A Symbiosis of Bio - Diversity And Architecture: Towards A Centre For Awareness And Research In The uMngeni Precinct.

By:

Meloshan Pillay

Supervised By:

Juan Solis - Arias

A dissertation submitted to the Faculty of Humanities, Development of Social Sciences,
University of KwaZulu-Natal, in partial-fulfilment of the requirements for the degree of
Master in Architecture,
Durban, 2018.

ABSTRACT

Rapid industrialization of the 20th and 21st centuries has pushed the envelope in developing goods and services for society, often inundating the biosphere's energy and resources, leaving vital ecosystems and natural landscapes in a state of decay.

A similar consequence can be experienced within the uMngeni Precinct, more specifically between the uMngeni Industrial Parks and the discharge point of the uMngeni River into the Indian Ocean.

This study then adopts a qualitative research approach that explores the influences of biodiversity on architecture. The analysis of primary and secondary data is supported by the overlapping principles of Human, Natural and Architectural Ecologies that fosters an architecture to utilize high – tech thinking coupled with low – tech technologies in creating ecological awareness and a platform for research in the uMngeni Precinct.

DECLARATION

A document submitted in partial fulfilment of the requirements for the degree of Masters, in the Graduate Programme in Architecture, University of KwaZulu-Natal, Durban, South Africa.

I declare that this dissertation is my own unaided work and carried out exclusively by me under the supervision of Mr. Juan Solis-Arias. All citations, references and borrowed ideas have been duly acknowledged. It is submitted for the degree of Masters in Architecture in the Faculty of Humanities, Development and Social Science, University of KwaZulu-Natal, Durban, South Africa.

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

………………………………..

Meloshan Pillay

11th May 2018

ACKNOWLEDGEMENTS

I would like to express my gratitude and reflect on all those who have contributed towards this dissertation. I would like to thank:

My family for the continuous support.

My supervisor, Mr. Juan Solis – Arias, for the supervision, commitment and patience throughout this study.

My friends and colleagues, old and new, for the support and encouragement.

DEDICATION

This dissertation is dedicated to my mother, brother and grandmother for the endless support, encouragement and wise words. Thank you for molding me into the person that I am today.

I am forever grateful.

LIST OF FIGURES

LIST OF TABLES

CONTENTS

PART TWO: DESIGN REPORT

CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

1.1.1 Background

The motivation behind this research is to create a platform of awareness, research and conservation, through architecture and the built environment. Industrial globalization has played a significant role in shaping human settlement throughout the last century. According to Giddens (1990: 64), globalization is "the intensification of worldwide social relations which link distant localities in such ways that local happenings are shaped by events occurring many miles away and vice versa", thereby changing all aspects of our everyday life. However, the term only deemed popular in the latter half of the 20th century.

Through the intensification of technology and the reliance on machinery, global connections allowed economies to flourish through networking and global exchange (Rapoport, 2006: 123). This suggests that technology provided a new platform to facilitate industry throughout the world. With the economic boom of the late 20th century, worldwide markets were fixed on churning out numbers to boost revenue. Much like these global economic ecosystems that were created, many of the natural ecosystems were then forgotten. Often, the impressive numbers and global growth left the natural landscapes in a derelict state.

Natural resources form the basis for life on Earth, and often, exploited through industries without a sustainable conscience. According to Kominoski and Rosemond (2012: 01), freshwater ecosystems offer critical service to humans, and are particularly vulnerable to global environmental changes. Serfontein (2012: 2) suggests that sustainable development is not merely about the preservation and restoration of heritage, but a global paradigm shift towards the understanding of man as a "parasite" towards the concept of human kind as a part of a greater natural system.

Aligned with the concept of Industrial Ecology, one may link the string of issues to Systems Theory (Von Bertalanffy, 1972), which suggests that human settlements are majorly influenced by natural water bodies and ecosystems. The term "sustainability" entered the consciousness of architects in the late 20th century, becoming an essential concern in the discourse of architecture (Bennetts, Radford & Williamson, 2003: i).

This study is to respond to the issue of the lack of sustainable ecosystems, natural environments and aquatic life, through the influences of biodiversity and ecology on architecture.

"Biodiversity supplies society with a range of ecosystem goods and services. When mankind destroys vital species and ecosystems, they are at risk of losing these life – supporting functions, thereby endangering themselves". (Our Biodiverse City, 2009)

1.1.2 Motivation / Justification of the study

The built environment has always been a part of man's life on Earth. Man's life occurs primarily within the built environment, which has been facilitating physical, mental and emotional wellbeing (Dokrat, 2012: 2). However, through industrial globalization, technology has created a barrier between man and nature, thus suggesting a disconnection between the two entities exist.

As industries expanded and shaped most landscapes, academics and scientists observed the rapid depletion of natural environments and ecosystems. However, industry formed a vital part of global economic growth, in 1st world and 3rd world countries, which inevitably strengthened exchange, but it could not go unnoticed that this "new" global trend was leaving a destructive path. Throughout the late 20th century and early 21st century, the terms "green" or "sustainable" made its way onto the front line of most products and services, which meant that these processes considered the environment. However, this ideology proved contradictory since global forces used "being green" to ensure greater sales towards their markets.

Of present days, the destruction of natural environments and ecosystems is a real-life phenomenon that impacts not only on rural landscapes, as perceived by global forces, but larger parts of the world. This gave rise to non-profit organizations and municipal sectors facilitating in the conservation, enhancement and regeneration of lost or destroyed biodiverse ecosystems and natural environments (Durban: State of Biodiversity, 2014).

The uMngeni River, located on the East coast of South Africa, suffers the same repercussions as described above, whereby natural ecosystems, aquatic and plant life have been destroyed through the development of Durban's CBD, and the industry within its immediate context. This natural body of water stretches over 255 kilometers and forms the basis of life for multiple communities and provides habitats for aquatic and terrestrial species. Furthermore, the river provides ideal ecosystems for aquatic invertebrates and fish (Umngeni River and Neighbouring Rivers And Streams, 2002: 4,5).

Considering the above discussion, it can be understood that the motivation behind the proposal of a center for awareness and research within the uMngeni precinct comes as a direct result of the derelict state of the river and its estuarine ecosystems.

Sustainability has recently become a popular theme in the angling industry within Durban, however, without well conserved ecosystems and habitats, species may not survive. Being a part of the angling and paddling community, one can identify the importance of the uMngeni River, not just for recreational purposes, but the development of aquatic and plant life which supports much of the fisheries along the East Coast. Therefore, further motivation of the response comes from first-hand experience and engagement of the uMngeni River.

1.2 DEFINITION OF THE PROBLEM, AIMS AND OBJECTIVES

1.2.1. Definition of the problem

As described above, the late 20th century saw man-made environments dominate and segregate natural environments and ecosystems, which was partially influenced by the global movement towards technology, industry and economies. At present, the negation towards the natural environment often leads to ecological and human well-being issues (Dokrat, 2012: 3). Whilst man pursues maximum expression of progress through the development of artificial landscapes, the research will then consider ways in which the built environment may facilitate in the conservation of natural landscapes. The primary problem refers to the manner in which ecological architecture can support and conserve natural ecosystems, as well as various socio – cultural clusters through awareness and research.

1.2.2. Aims

The research aims to consider ways in which the processes of natural environments may inform architecture and the built environment. Furthermore, architecture will then seek influences from Ecology in Architecture and Industrial Ecology towards the conservation of natural landscapes.

1.2.3. Objectives

The overall aim of this research is to formulate a set of criteria towards the balance between man-made industrial environments which interface natural environments. This refers to the creation of an architecture that is inspired by industrial and ecological processes towards conservation of the uMngeni precinct and its vital ecosystems. The objectives of this research are as follows:

- To understand man's place on earth in relation to natural and man – made environments.
- To explore ecological processes that may facilitate an architecture towards achieving industrial symbiosis.
- To consider systems that will ensure an architecture, is to consume local energies and materials towards a state of equilibrium within its host environment.
- To improve the quality of water and natural ecosystems of the uMngeni River, through industrial ecological influences on an architecture.

1.3 SETTING OUT THE SCOPE

1.3.1. Delimitation of the research problem

The research will pursue the understanding of ecosystems and its impact on human settlement through awareness, research and preservation. Furthermore, the research intends to:

- Define and explore the relationship between traditional landscapes and ecosystems.
- Explore possible reasoning for dilapidated ecosystems and natural environments.
- Develop a set of theoretical criteria in which one may link biodiversity to architecture.

The research does not intend to:

- Generate a universal solution for dilapidated ecosystems in all contexts.
- Deal with political factors.

Where biodiversity, ecology and industry are discussed, it shall relate to influences and factors within the stated context. Therefore, research will focus on the uMngeni River and surrounding precinct, with attention on socio – economic and cultural systems, plant and aquatic life, industrial systems, as well as the water body itself.

1.3.2. Definition of terms

Aquatic: (*adjective)* relating to or pertaining to water: any form of animal or plant life that may live or grow under water.

Biodiversity: (*mass noun)* is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

Ecology: (*mass noun)* the branch of biology that deals with the relations of organisms to one another and to their physical surroundings.

Ecosystems: (*noun)* all the living things in an area and the way they affect each other and the environment.

Entropy: (*noun)* the lack of order or predictability within a thermodynamic system.

Evolutionary Thermodynamics: (*noun)* a branch of science that deals with the transfer of work, energy and resources from one system to another.

Globalization: (*mass noun)* a phenomenon by which the experience of everyday life, as influenced by the diffusion of commodities and ideas, reflects a standardization of cultural expressions around the world.

Industrial Ecology: (*noun)* investigates the efficiency and effectiveness of industrial systems, with a sustainable approach towards the extraction of resources and the ability to create byproducts from waste.

Open System: *(noun)* an open system refers to a system and/or process that can effectively gain or lose energy from the "host environment" for its evolution.

Passive Design: Passive design refers to a design approach that uses natural elements, often sunlight, to heat, cool, or light a building.

Symbiosis: *(noun)* the living together of two dissimilar organisms, as in mutualism, commensalism, or parasitism.

1.3.3. Stating the assumptions

It is assumed that there is a dominance of man – made landscapes over natural environments which leaves vital estuarine ecosystems in poor condition. This document will therefore be written under the influence of the basic assumptions:

- Often, industry offers little opportunity for public access to green spaces, whilst being harmful to the natural environments and ecosystems that exist within the precinct.

- Ecosystems do not only support mankind but are vital natural structures found in and around the immediate environment.
- The uMngeni River has been deteriorated due to global forces. It cannot be ignored that this vital body of water serves as a platform for life, ecosystems, and aquatic life within the Durban Coastline.
- The architecture must therefore be more than aesthetically pleasing, but largely a vibrant place for conservation, awareness and research.

1.3.4. Hypothesis

The global movement towards industrialism has created a fragmentation between architecture and the natural landscape. By understanding biological, industrial, historical and traditional norms, one can use these processes to facilitate a response towards creating awareness, conservation of natural landscapes and architecture that is in equilibrium with nature.

1.3.5. Key Questions

Primary Question:

- How can biodiversity facilitate architecture towards an industrial symbiosis that will positively impact on the conservation of natural environments and estuarine ecosystems?

