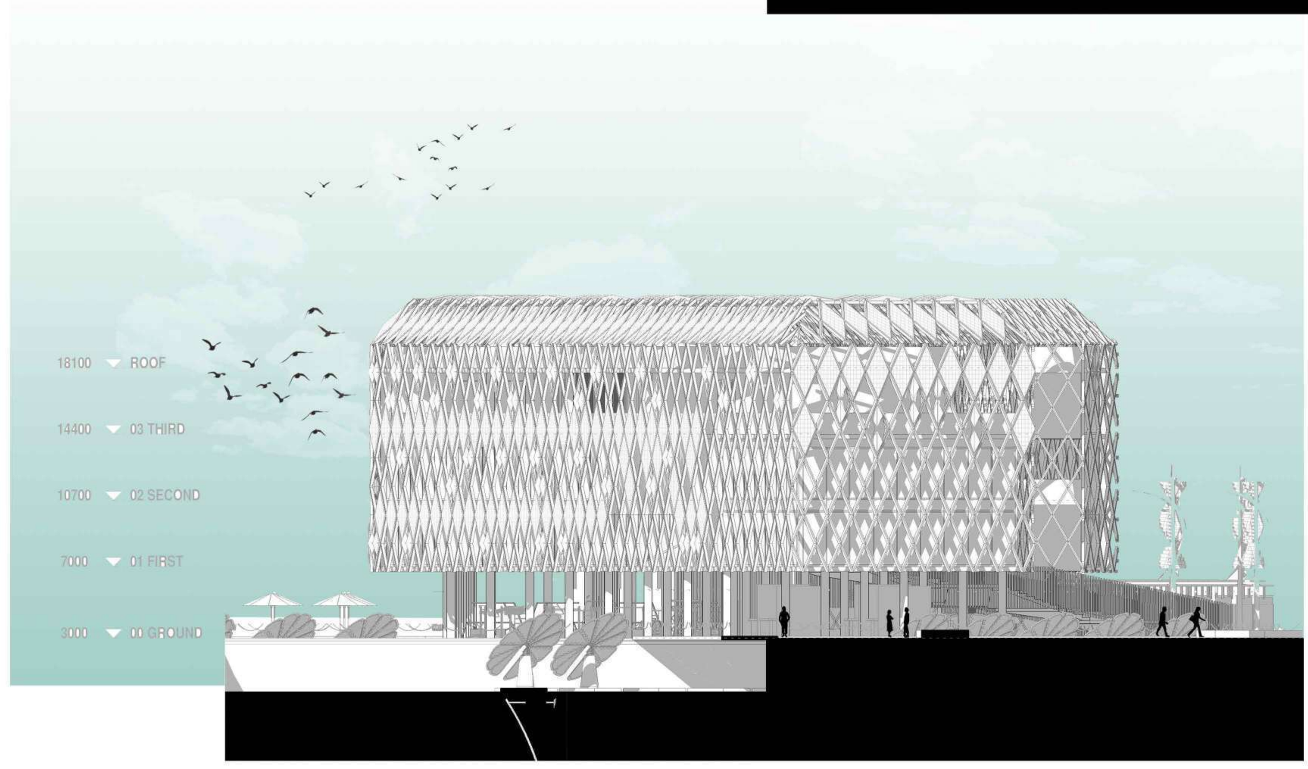


SOUTH WEST ELEVATION | SCALE 1:250

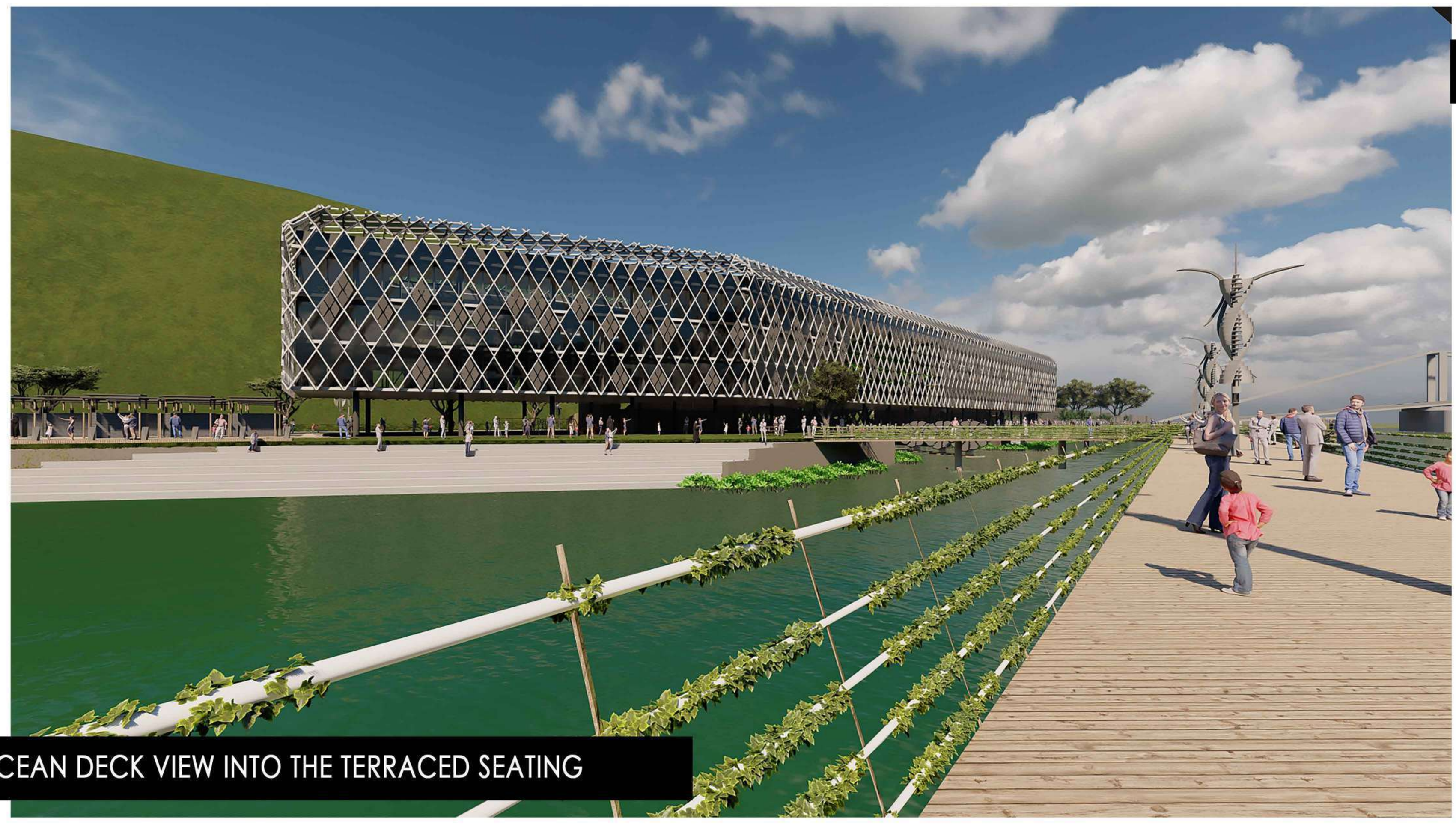