Secondary Questions:

- What is the relationship between man, nature and industrial landscapes?
- How can ecological processes influence an architecture towards an industrial symbiosis?
- What systems can be employed to ensure an architecture that is in equilibrium with its host environment?
- How can industrial ecology foster an architecture to conserve natural ecologies?

1.4 THEORIES AND CONCEPTS

1.4.1. Ecology in Architecture

The state of the uMngeni River suggests that the research is to consider a sustainable approach towards the architectural response. However, within the paradigm of sustainability, the theory of ecology deems to be a beneficial theoretical platform to create an architecture that will address issues around ecosystems, biodiversity and awareness.

Ecology in Architecture refers to the ecological interactions of the built environment with the natural environment. Gu and Evans (2010) suggest that a conceptual framework for ecological architecture may seek inspiration from an open systems evolution, based on evolutionary thermodynamics. This theoretical approach explores three key principles that refer to: *Natural Ecology*, *Human Ecology* and *Architectural Ecology*. These attributes, as described by Gu and Evans (2010: 49) optimize the performance of the built environment towards a sustainable symbiosis of nature and architecture. The concept of ecology in architecture, as well as its three attributes will be further unpacked in Chapter Two, whereby, each of the three attributes discussed above will be paired with a theory and concept to ensure an explicit link to architecture. Where, Natural Ecology will be explored through The Theory of Ecology, Human Ecology will be explored through Place Theory and Architectural Ecology will be explored through Systems Theory. This ensures that there is a clear and concise theoretical framework which will inform the subsequent chapters.

1.4.2. The Theory of Ecology

The theory of ecology considers the impacts of man-made environments on the natural environment. Within the discourse of architecture, one can then assume that the Theory of Ecology refers to any form of design that will minimize environmental desolation. For this form of design to prosper, it will need to integrate itself with the process of living, as well as, its ability to adapt and integrate with the processes of nature (Sim Van der Ryn, Stuart Cowan, 2013).

Within Deep Ecology, architecture in the modern age can be conceived as the modification of the planet's ecosystems (Naess, 1992), which refers to global development towards industry, production and rapid urbanization (Gu and Evans, 2010). Thus, suggesting that man-made environments diminish most forms of nature. It is for this reason that the Theory of Ecology is to inform the principle of Natural Ecology described above. Naess (1992: 29), argues that, in order for ecological sustainability to be achieved – it must protect the richness of diversity of life forms (on a global scale). Furthermore, Naess suggests that humans and their cultural norms form part of life forms, and therefore should be protected. This allows the research to consider the connection between people and culture, and the influence of this towards their place on Earth.

1.4.3. Place Theory

"Place Identity" or "Sense of Place" refers to the relationship between people and the physical environment. Considering architecture as an attribute within the physical world, it can be a vital influence in the creation of Place. Within the 21st century, the idea of place has been lost (Rapoport, 2006), where global trends sparked the rise of homogeneous landscapes losing identity and traditional norms and values. Therefore, Place Theory will serve as a fundamental analytical tool towards unpacking the principle of Human Ecology.

1.4.4. Industrial Ecology

Industrial Ecology explores the idea of an industrial system that is one with the biosphere (Erkman, 1997), to which it informs ecological architecture towards a symbiosis with the uMngeni River. Furthermore, this considers processes of resource inputs for a specific activity or process, to the outputs of waste bi – products that may become a resource for other living entities (Jelinski, Graedel, Laudise, McCall and Patel, 1992).

1.5 RESEARCH METHODS AND MATERIALS

1.5.1. Introduction

The research will employ a qualitative research method towards investigating the quality of water, life and biodiversity within the uMngeni River. Furthermore, the qualitative approach will seek to unpack data through the grounded theory and content analysis methodology that puts emphasis on human interaction and social clusters (Cohen, Manion, Morrison, 2013: 462). The aim of this approach is to explore the overlapping principles of Architectural Ecology, Natural Ecology, Human Ecology and Industrial Ecology that will form the basis in which the built environment will respond to various issues in achieving balanced ecosystems.

1.5.2. Ethnography

The research will focus largely on the various "beach" cultures and local communities who interact with the banks of the uMngeni River, as well as the fields of marine biology and environmental sciences.

1.5.3. Primary Data Collection

The research aims to explore the impacts of the river on the livelihoods of social and cultural clusters, as well as the manner in which ecological architecture may facilitate the rehabilitation of natural ecosystems. The data collection process will consider three concise focus areas:

Considering the motivation behind this research, the first process will consider first – hand experiences, observations and photography towards an ethnographic study (Cohen, Manion, Morrison, 2013: 396).

The aim of this process is to capture the essence of place, with regards to the users, for instance; the observation and engagement of professional or recreational anglers that may offer insight of values and norms towards the uMngeni River. The data collected from each of these cultural or socio - economic clusters, ensuring that the architectural intervention responds to issues on a local level.

The second process will consist of a less structured interview schedule (Cohen, Manion, Morrison, 2013: 352). This process is primarily site specific and requires rich and personal data, therefore it is to be word – based and open - ended that will capture the specificity of a situation. These interviews seek to gather data on how the conservation and revitalization will benefit immediate communities and natural ecosystems through architecture that will provide awareness and infrastructure.

The third process will consist of interviews with professionals that are affiliated with architecture, ecological architecture, environmental sciences and marine biology. It is vital that the research explores information from these participants, as they hold vital data that will inevitably influence the idea of ecological architecture within an industrial landscape.

1.5.4. Sampling Methods

A purposive sampling method will be employed to effectively capture information from professionals within the field of environmental sciences, marine biology and the beach cultures of the precinct. Being affiliated with the angling community in Durban – it assures that the research is well networked and is exposed to learned individuals. Therefore, the purposive sampling approach will be adopted which allows participants to be handpicked (Cohen, Manion, Morrison, 2013: 115). This ensures that the research will build up a sample that has richness and satisfies specific needs.

The sampling will consider between 10 - 20 participants in order to understand the impacts of the built environment, towards the preservation of natural ecosystems. The sample age is to be between 20 – 60 years of age. This age gap will ensure a variety of information, whilst older participants would have experienced the uMngeni precinct during the rise of industry in the area, as well as experienced the mass flooding that occurred in the 1980s that may have altered the natural ecosystems.

1.5.5. Case Study

The focus area of study is the uMngeni precinct, KwaZulu – Natal, South Africa. More specifically between the uMngeni Industrial Park and the discharge point into the Indian Ocean. Observations and interviews will be carried out in this area as it holds deep ecological significance and has various cultural, industrial and biological attributes associated with it. Moreover, interviews will be conducted in either English or isiZulu where necessary, as it is vital to develop a sample that includes various ethnicities.

1.5.6. Secondary Data Collection

The research will obtain relevant information from secondary data sources. This study will inform the problem statement, as well as the research questions towards the development of an Ecological Architecture. The literature will be explored from a global to a local lens towards the uMngeni River system.

The literature review will consider only published authors within relevant fields, towards the understanding of how architecture may facilitate the conservation of natural ecosystems. Furthermore, to achieve this, the three principles of Ecology in Architecture will be unpacked through the theoretical framework of Ecology, Place Theory, Systems Theory and the concept of Industrial Ecology. This will form a lens from which the research may seek inspiration into the conservation, preservation and awareness of the uMngeni River through the built environment.

Various literature will be obtained from journals, articles, books, electronic data, and academic papers. To further inform the research, precedent studies will be reviewed, enabling a better understanding of natural ecosystems and architecture and how these two entities may function in equilibrium.

1.6 CONCLUSION

Chapter One outlined the derelict state of uMngeni River and the impacts of industry, various communities, cultural and social groups upon its ecosystems. Personal experiences and engagement further instated the motivation towards the conservation of this estuarine body of water through an architectural lens. It is for this reason, that the research has considered Ecology as the vehicle to address these issues towards an architecture. The process of ecological architecture must be inclusive to the realms of man, nature and the built environment. Furthermore, the theoretical framework establishes the ideology that architecture should move beyond the paradigm of artistic forms and objects, but rather towards a process of design where social and environmental attributes of the immediate context should form the nucleus of a system. This process ensures that the response considers the building end - user whilst allowing an architecture to achieve a symbiosis with the natural and industrial environments.

1.7 THESIS STRUCTURE

The following dissertation is structured into two parts. Part one consists of seven chapters that form the research approach towards achieving an architectural design response for the uMngeni precinct. Chapter One serves as an introduction into the research outlining the background, motivation, objectives, research questions and research methodology employed within this study.

Where Chapter One provides a brief outline of the theories and concepts utilized within this research, Chapter Two will explore these in more detail, essentially developing the theoretical framework that is to influence the rest of this dissertation. Chapter Two will be further analyzed through supportive literature.

Chapter Three consists of literature reviews which are informed by the objectives and research questions, unpacking existing knowledge based on man's connection with industrial landscapes, nature as a mechanism that may inspire the built environment, architecture as a system in nature and industrial ecology as a tool to achieve eco – efficiency and eco - effectiveness.

Two precedent studies will be explored within Chapter Four, where these existing architectures are unpacked and critically analyzed through the theoretical framework established in Chapter Two and the research questions stated in Chapter One.

Chapter Five will investigate a case study. A local building or facility that embodies features and qualities that is to influence the research and architectural response within this study.

Chapter Six serves as an analysis of empirical data gathered through interviews and observations which draws links from the primary and secondary research questions established in Chapter One.

Chapter Seven serves as a continuation of Chapter Six, where the analysis and discussions of the findings begin to inform the conclusions and recommendations within this research. Thus, ensuring that the research achieves its aims and objectives, as well as provides necessary answers to the research questions, inevitably generating the basic principles that shall foster the architectural design response in Part Two.

Chapter Eight contains the bibliography of the research, thus ensuring all references, citations, and adopted ideas that are duly acknowledge.

Part Two will follow, compromising of the architectural design response for the uMngeni precinct.

CHAPTER TWO: THEORETICAL AND CONCEPTUAL FRAMEWORK

2.1 INTRODUCTION

This chapter seeks to explore the influence of biodiversity and ecology on the built environment, thereby understanding the impacts of architecture on natural landscapes. In order for the research to understand the fundamental attributes of biology and ecology, it had to consider the powerbrokers within the specific fields. These key thinkers who have contributed to the fields of biology and ecology include; the Greek philosopher Plato (428 – 348 BC), who regarded biology as a process that should influence the life of man – kind. Aristotle (384 – 322 BC), a student of Plato, one of the first academics to arrange biological forms into "origin groups" – centuries later influencing Darwin (1859) with the theories of Natural Selection and Evolution that science is so familiar with today. Other inspiration comes from the writings of Heidegger (1889) who provides insight to deep ecological meaning.

It can then be assumed that the authors mentioned above provided a platform for the concept of Ecology in Architecture. The research will explore Ecology in Architecture as the key concept, that provides three principles (Gu and Evans, 2010). These principles refer to *Natural Ecology*, *Human Ecology* and *Architectural Ecology*. In order for the research to understand these principles explicitly, they will be paired with theories (*fig 1*), which will ensure a link to architecture and the built environment. Where *Natural Ecology* will be investigated through *The Theory of Ecology*, *Human Ecology* will be investigated through *Place Theory* and *Architectural Ecology* will be investigated through *Industrial Ecology*. Moreover, *Industrial Ecology* will also serve as a contextual concept which will facilitate design ideologies later in the process towards an ecological architecture within the uMngeni precinct.