EXTENSION OF PROMENADE FILTER INTO PLAZA

NORTH WEST ELEVATION | SCALE 1:250

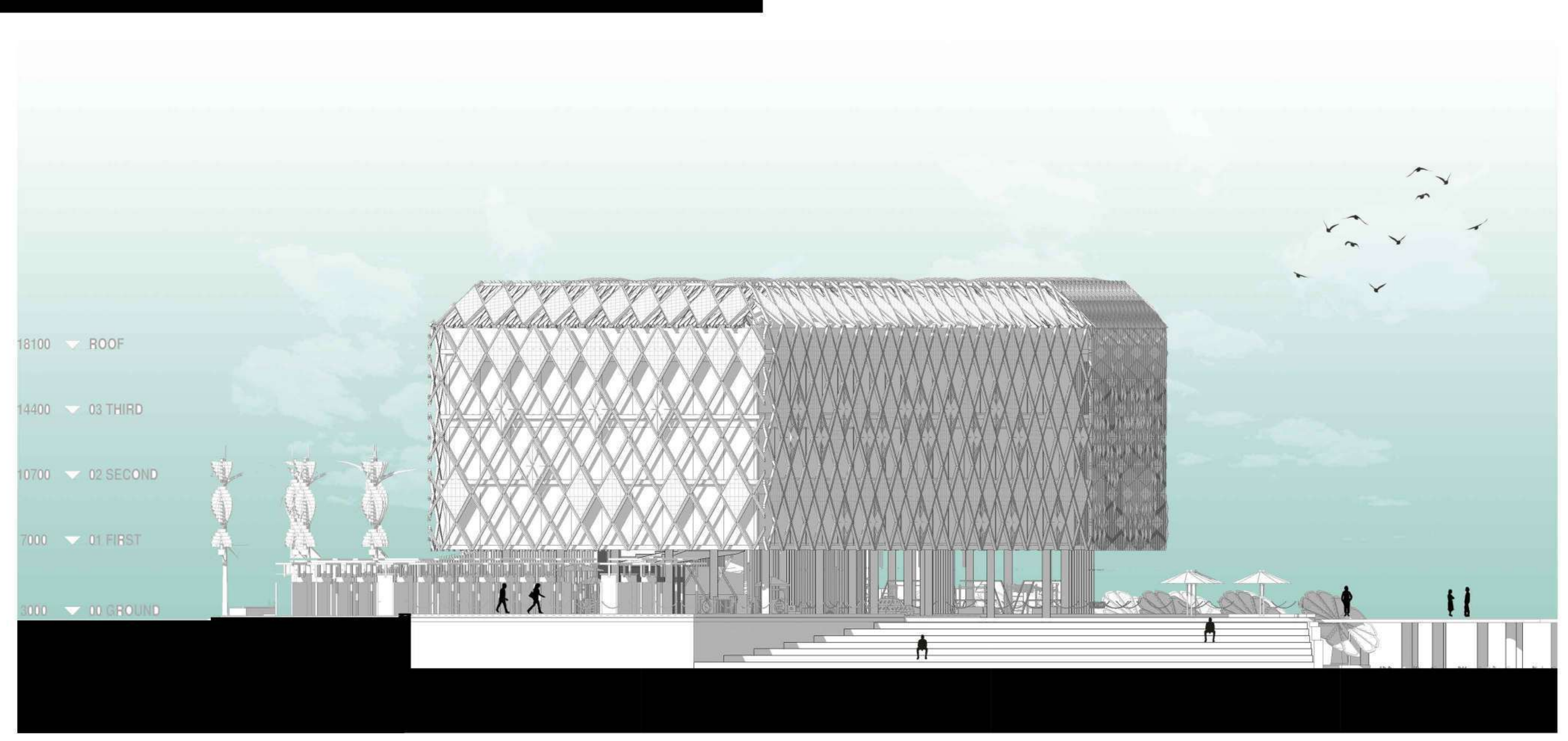