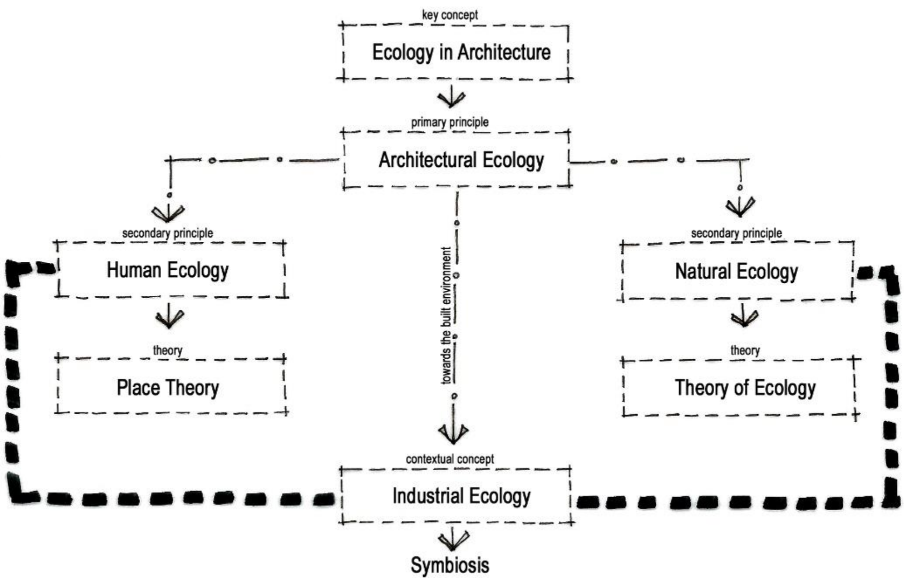


Figure 1: diagram illustrating theoretical framework: unpacking "ecology in architecture" and its three principles through theories and a concept towards an architecture that is in symbiosis with the uMngeni River. 2018, By Author

2.2 ECOLOGY IN ARCHITECTURE: [Natural Ecology, Human Ecology and Architectural Ecology]

As discussed above, Ecology has been theorized by various Greek philosophers centuries ago, therefore term *ecology* is conceived from the Greek *oikos* (*fig 2*), which means "household" and *logos*, meaning "study" (Odum and Andrews, 1971). Thus, the study of the environmental house considers all living organisms in and around itself, as well as all their functional processes that make the "house" inhabitable. Odum and Andrews (1971: 2) suggest that ecology is literally the study of "life at home", with an emphasis on "patterns and organization of relations between living organisms and their environment" (*fig 3*). Considering the early development of ecology, the term had only been coined more recently, by German biologist Ernst Haeckel (1869). He defined ecology as "*the study of the natural environment including the relations of organisms to one another and to their surroundings*" (Haeckel 1869).

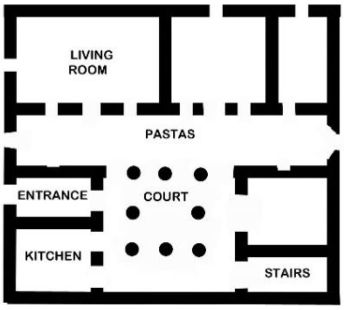


Figure 2: illustrating diagrammatic and spatial layout of a Greek Oikos from which "ecology" is conceived, (online). 2018.

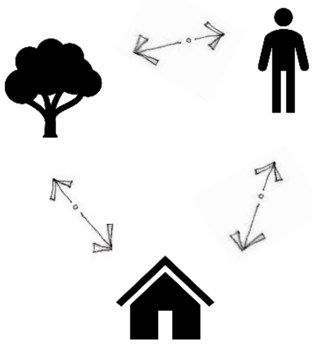


Figure 3: diagram illustrating relationships between man, nature and the built – environment that had be conceived through the ideologies of "ecology". 2018, By Author.

Within the paradigm of the 21st century, it can then be assumed that ecology has been impacted on by man and the built environment, thus leading the research to explore "ecology in architecture". This refers to the overlapping processes of buildings and natural environments. Buildings assimilate materials, resources and energy from their host environments (Gu and Evans, 2010), and often exude waste. However, throughout the late 20th and early 21st centuries, architecture did not support their host environments, as they were driven by industrial - economic and global factors (Rapoport, 2006).

This shift in thinking left ecosystems in a derelict state and required a call for a new ideology towards the symbiosis of ecology, biodiversity and architecture. According to Gu and Evans (2010), ecological architecture can be conceived based on *evolutionary thermodynamics*. This refers to ecological interactions between the built environment and natural "host" environment that actively engages with the end - user and their social and cultural norms towards a sustainable symbiosis, maximizing resource distribution according to the maximum entropy principle. The research chose to employ the concept provided by Gu and Evans (2010) as their framework is based on similar issues faced within this dissertation – which refers to rapid industrial development resulting in environmental depletion.

This theoretical framework proclaims that the built environment is to seek motivation from the living "systems" of nature, whereby an architecture should not be treated as a mere object, but rather a process that can adapt to change. As discussed above, to understand the process of ecological architecture, Gu and Evans (2010: 57) provide three principles of ecology that contribute to an evolutionary thermodynamic system. These principles refer to *Natural Ecology*, *Human Ecology* and *Architectural Ecology (fig 4)*.

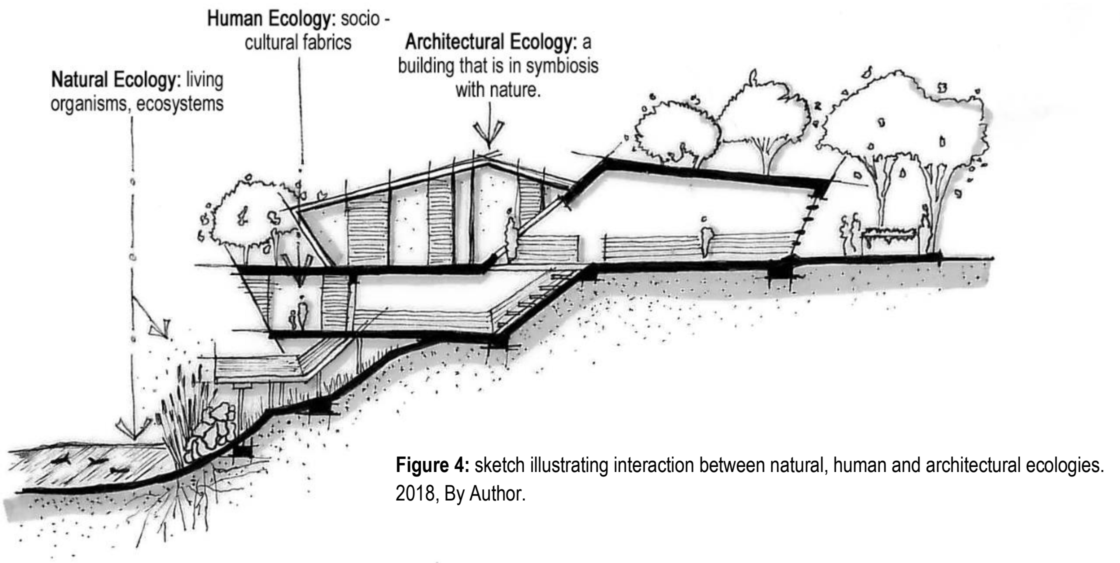


Figure 4: sketch illustrating interaction between natural, human and architectural ecologies. 2018, By Author.

Natural Ecology refers to all living organisms that are affiliated within a specific site, context or landscape. Gu and Evans (2010: 49), suggest that this attribute provides the platform for natural ecologies to manifest, resulting in the term - "host environment". Furthermore, the host environment provides multiple opportunities that may add complexity to a landscape, such as resources, materials, energy and cultural or traditional ties. Later within this chapter the principle of Natural Ecology will be unpacked through The Theory of Ecology, thus influencing – "*nature as a system in architecture*".

Considering that natural ecology provides a platform for life, man tends to cling to these environments, where he can survive. Therefore, *Human Ecology* refers to man as a "participant" within the natural world. Gu and Evans (2010: 49), refer to man as the "end – user", who seeks more than just survival but cultural, traditional, socio – economic and recreational engagements with natural ecologies to secure his place on Earth. Further justification can be explored through Bubolz and Sontag (2009: 419) who suggest that the principle of Human Ecology is a unique concept that considers humans as both a biological organism and a social being who interact with their environments. Human Ecology will later be investigated through Place Theory, thus influencing – "*man as a parasite within the biosphere*".

Once man has claimed his place within the natural landscape, he finds himself seeking shelter, privacy and "escape". *Architectural Ecology* then refers to the design or arrangement of the built environment that must be in equilibrium with nature, in conjunction with the needs of man. Gu and Evans (2010: 49) state that architecture should behave like a living mechanism, whilst adopting resources from the "host environment", with little to no waste, thereby accommodating for local and global communities to ensure a sustainable symbiosis (*fig 5*). Furthermore, "*through the medium of architecture, as a man – made intervention into nature, an ecologically positive relationship of man and nature can be achieved*" (Gu and Evans, 2010: 57). Architectural Ecology will later be explored through the concept of Industrial Ecology, which enables the research to develop ideologies towards an architectural response for the uMngeni River's estuarine ecosystems. Lastly, this exploration will provide an insight to – "*architecture as a system in nature*".

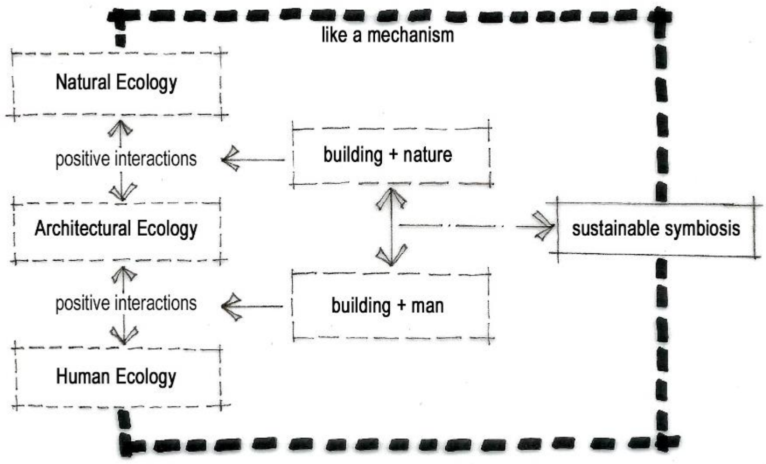


Figure 5: diagram illustrating the processes of natural, human and architectural ecologies towards a symbiosis. 2018, By Author.

2.3 THE THEORY OF ECOLOGY: [Natural Ecology]

The Theory of Ecology derives from the arrangement, distribution and abundance of all organisms within an ecosystem, including causes and consequences (Scheiner and Willig, 2008: 23). The theoretical framework consists of a domain that serves as a platform with which principles may be affiliated. Authors, Scheiner and Willig (2008) suggest that there are seven principles that influence the ecology theory.

With influences from Darwin's (1859) Evolutionary Theory, the first principle refers to the heterogeneity of organisms and the manner in which they are distributed in space, suggesting that there is an abundance of species that are heterogeneous in nature at almost every spatial scale. This distribution means that there is a chance for other ecological processes.

The second principle refers to the interaction between organisms. Influenced by the first principle, it considers the interaction between various ecological processes that create a richness of diverse heterogeneous organisms that occur in time and space.

The third principle is "contingency" which refers to the possibilities of future events or circumstances that one cannot predict in confidence. However, this principle puts emphasis on the importance of contingency, as it is the cause of heterogeneous distributions of organisms - an example being; a seed landing on a specific fertile spot and not on another.

The fourth principle considers the heterogeneity of the natural environment that is a direct consequence of the processes of planet Earth and space. It investigates the orbital properties of the Earth, where geophysical processes create heterogeneity within environments, resulting it variations of temperature, atmospheric pressure and seasonal change.

The fifth principle refers to heterogeneity of resources, which is a culmination of the domains of planet Earth and space sciences. These resources are influenced by heterogeneous environments that they thrive within, however, unlike an environmental condition, resources are prone to competition or condition. Scheiner and Willig (2008: 28) further justify this ideology by arguing that geophysical processes of the Earth determine the competitiveness of a resource, for example: water – which is subjected to competition (by plants within a desert environment), and condition (by fish within an estuarine environment). These distinctions within the natural environment result in different ecological outcomes.

The sixth principle refers to the "mortality" of all living organisms. It suggests that all organisms within an ecological system are prone to death or deterioration over time. As the third principle suggests, this phenomenon cannot be predicted with accuracy.

The seventh principle refers to the evolution of ecological properties, again influenced by Darwin's (1859) Evolutionary Theory that encompasses the above attributes towards the Ecology Theory. This principle focuses on merging the ideologies of ecological processes and evolution (Collins, 1986; Mitman, 1992).

Moreover, the process discussed above may seek inspiration from Heidegger's Deep Ecology theory (Zimmerman, 1993) where, the "deep ecological" concept suggests that religious and philosophical ideologies privileged man when compared to the proletarian works of nature (*fig 6*). In order for sustainability to be achieved, the understanding of man and nature must be one that is non-anthropocentric and non-dualistic. This non-dualistic ethical change must allow man to appreciate various life forms, rather than treating them as interchangeable raw materials (*fig 7*) (Zimmerman, 1993: 200), which begins to elucidate the "awareness" component with this research.

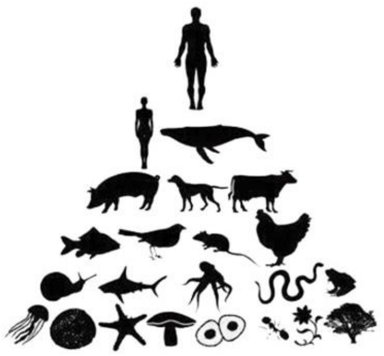


Figure 6: image illustrating the "privileged" ideologies of man, whilst other life forms fall beneath him as mere resources, (online). 2018.

Figure 7: image illustrating man as a non – dualistic entity that is in equilibrium with other life forms, (online). 2018.

Linking this theoretical framework to the built environment and the state of the uMngeni River, suggests that architecture is to consider the richness of organisms that exist within ecosystems in all their spatial scales. Furthermore, an architecture must acknowledge the fact that ecological processes need to interact in order to thrive or evolve, therefore, it cannot create a fragmentation between these processes – rather, it should facilitate or improve on it. The theory also gives insight to architectural design solutions that must be flexible and resilient in nature, whilst having the capacity to deal with stressors or impacts. As mentioned above, the Earth and its geophysical processes must be understood in order for an architecture to respond to its natural environment. In addition, the natural environment provides an abundance of heterogeneous resources and energy which architecture should seek to consume whilst giving back to local ecosystems. Moreover, architecture should respond to people, and their evolving cultural and traditional norms that are often affiliated within natural heterogeneous landscapes.

Within the paradigm of the Theory of Ecology, one may assume that the built environment should consider a "heterogeneous architecture". Lastly, this theoretical unpacking of Natural Ecology will influence literature explored within – "*nature as a system in architecture*".

2.3 PLACE THEORY: [Human Ecology]

Justification for exploring Place Theory through understanding the principle of Human Ecology; "place" suggests that there is a bond between the end - user and the space – which then reinforces the motivation behind this dissertation, as the uMngeni River and surrounding precinct holds personal significance. This investigation seeks to inform the literature to be explored within - "*man as a parasite within the biosphere*", which holds socio – economic and cultural connections towards man within the natural landscape. By further understanding these attributes that influence Human Ecology, an architecture may use these properties to achieve a symbiotic design with nature.

Place thus refers to the relationship between man and his physical setting. Oppose to space, place is defined by a setting that is encompassed with values and meaning by the end – user (Najafi and Shariff, 2011). Furthermore, studies carried out by Najafi and Shariff (2011: 1054) suggests that deep connections between people and their physical environment often influence their behavior and well-being. In most cases, place holds messages and meaning that are decoded and perceived by people based on their experiences, activities, memory and traditional norms (Rapoport, 1990). However, this concept changes with contemporary global growth, where homogeneous landscapes convey little to no meaning, subsequently resulting in man suffering from "placelessness". Rapoport (2006: 123) argues that the conflicting notion between heterogeneous and homogenous landscapes is the inevitable outcome of global – industrial growth (*fig 8*), where heterogeneous refers to a "local" landscape and homogeneous refers to a "global" landscape. This suggests that *local* can be conceptualized as *traditional*, with emphasis on traditional family and social structures, as well as lifestyles and belief systems, resulting in place being arranged in relation to these attributes. Therefore, *global* can then be conceived as *modern*, which is often primarily affiliated with commerce and trade, as well as the reliance on technology, transport, social media and television. Rapoport (2006) suggests that, the reliance on global products,

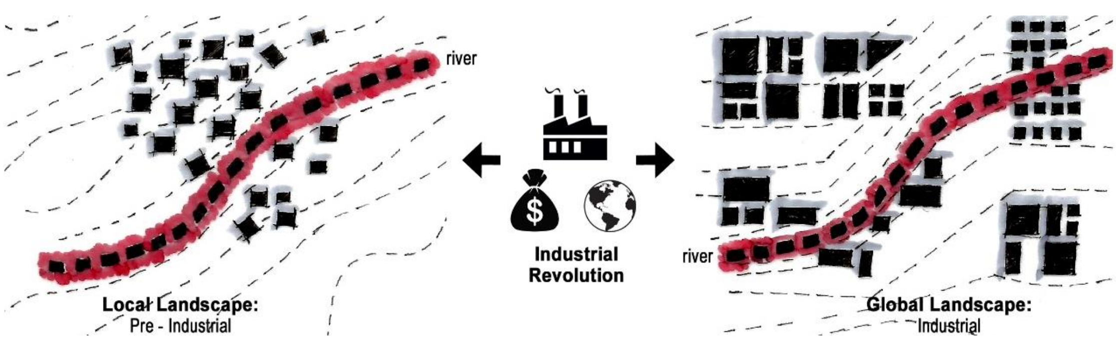


Figure 8: diagram illustrating local vs global landscapes. It is to illustrate the organic growth of a local landscape that respects nature, where as a global landscape is fragmented by city, residential and industrial zoning, whilst harshly shaping the landscape to suit their needs. 2018, By Author.

services and processes often create places that are similar, thus establishing a homogeneous landscape. Therefore, *placelessness* refers to a setting with no personality affiliated to it (Relph, 1976).
Further justification of place can be defined by Norberg-Schulz (1985), who argues that place is a physical environment that has character. He further suggests that the change of space into place is the fundamental purpose of architecture. For place to be achieved, it must consider emotional ties with the physical environment through semiological symbols and meaning and be influenced by the phenomenological concept of "spirit of place" (genius loci). Much like the processes discussed in Natural Ecology, the structure of place, resembles a similar process; where place is not a fixed condition, but instead is defined and redefined by evolutionary shifts within society. Therefore, every place is perceived differently by man (Najafi and Shariff, 2011).

As discussed above, place plays a significant role in architecture, linking this to issues experienced within the area of the uMngeni River. One can then assume that the estuarine body of water has little to no "place" affiliated with it. Firstly, the river and the immediate context suffer from rapid industrial globalization thus creating a *global homogeneous* context – which suggests that the precinct experiences placelessness. This is a fundamental issue regarding perception discussed within Deep Ecology, illustrating the lack of quality and care towards the river itself. However, in order for an architecture to achieve place, it must not only consider the principle of Natural Ecology, but the cultural, social and meaningful ties that influences Human Ecology.

2.4 INDUSTRIAL ECOLOGY: [Architectural Ecology]

By unpacking the principles of Natural Ecology and Human Ecology towards achieving Architectural Ecology through the relevant analytical theories above, one may now generate the ideology of an ecological architecture. However, should the theoretical framework begin to contextualize the research problem, it finds itself seeking influences from *Industrial Ecology*. Therefore, Industrial Ecology will influence the principle of Architectural Ecology and serve as an overarching concept within this dissertation.

This concept deals with the consequences of industrial processes as a result of human activity, therefore, justification for this exploration comes as a direct consequence of the existing industrial zones that impact on the derelict state of the uMngeni River and its ecosystems. Thus, influencing the literature reviewed within – "*the nature of industrialism*" and "*architecture as a system in nature*".

Industrial Ecology investigates the relationship between human actions and the natural environment, with a focus on mans' reliance on the industrial world. Considered a contradictory term, an oxymoron for the most part, due to society's perception of industrial systems separate from the biosphere, where one would find cities and factories on one side, and nature on the other (Erkman, 1997). Industrial Ecology explores the opposite assumption: industrial systems may be considered a type of ecosystem. It is a concept within which an "industrial system" is not viewed in isolation from its surrounding systems but rather, in equilibrium with them (Jelinski, Graedel, Laudise, McCall and Patel, 1992).

According to Ehrenfeld and Gertler (1997), with economic influences, industrial systems behave like an "open system", drawing in raw materials from the natural environment and returning large amounts of underutilized by – products in forms of waste and pollution.