DISTINCTIVE PUBLIC ENTRANCE INTO BUILDING

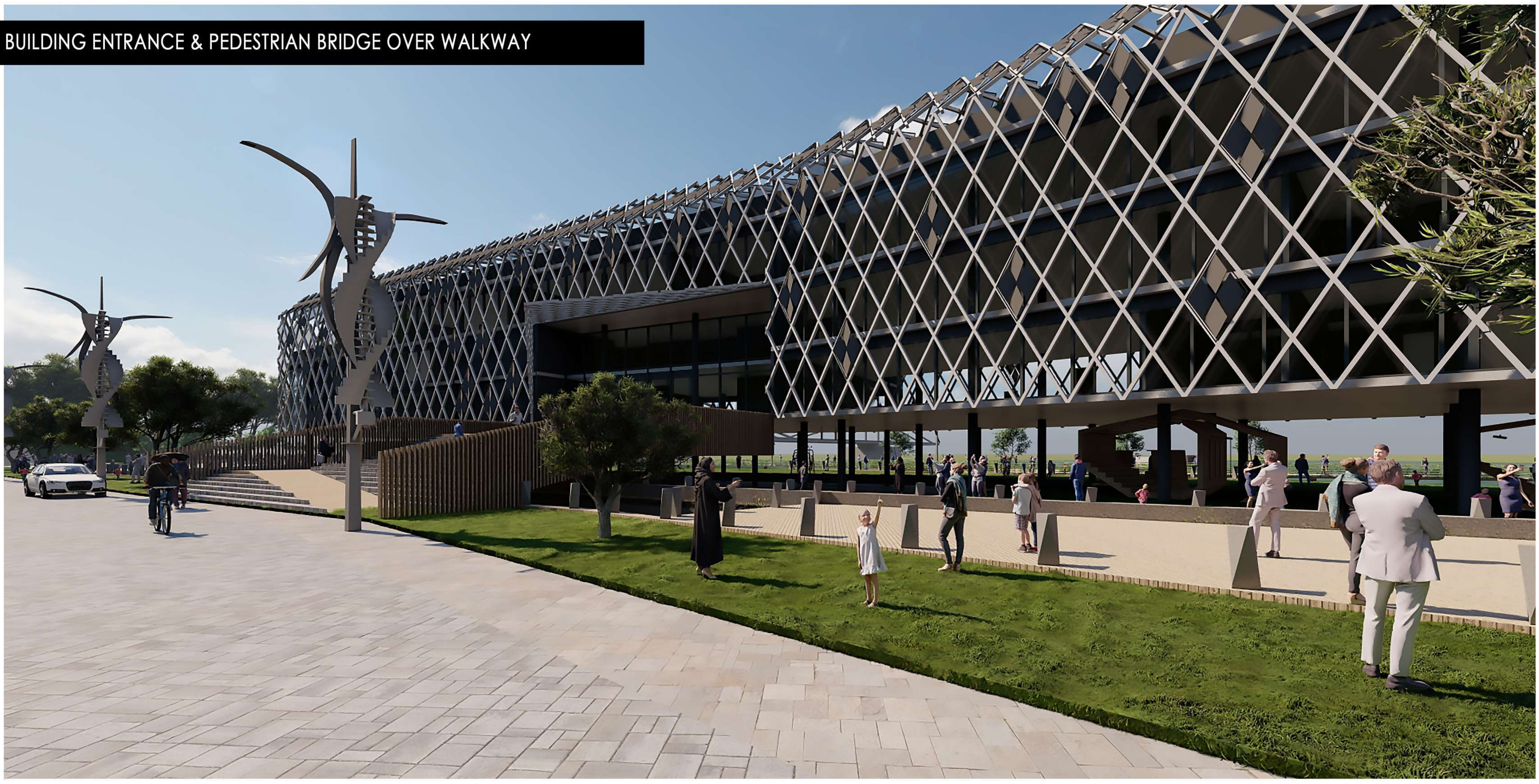


OCEAN DECK VIEW INTO THE TERRACED SEATING