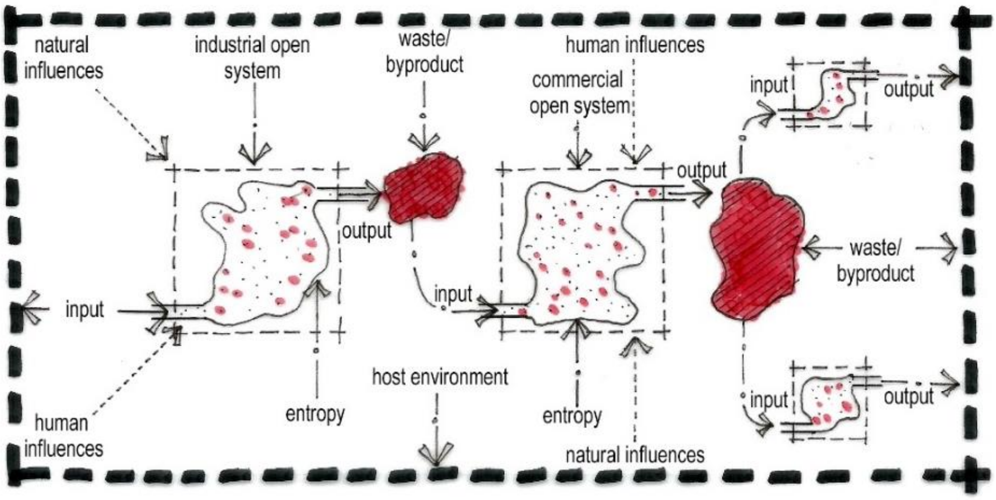


Figure 9: diagram illustrating processes of industrial ecological system that gains input from the host environment for its processes and emitting waste to which another system may use for its own inputs – whilst the system carries on, essentially minimizing "waste". 2018, By Author.

Therefore, the concept suggests that design principles are to consider avoidance of upsets to the natural ecosystems, closing of material loops and to be thermodynamically efficient. Industrial Ecology goes further, through the concept of Systems Theory, where an industrial system must be isolated, unpacked to understand the ways in which it functions and its relationship with the biosphere. Thereafter, based on the understanding of the Natural Ecologies, reconfigure the design to ensure that it is compatible with existing ecosystems (Erkman, 1997).

Industrial Ecology considers ways in which Architectural Ecologies (industrial system) are to behave within Natural Ecologies that encompass activities based on Human Ecologies. Thus, aligning the concept towards the research, it gives insight into architectural design ideologies, as well as provides a systematic approach of dealing with forms of waste and pollution within uMngeni River. Lastly, Industrial Ecology informs the architectural response towards the concept of an "open system" in which an architecture must absorb resources from the “host environment” for its activities and processes, whilst exuding waste that becomes a resource for other life forms (*fig 9*) (Jelinski, Graedel, Laudise, McCall and Patel, 1992).

2.5 CONCLUSION

Chapter Two has instated the theoretical framework for this research in order to achieve ecological architecture through the principles of Natural Ecology, Human Ecology and Architectural Ecology. This investigation informed the built environment towards a homogenous architecture that is resilient in nature, whilst conserving the ecosystems in all spatial scales. Additionally, an ecological architecture must recognize the deep ecological meaning that natural landscapes offer to man, his culture and experiences through the creation of place. The architectural component itself should not be treated as a fixed condition, but rather an array of interrelated processes and systems that work to achieve a successful “whole”. Thus, in order for an ecological architecture to be conceived, it must contextualize itself towards integrating with its host environment ensuring an abundance of resources, material and energy, and emitting waste that is useful for other living entities.

Chapter Three will follow with supportive literature that is to align itself with the above theoretical framework, as well as providing a means for answering the research questions stated in Chapter One. As mentioned above, Industrial Ecology will serve as an overarching concept to which it will investigate – “*the nature of industrialism*”, unpacking the rethinking of the Next Industrial Revolution.

Human Ecology through Place Theory follows, where it will investigate – “*man as a parasite within the biosphere*”, understanding man’s relationship with the biosphere before, during and after the Industrial Revolution.

Thereafter, Architectural Ecology through Industrial Ecology investigates – “*architecture as a system in nature*”, where the research shall critique eco – efficient systems that architecture may utilize in achieving an equilibrium within its host environment.

Natural Ecology through the Theory of Ecology then sums up the literature review where it investigates – “*nature as a system in architecture*”, in which the research unpacks eco – effective systems in nature that could influence the architectural process towards environmental conservation in an industrial landscape.

CHAPTER THREE: UNPACKING EXISTING LITERATURE

3.1 INTRODUCTION

The many intentions of the Industrial Revolution were for the most part good: bringing goods and services to large parts of society, providing them greater choice and opportunity, essentially raising the standard of living throughout the world (McDonough and Braungart, 1998). However, with crucial consequences. The result; ecologically stressed ecosystems and vital rivers, forests, oceans, soil, air and animals that were not part of the agenda, thus, making it evident that human - industrial activities are beginning to inundate the biosphere's energies and resources.

The following chapter will question and unpack existing knowledge that is to inform ecological architecture towards an industrial symbiosis within the uMngeni precinct. Therefore, this study aims at uncovering man as a non – dualistic end – user within an industrial landscape and an architecture's ability to seek inspiration from ecological processes that shall foster the cohesive interrelations between Natural Ecology, Human Ecology and Architectural Ecology through the theoretical framework explored above.

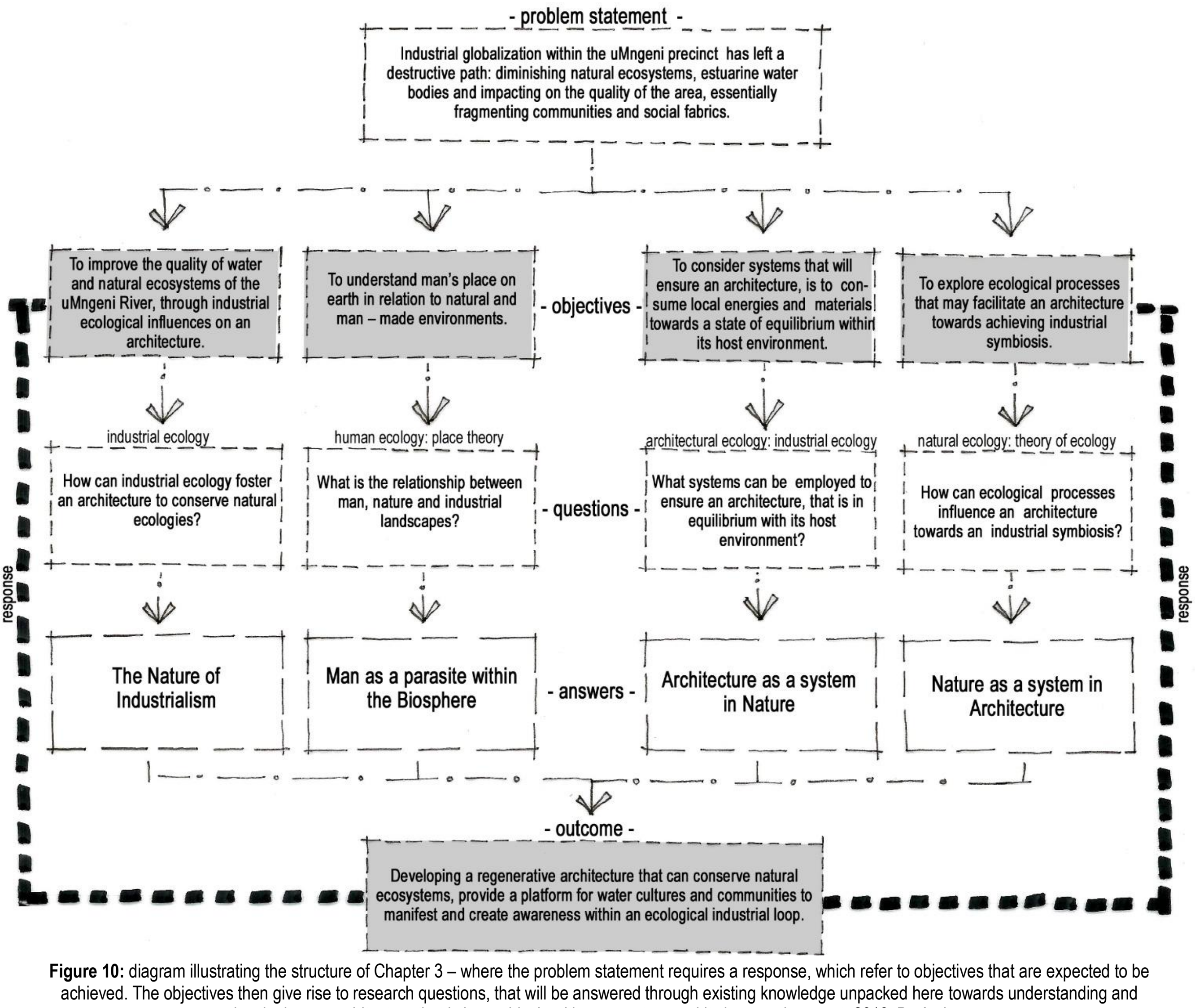


Figure 10: diagram illustrating the structure of Chapter 3 – where the problem statement requires a response, which refer to objectives that are expected to be achieved. The objectives then give rise to research questions, that will be answered through existing knowledge unpacked here towards understanding and developing an architecture that is in symbiosis with man, nature and its host environment. 2018, By Author.

> *"Imagine, for example, buildings that make oxygen, sequester carbon, fix nitrogen, distill water, provide habitat for thousands of species, accrue solar energy as fuel, build soil, create microclimate, change with the seasons, and are beautiful."* (McDonough and Braungart, 2003:14)

3.2 THE NATURE OF INDUSTRIALISM

This section of literature review investigates the "nature" of industry and its impacts upon natural and human ecologies. The aim of this study is to understand how the rethinking of the current Industrial Revolution may facilitate an architecture towards conserving natural ecosystems.

3.2.1 The next industrial revolution

During the Spring of 1912, the world saw one of the largest man – made objects disembark on a journey from Southampton towards New York. The 66,000 tons embodied the industrial age, portraying mankind's progression towards new technologies, luxury and prosperity (McDonough and Braungart, 1998). The *Titanic* – a brutal steel structure powered by chemicals, nuclear reactors and fossil fuels, pouring waste into the ocean and smoke into the atmosphere. It was mankind's attempt to work by his own rules as opposed to that of the natural world.

During the Industrial Revolution, man viewed resources as boundless and the natural world had been perceived as something that had to be tamed and subjugated (McDonough and Braungart, 1998). Blinder (2006) states that the world is currently within the state of its 3rd Industrial Revolution – *The Age of Information.* However, recently industrialists realized that conventional industrial processes and activities will not maintain a long-term sustainable society, therefore a change of thinking had to be considered, thus The *Next* Industrial Revolution.

According to McDonough and Braungart (1998), during the 1992 Earth Summit in Rio de Janeiro, 30 000 people from around the globe recognized the limits of the Earth's resources and energy. This included world leaders from 167 countries and various professionals within the relative fields that had responded to industrial - environmental destruction. To the disappointment of the Summit, no legal agreement had been instated, however, many participants had endorsed a specific new strategy: *[eco] – efficiency* (McDonough and Braungart, 1998).

3.2.2 A change of thinking: "cradle to the grave" to "cradle to cradle"

Aligned with Industrial Ecology discussed in Chapter Two, this change of ideology is a direct consequence of the "*Next Industrial Revolution*". McDonough and Braungart (1998) argue that, eco – efficiency has become the "buzzword" for modern industry, where machinery would adopt faster and cleaner engines, with the hope that eco – efficiency would transform industry from a system that extracts, produces and exudes, into something that considers environmental, economic and ethical impacts. Eco – efficiency, therefore, refers to "*doing more with less*". The term had originally been articulated within a published report in 1987 by the United Nations' World Commission on Environment and Development, warning that industries are to be more efficient with regards to the use of resources, whilst creating less waste and pollution, minimizing impacts on human health and conserving the environment (McDonough and Braungart, 1998). By the mid-to late-1990's, eco – efficiency had infiltrated most large-scale industrial companies, assisting in the reduction of resource and energy consumption, the omitting of waste and pollution and realizing substantial savings through these processes.

When one hears that an eco – efficient industrial system has minimized its airborne cancer – causing emission by 75%, one may automatically feel a lot more secure. This highlights another key attribute of, eco – efficiency: where it decreases fear or guilt. McDonough and Braungart (1998) state that eco – efficiency is a well – intended concept, however it does not offer long term sustenance. Within the field of the built environment, industry forms part of architecture. Therefore, eco – efficiency within this paradigm considers "passive design" techniques in an architectural design, and its ability to cause less damage to the environment. Or does it?

Evidently, eco – efficiency is an admirable notion that has played a significant role in reducing ecological destruction within the late 20th century, but minimizing the energy used by an eco – efficient building or exuding less waste or building material to landfills, does not deal with the existing pitfalls of modern architecture and industry (McDonough and Braungart, 2003). Consider contemporary eco – efficient industrial processes that aspire to reuse, reduce and recycle; many of which refer to "downcycling", as the initial material is reused over time to produce something cheaper, for example – transforming plastics into lower - quality hybrid materials for speed bumps or park benches. Consequently, the original high - quality material is then "lost" and discharged into landfills, thus describing a linear, one way "*cradle to the grave*" ideology. McDonough and Braungart (1998) argue that eco – efficiency then serves as an illusion of change as it does the opposite for the environment and its ecosystems, because it allows industrial systems to destroy nature quietly, persistently and completely.

Nature on the other hand, is highly assiduous, immensely creative and productive, in some cases even "wasteful" – nature's industry is then, not efficient but *effective*.

Consider the cherry tree: this natural ecological entity produces thousands of blossoms only to give life to another. Its abundance is still useful and safe. After the blossoms fall to the ground, they return to the earth and become a source of nutrients for other life forms, thus contributing to flourishing ecosystems (McDonough and Braungart, 1998). This refers to one of the fundamental principles of the Next Industrial

Revolution – *Waste Equals Food*. The cherry tree then serves as a mere representation of nature's industry that functions according to life cycles based on metabolisms and nutrients (*fig 11*). This cyclical process receives much of its energy from the sun and has the ability to adapt to various local situations. McDonough and Braungart (1998) suggest that within this natural ecological process, waste that remains waste, does not exist.

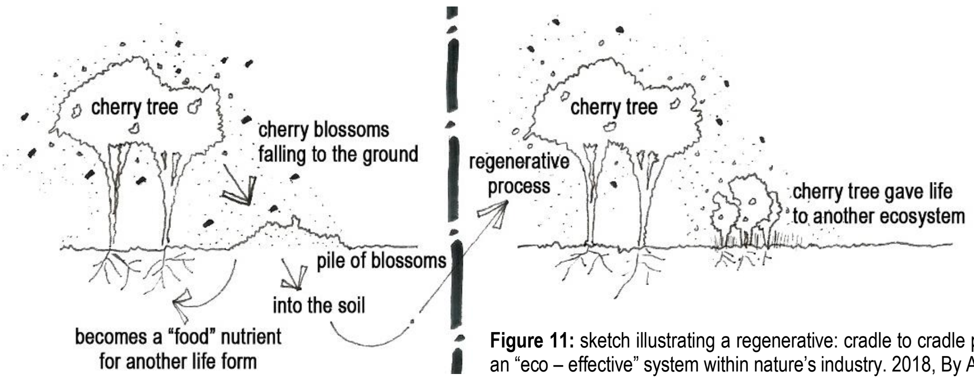


Figure 11: sketch illustrating a regenerative: cradle to cradle process of an "eco – effective" system within nature's industry. 2018, By Author.

Contrary to this, human industrial waste cannot be regarded as "food", as in most cases, it is toxic. Thus, consider two different industrial systems: a load of poisonous junk and a heap of cherry blossoms. According to McDonough and Braungart (1998), there is an *effective* alternative that will foster both nature and business towards something that is abundant and productive. This refers to "*[eco] – effectiveness".* The concept of eco – effectiveness can be defined by Industrial Ecology explored above, where human industrial activities and processes are to be regenerative as opposed to depletive, which proposes a "*cradle to cradle"* cycle of life (*fig 12)*. Thus, influencing the evolutionary processes of architecture, where it may adopt an eco – effective, cradle to cradle ideology towards its symbiosis within its natural host environment.

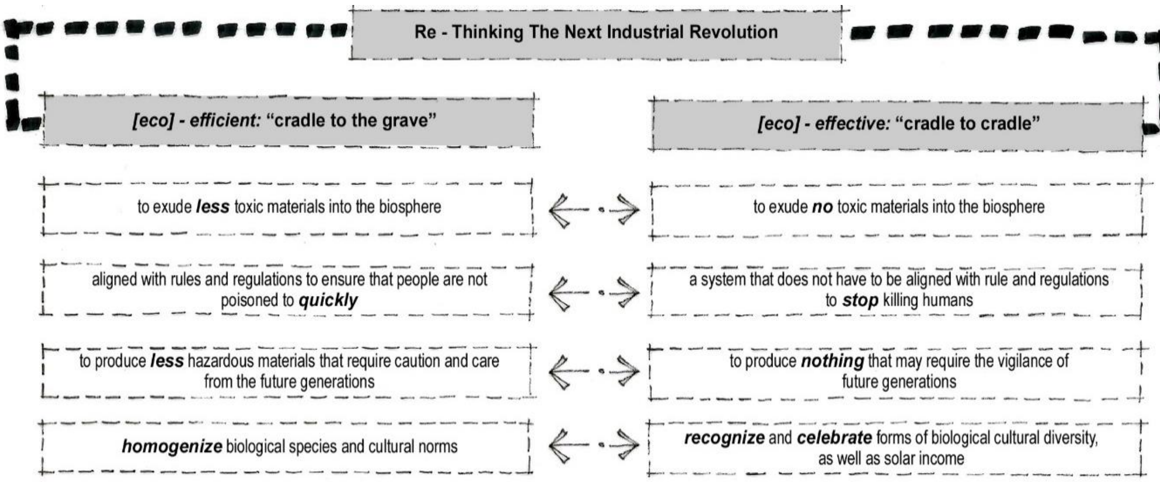


Figure 12: illustrating a comparative analysis between [eco] – efficiency and [eco] – effectiveness that demonstrates the rethinking of the Next Industrial Revolution. 2018, By Author.

3.2.3 Material metabolism

By understanding the eco – effective, cradle to cradle concept discussed above, architects and designer are to realize that materials can be conceived as nutrients that flow in nature or can be arranged to create a thriving *metabolism*. Material metabolism then refers to a material's life – cycle (McDonough and Braungart, 2003). Moreover, within an industrial process, a material's life – cycle can be defined by "*material flow*", to which it analyzes the amount of energy it takes to give "life" to a material, as well as the energy and resources to "kill" or "regenerate" one. Therefore, by aligning material metabolism with that of eco – effectiveness, it suggests that a "*material flow*" then becomes a closed loop - cycle of birth, growth and decay. As discussed above, the Next Industrial Revolution considers the principle of "waste equals food", thus forming a vital part of this research as industrial human waste is a formidable contributor to the state of the uMngeni River and its context.

3.2.3.1 Waste equals food: biological and technical nutrients

Early nomadic civilizations were known for leaving behind organic waste, restoring nutrients within soil and contributing to the immediate environment. Modern society, however, tend to dispose of waste as quick as possible (McDonough and Braungart, 1998). This process means that the organic potential found within human waste is lost and cannot contribute to thriving ecosystems or the soil. Often, the waste includes chemical and synthetic materials that put further strain on the environment as they cannot be absorbed.

Aligned with the ideologies of eco – effectiveness and material metabolisms, McDonough and Braungart (1998) stipulate that in order for mankind to thrive within a world influenced by nature, all industrial products, processes and materials must provide a source of nourishment after each life – cycle. Considering the outcome of modern processes, most of the products and materials are not natural, therefore anything produced that is not biodegradable should be conceived as a *technical nutrient*, that flows within a continuous cycle – creating a *technical metabolism,* for example: a circuit board that is continuously reused as a circuit board after every life cycle. Supportive to this, a *biological nutrient* is then, anything produced by industrial processes that can be returned to the soil as food for organisms and ecosystems, thus creating a *biological metabolism* (McDonough and Braungart, 1998). Bjørn and Strandesen (2011), argue that there should be great care taken to avoid the cross contamination between technical nutrients and biological nutrients. Such a contamination will result in a material that can never be upcycled, but simply downcycled to that of a lower value and quality.

3.2.4 Equity, economy and ecology

As discussed above, the change of thinking from an eco – efficient "cradle to the grave" approach to an eco – effective "cradle to cradle" concept provides one with the understanding of design ideologies that can provide a platform to which man – made interventions may conserve ecosystems. Therefore, the Next Industrial Revolution provides effective intentions throughout a variety of human issues (McDonough and Braungart, 1998). Within the paradigm of sustainability, conservation and revitalization, people have established three attributes that can address these concerns: *equity, economy* and *ecology.*

"Equity"; refers to *social justice*. This attribute seeks to understand whether a design may depreciate or enhance society and local communities. McDonough and Braungart (1998) provide an example: shoe factories overseas have been accused of exposing employees to hazardous chemicals that surpass the safety limits. Eco – efficiency within this scenario would then reduce the amounts of hazardous chemicals to meet specific health and safety standards where eco – effectiveness would not make use of toxic chemicals in the first instance. As a progressive species, what an achievement it would be for society, if no person had to work in inhumane conditions (McDonough and Braungart, 1998). Within the paradigm of architecture, eco – effectiveness begins to give insight to a design that can enrich human ecologies whilst causing no harm to a person's wellbeing.

"Economy"; refers to *market viability*. This investigates the "need" for a product, service, activity or process – with emphasis on the producer or designer and consumer or end - user. McDonough and Braungart (1998) suggest that design is to be intelligent and safe, whilst being affordable and accessible to large parts of society, thus ensuring a greater profit to the company or designer. This exchange is vital, as commerce is the fundamental catalyst for change within an industrial age (McDonough and Braungart, 1998). Considering architecture as a process, this attribute suggests that eco – effective architectural design is to consider the urgency for a building and its ability to improve on problems faced by man and nature. Furthermore, it must explore the richness of human ecologies of the immediate context, to which access and affordability plays a significant role in creating place, as well as a return for economic fabrics.

"Ecology"; refers to *nature* and the *environment*. This considers the impact of a product, service, activity or process upon the environment: are the materials of a technical nutrient or a biological nutrient? According McDonough and Braungart (1998) this attribute is the most important, as it questions any man – made intervention, that is to be aligned with the principles of the Next Industrial Revolution:

- *Waste equals food* – the cradle to cradle cycle of material metabolisms explored above.
- *Respect diversity* – a design's ability to respect both natural and human diversity.
- *Use solar energy* – a design's ability to make use of the biosphere as a source of energy.