SOUTH EAST ELEVATION | SCALE 1:250

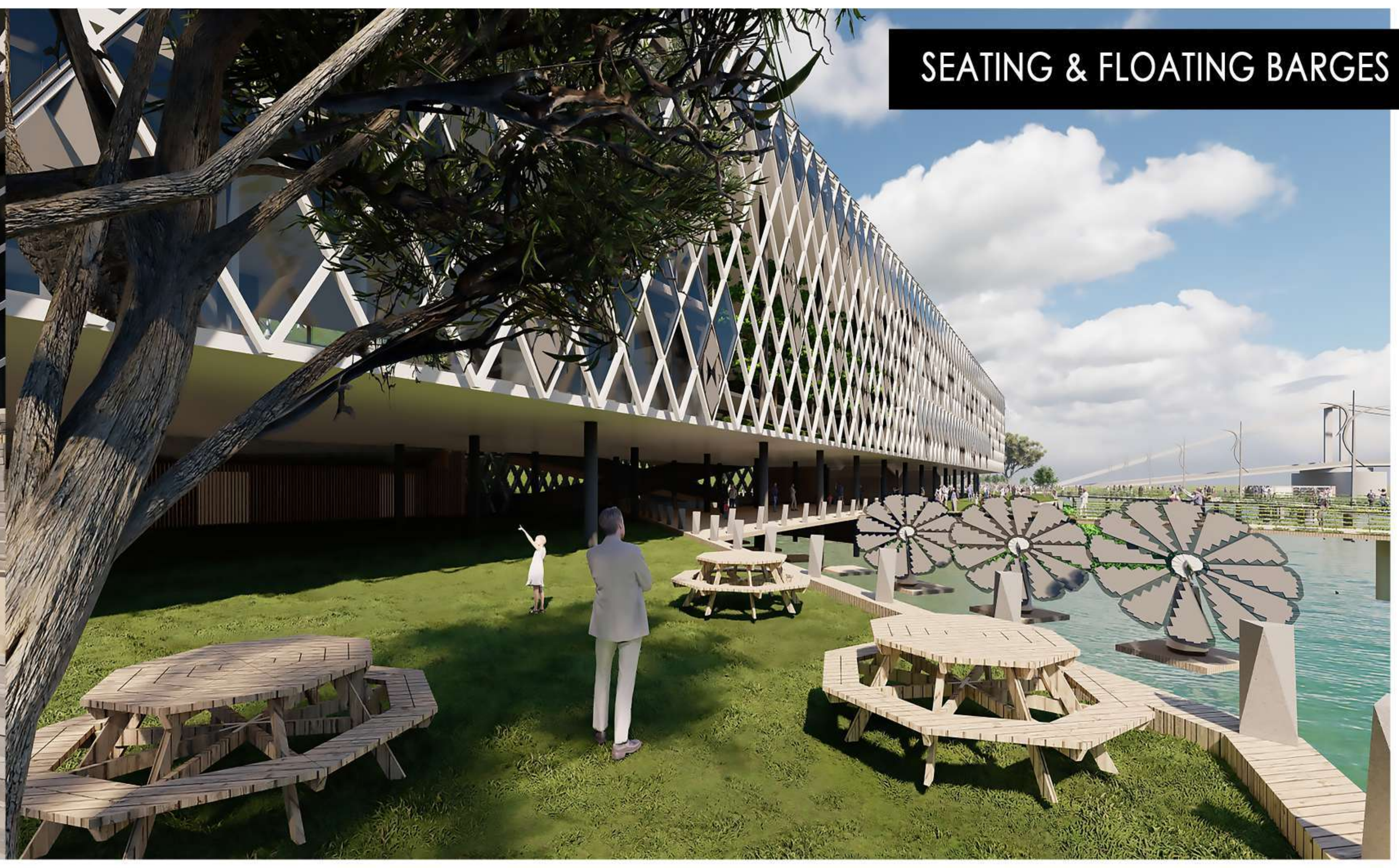


VIEW OF BRIDGE, HARNESSING OF RENEWABLE ENERGY