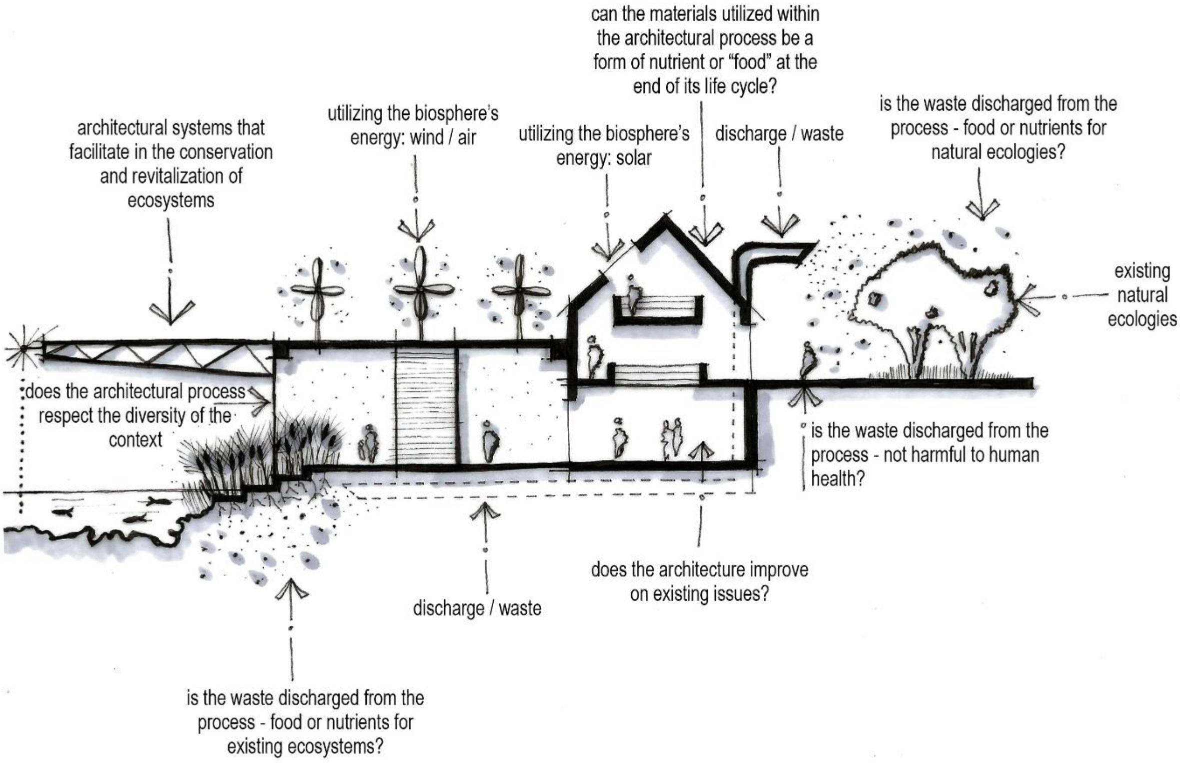


Figure 13: towards an industrial symbiosis: sketch illustrating the rethinking of the next industrial revolution through the concept of industrial ecology towards an architecture that has the ability to conserves the biosphere and the biological and social diversities that exist around it. 2018, By Author.

3.2.5 Towards an industrial symbiosis

This section of literature review unpacked the characteristics of industry and its impact upon the natural environment. This exploration has led the research to consider the rethinking of eco – efficiency to eco – effectiveness within industrial systems and processes, however; this does not undermine the ideologies of eco – efficiency. Braungart, McDonough and Bollinger (2007) suggest that effectiveness and efficiency are complementary concepts, where efficiency refers to "doing things the right way" and effectiveness then refers to "doing the right things". By integrating the rethinking of the Next Industrial Revolution towards the issues experienced within the uMngeni precinct – it provides a platform for architecture (*fig 13*) within an industrial landscape to conserve ecosystems (*through waste equals food, respect diversity and use solar energy*) towards an industrial symbiosis. Furthermore, where eco – efficiency regards industry as bad, eco – effectiveness provides a vision for industry that is good, which serves as a support system for ecological processes and provides socio – economic cohesion. Braungart, McDonough and Bollinger (2007) state that this serves as a tool that can be utilized within industrial systems, in order to achieve environmental awareness and the motivation to lessen ecological destruction, thus further supporting the research towards achieving an architecture that intends to create "ecological awareness". The research will now explore man's relationship with nature and architecture within an industrial paradigm.

"Architecture, with all its varying phases and complex developments, must have had a simple origin in the primitive efforts of mankind to provide protection against inclement weather, wild beasts and human enemies." (Fletcher, 1924:1)

3.3 MAN AS A PARASITE WITHIN THE BIOSPHERE

This section of literature review investigates man as a non – dualistic entity that coexists in equilibrium with other living organisms within the biosphere. Moreover, the study is to investigate man as an end – user of space (Gu and Evans, 2010) through the principle of Human Ecology and Place Theory, where the research shall critique man's relationship with the natural environment through his architecture and the condition of his livelihood. Thus, this exploration deems to be vital to inform an ecological architecture that conserves not only ecological, but socio – cultural diversity within an industrial landscape.

3.3.1 Pre – industrial society

To fully understand man and his social, cultural and economic conditions and his relationship with natural ecologies, the research must dwell deeper to unpack life before the rise of industry. As proclaimed earlier, McDonough and Braungart (1998) stated that early nomadic societies were known for their movement patterns within the natural landscapes. This suggests that these societies were highly dependent on nature and achieved exceptional knowledge of their natural environments (Commoner, 2014).

Figure 14: illustrating a common day of the life within a pre – industrial society, where the main occupation of the time referred to agriculture, farming and the extraction of raw material from the natural environment, (online). 2018.

Much like the early nomadic people, pre – industrial societies possessed a relatively substantial understanding of their environment and continuously changing ecosystems, thus until the Industrial Revolution, the main occupation came from those affiliated with agriculture, mining, fishing and forestry, as illustrated in figure (*14*) (Bell, 1976). These novelties seem to be in equilibrium with common ideologies of the time – where, what pre – industrial man does to the biosphere is relative to his relationship to things around him (White, 1967). Therefore, the idea of Human Ecology is deeply governed by beliefs of the natural world – that is, by religion. It is not within this research that it shall critique the religious and cultural thinking's of pre – industrial society, but it is to understand the impacts on the natural world. According to White (1967: 52), God had designed nature explicitly for the exploitation by man to fulfill his needs, as he is not a part of nature, but rather he had been created in the image of the divine. Therefore, this allowed pre – industrial societies to “conquer” natural ecologies and claim these landscapes as their own, thus, no two pre – industrial landscapes are similar. This begins to give insight to understanding Human Ecology through Place Theory, where various groupings of people would begin to develop and shape their natural environments according to their needs, more so, to develop their “place” within the biosphere through the alignment of cultural, religious and semiological influences (Relph, 1976).

These natural environments conceived by pre – industrial man could then be referred to as “local” environments which support the traditional arrangements of time, space, communication and meaning (Rapoport, 2006: 123). Therefore, physical features such as rivers, streams, mountains and dense greenery become a common ground for pre – industrial inhabitance. As figure (*15*) illustrates, the inhabitance of the Ganges River, where people shaped the natural ecosystem in accordance with their demands, beliefs and socio – economic activities.

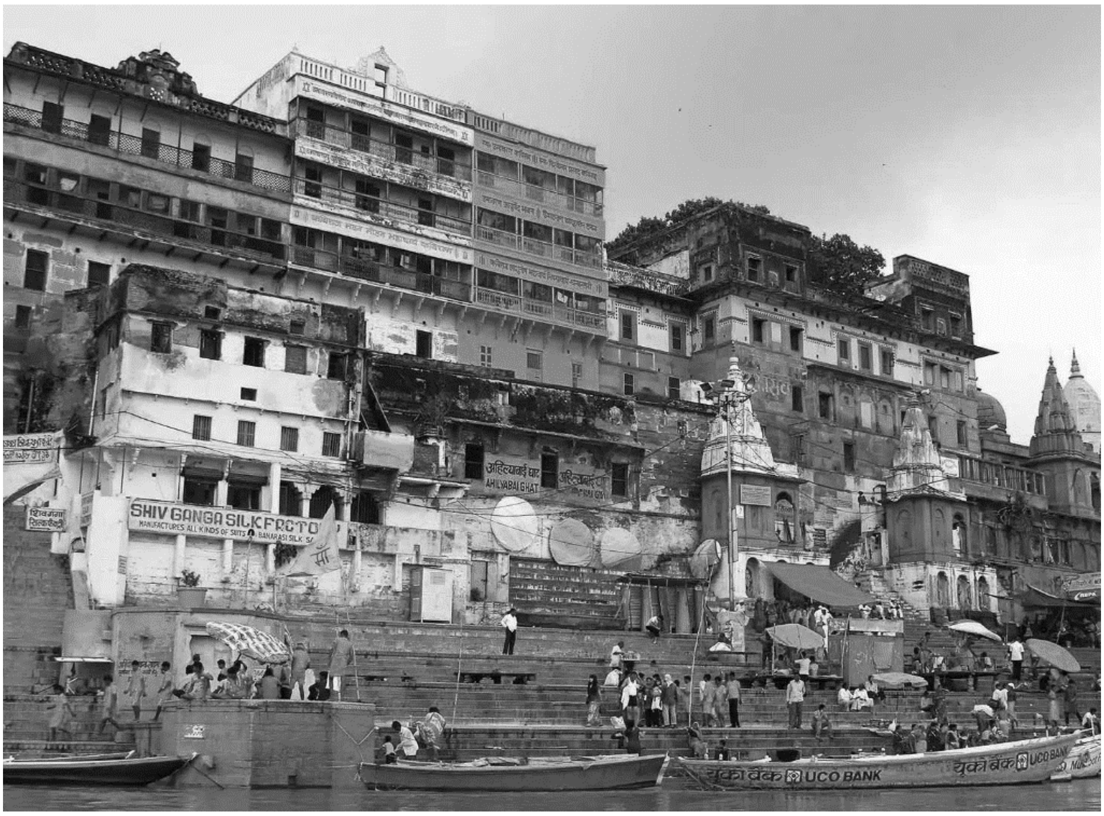


Figure 15: illustrating the River Ganges, also known as “Ganga” that flows through India and Bangladesh. It is to illustrate the inhabitance of this Natural Ecosystem, to which it is affiliated with Place – culture, tradition, meaning and social – economic activities, (online). 2018.

Figure 16: illustrating external view typical Danish House. Vestergaard (image). 2014. Preindustrial versus postindustrial architecture and building techniques. Vernacular Architecture, pp.747-752.

Figure (*16*), gives insight to the larger family structures established by pre – industrial societies, where the size of their dwellings was of a substantial size and form, as most of the daily activities were in close proximity to the household (Vestergaard, 2014).

Vestergaard (2014) stipulates that households within a pre – industrial community, is of an eco – effective architecture, whereby an architecture is arranged through the principles of convenience, flexible functionality, sunlight and local resources, exuding little to no waste. Figure (*17*) below then illustrates the immense indoor and outdoor interface within a typical pre – industrial dwelling that supports those principles. Moreover, these dwellings have the ability to be dismantled with ease and returned to the soil safely, thus serving as a biological nutrient, essentially conserving ecosystems within the immediate context.