BUILDING ENTRANCE & PEDESTRIAN BRIDGE OVER WALKWAY

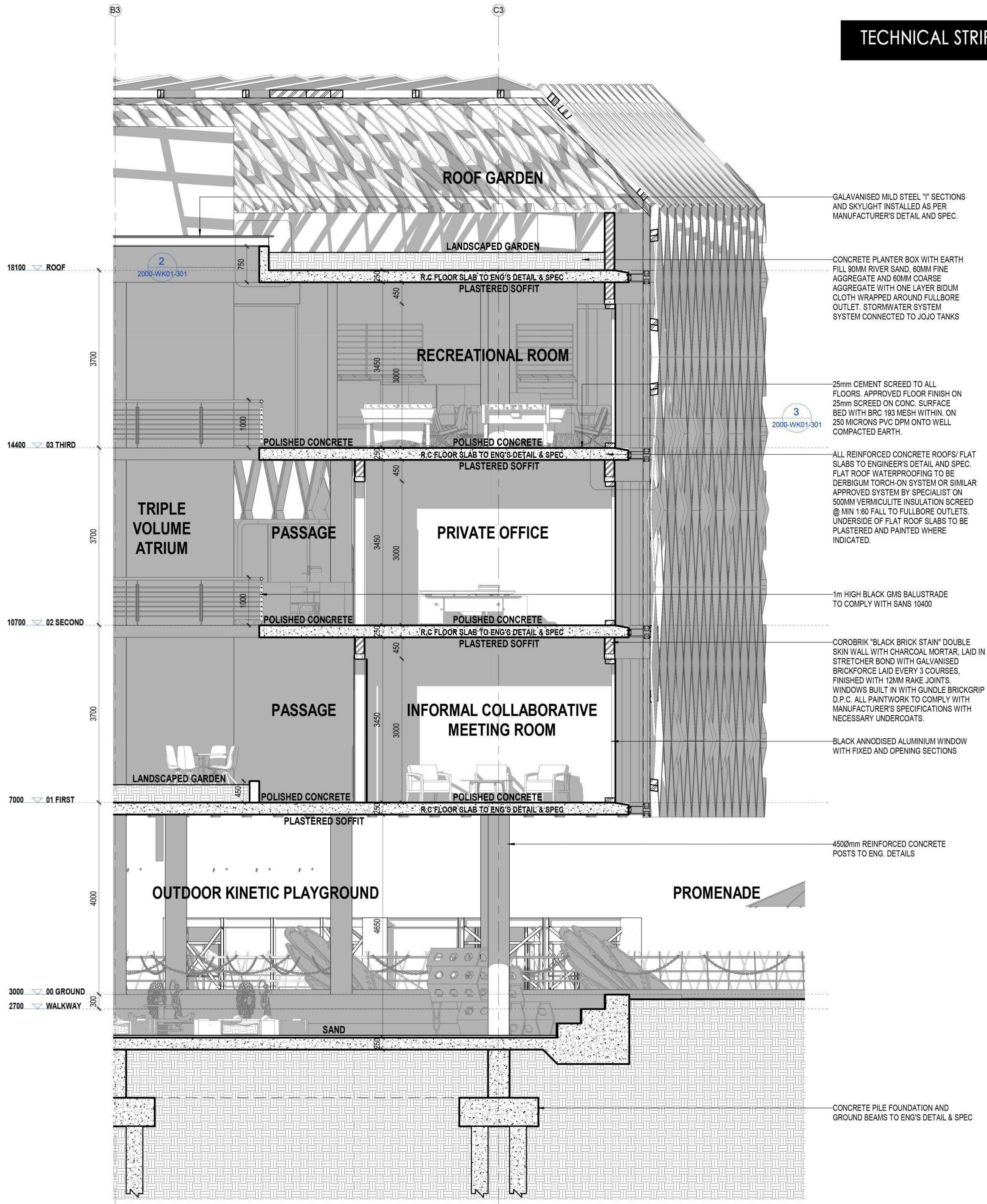
RAMPED ENTRANCE & GREEN FACADE



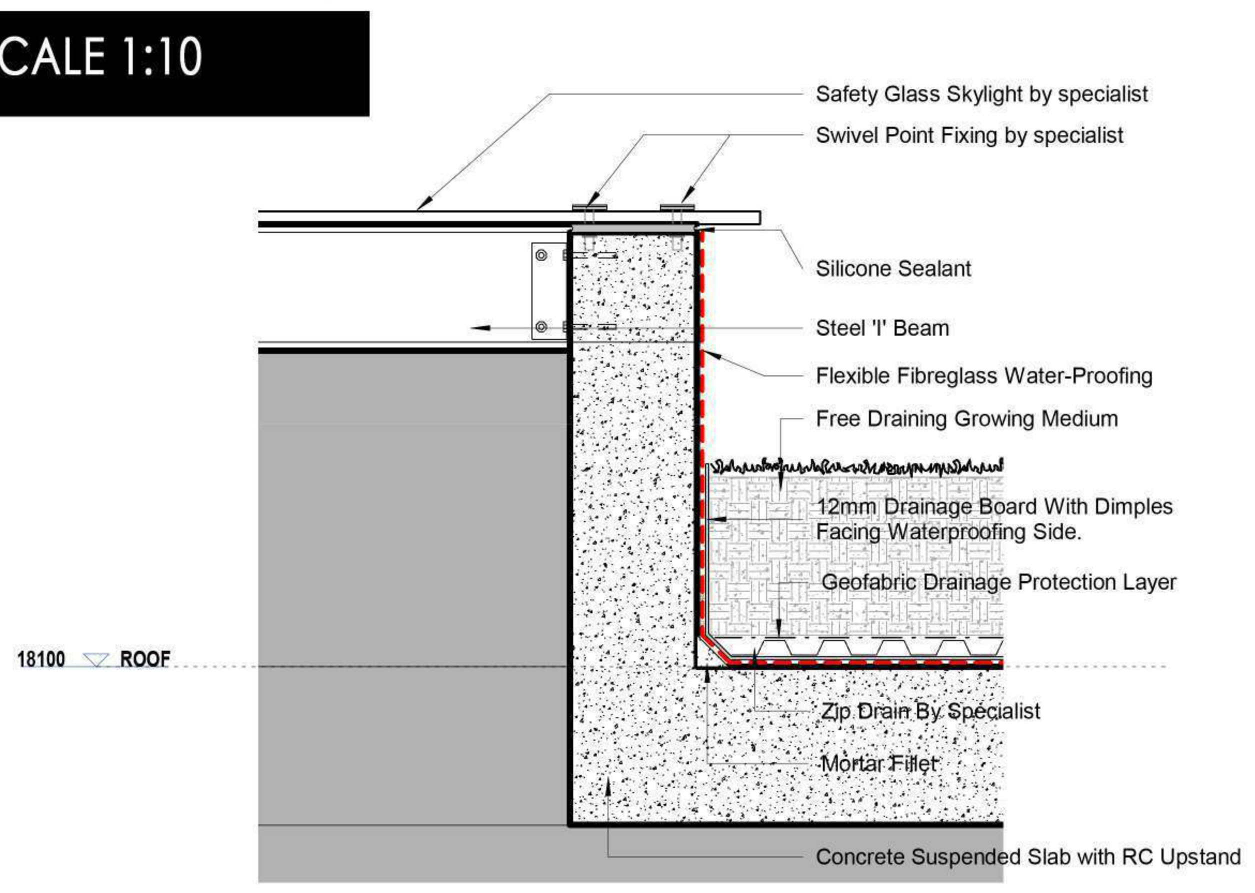
SEATING & FLOATING BARGES

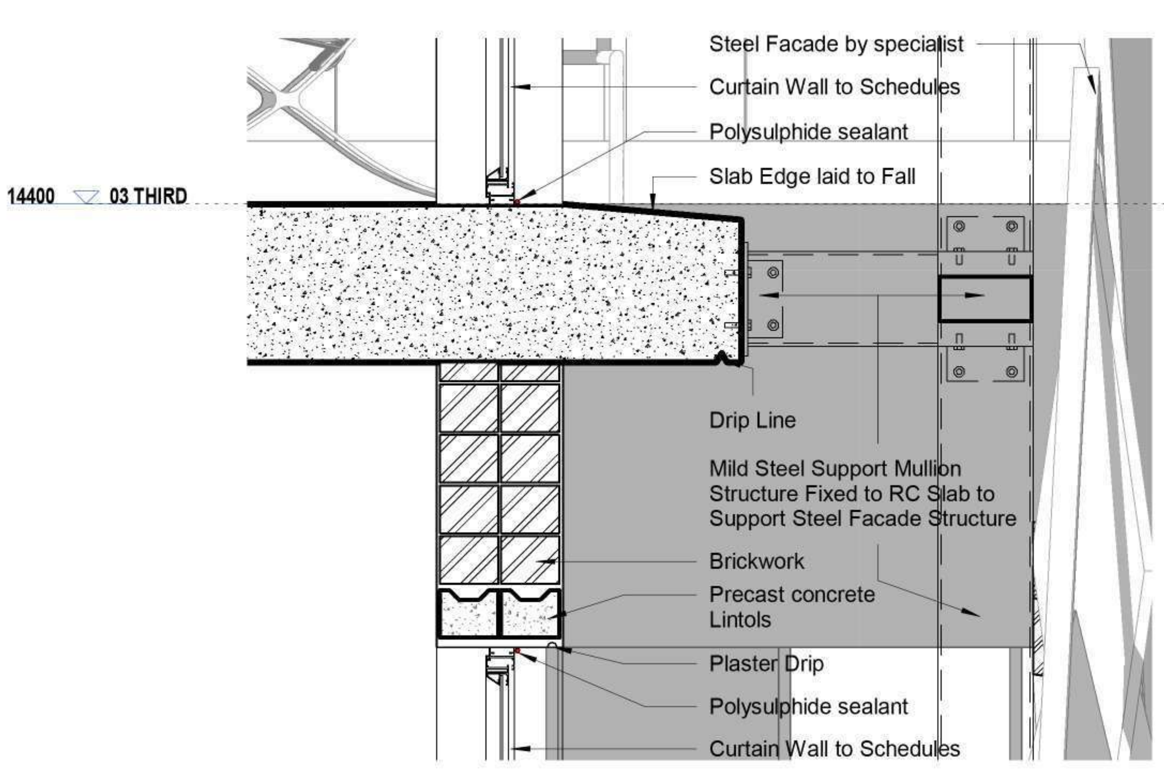
PEDESTRIAN VIEW INTO PERMEABLE STUDY SPACE

TECHNICAL STRIP SECTION | SCALE 1:50



TECHNICAL DETAILS | SCALE 1:10





SUSTAINABLE PRACTICES