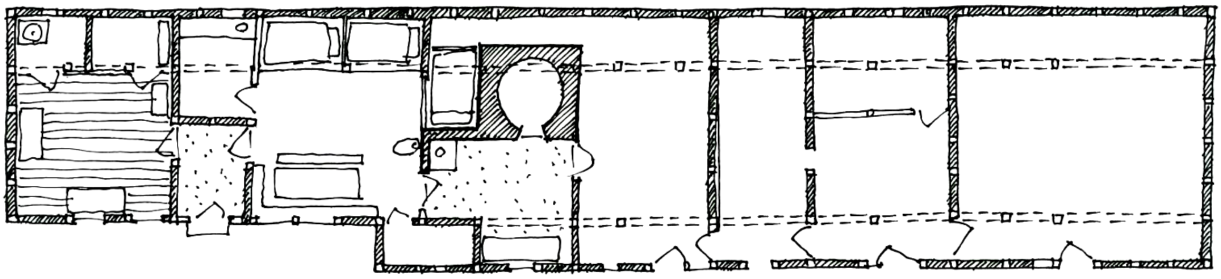


Figure 17: illustrating the plan of a typical Danish House during the mid – to – late 1700s. Vestergaard (image). 2014. Preindustrial versus postindustrial architecture and building techniques. Vernacular Architecture, pp.747-752.

The above discussion provides the research with an understanding of man's conditions within a pre – industrial society and his relationship with the natural environment despite shallow ecological thinking.

This demonstrates man's simplistic way of life that allowed him to utilize raw materials and renewable energy provided by the biosphere for his survival (Bell, 1976). As portrayed within his architecture, pre – industrial man unintentionally designed his structures and landscapes to that of an eco – effectiveness, which contributed to conserving his immediate environment and ecosystems that may have coexisted with him.

3.3.2 Industrial society

Pre – industrial society demonstrated man's agrarian connection with nature and architecture, as well as his vast knowledge of natural environments and ecosystems. Therefore, the research will now investigate man's social, cultural and economic conditions during the rise of industry in order to unpack the paradigm change between his relationship with the natural world. As mentioned within the previous subchapter, McDonough and Braungart (1998) stated that during the Industrial Revolution, man had viewed natural ecologies as something that had to be conquered, with the shallow ecological thinking of pre – industrial societies. This meant that newly industrial societies had then perceived nature as a source of inexhaustible energy, resources and fuel.

Figure 19: illustrating an American blast furnace during early 20th century alongside a riverbank with no regards for its ecosystems, (online). 2018.

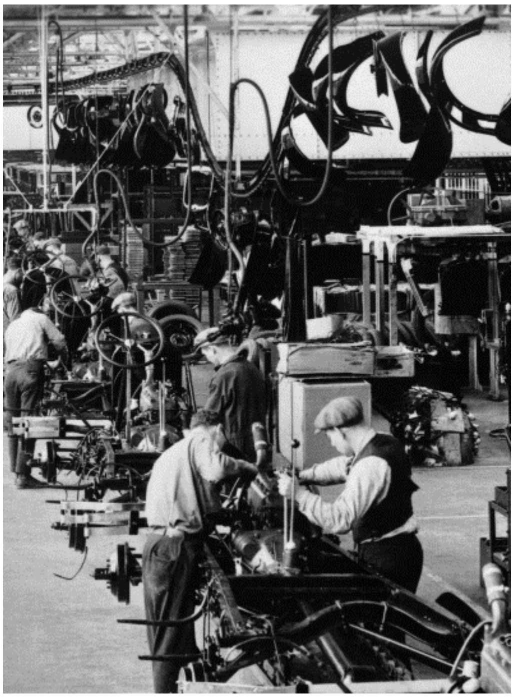


Figure 18: illustrating industrial man cocooned in a steel and a concrete environment, working up to 16 hours a day to achieve economic freedom with not a piece of greenery insight, (online). 2018.

According to Bell (1976: 46), the main occupation of industrial societies was based on the exploitation of the natural environment, creating their own energy – electricity, oil, nuclear power, chemicals and the utilization of fossil fuels (*fig 18*). This refers to the fundamental purpose of environmental depletion during the Industrial Revolution: Financial Capital. For industrial man, the aspirations of the industrial age were then positive ones, as they provided a higher standard of living, thus leading to rapid global development in all industrial society sectors, which a nation's economic performance had been measured by "quantitative growth" (Simonis, 1989). The new profound success of industrial societies suggest that man had slowly lost his connection with the natural environment, as he began to rely more on the machine as opposed to the processes of the natural world, depicted in figure (*19*).

Rapoport (2006: 123) proclaims that, global exchange of goods and services amongst industrial societies meant that things, including landscapes and architectures had the tendency to look alike. Investigating this through Human Ecology and Place Theory, one begins to foresee ways in which industry had created a fragmentation between industrial societies and their natural environments. This suggests that these societies suffer from placelessness, where economic enlightenment drove them away from cultural and traditional ties, that were often affiliated with natural ecologies. Moreover, as the natural landscapes began to take a similar shape due to the reliance on the car, parking lots and fuel stations (Rapoport, 2006), this inevitably impacted on the architectures within an industrial society.

Figure 20: illustrating an exterior view a typical "modern" Danish housing after the industrial revolution, Vestergaard (image). 2014. Preindustrial versus industrial architecture and building techniques. Vernacular Architecture, pp.747-752.

Industrial impacts then gave rise to a highly segregated way of life, known as the suburban house (*fig 21*), which encompassed a "nuclear family", where the family's daily activities were far away from the household. Moreover, dwellings of an industrial society are of an eco – efficient architecture, as they consider passive design techniques such as smaller building footprints (*fig 22*) and enhanced south facing windows (Vestergaard, 2014). However, they utilize high performing industrial components and regulated

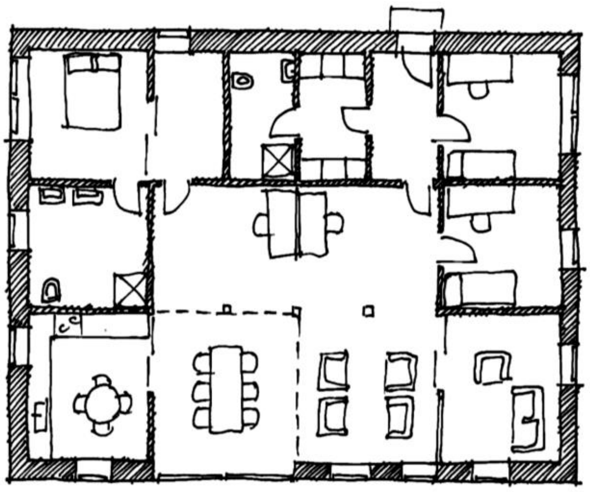


Figure 21: illustrating a plan view of a typical "modern" Danish housing after the industrial revolution, Vestergaard (image). 2014. Preindustrial versus industrial architecture and building techniques. Vernacular Architecture, pp.747-752.

indoor climate control, essentially placing the environment under greater stress.

The exploration above gives insight to the beginning of mass environmental destruction. This refers to industrial man's lack of place within the biosphere, where he is continuously driven by equity and commerce, and slowly loses his relationship with his natural environment, which is also evident through his homogeneous architectures and landscapes.

3.3.3 Post – industrial impacts: "the emergency"

This subchapter explores the overlapping consequences of pre – industrial and industrial society. Bell (1976) states that pre – industrial society had been governed by agriculture and raw materials, whereas industrial society had been framed by capitalism and mass production. Therefore, post – industrialism refers to the current state of industry: *The Age of Information and Knowledge*.

As discussed earlier, McDonough and Braungart (1998) stipulated that it was only until *The Age of Information and Knowledge* did industrialist recognized that traditional industrial processes and activities were leaving a destructive path, minimizing the environment's lifespan annually. Within this section shall the research mention the environmental crisis caused by decades of industry. As industry is not the lone source of the issue, it is man's actions, activities, processes and thinking. According to White (1967), it is a matter of great difficulty to pin point exactly where, when and to what impacts human induced change came, however, towards the end of the 20th century ecological backlash was prominent.

Many global forces believe that the destruction of natural ecologies by humans are part of a paradigm shift towards our evolution. In response to this statement, as well as the research question, Commoner (2014) states that Human Ecologies are biological entities that will return to the soil when life is lost, therefore we are a part of the natural world. Societies who call themselves "advanced" have escaped from their dependence on the natural world; where a Bushman seeks water from tubers, modern man gets his water by the turn of a tap. Instead of utilizing solar gain when it is required, and avoiding it when it is overwhelming, we heat and cool our environments with machinery (Commoner, 2014). This then leads the research to assume that Human Ecologies have lost their *place* within the biosphere along with deep ecological, traditional and meaningful bonds, as they have created their own environments and no longer depend on that of the natural world.

By understanding man's once profound relation with the natural environment, where he would utilize the resources provided by the biosphere, this will then influence the next chapter where the research will consider architecture that utilizes renewable resources towards its efficiency and environmental conservation.

"The building requires the site for its existence, but we view them as separate elements. Perhaps, we can expand the definition of architecture to: the art or practice of designing and constructing place, through the integration of the site and building." (Littman, 2009:2)

3.4 ARCHITECTURE AS A SYSTEM IN NATURE

The above statement reveals that architecture is not to be viewed in isolation, but as an integral system within nature. Therefore, this section of literature review is to investigate Architectural Ecology through Industrial Ecology: where it is to unpack the interconnectedness of the built environment and the host environment that contributes towards a whole system - the biosphere (Von Bertalanffy, 1972). The aim of this exploration is then to investigate existing systems in nature that may contribute to an architecture's ability to conserve natural and human ecological processes.

3.4.1 [Eco – efficiency]: utilizing the biosphere's renewable energy and resources

As discussed earlier, McDonough and Braungart (1998) argued that "*eco – efficiency is an admirable notion that has played a significant role in reducing ecological destruction…".* Therefore, this section will deal with an "eco – efficient architecture*"* that utilizes the biosphere's renewable energy and resources. Aligned with the thinking of the Next Industrial Revolution, the research shall dwell on the systems of: *solar energy*, *wind energy*, *water energy and water harvesting, as well as architectural form and energy flow.*

3.4.2 Solar energy

Bjørn and Strandesen (2011) proclaim that solar energy is the fundamental source of renewable energy within the biosphere. Further justified by McDonough and Braungart (1998) who suggest that, for any industrial process or activity to deem itself efficient, it must utilize the energy income from the sun. Thus, solar energy refers to nuclear processes occurring in the sun's core, which causes a constant conversion of mass into light and heat energy (Lyle, 1996). The "great ball of light" radiates x – rays and then photons which comprise of mostly visible, infrared and ultraviolet light, that disperses into space eventually entering the Earth's atmosphere. According to Lyle (1996: 53), ultraviolet light is filtered within the ozone layer in the upper most region of the atmosphere, whilst in the lower regions, infrared light is filtered by water and carbon dioxide molecules. Thus, approximately 45% of photons discharge from the Sun strike the Earth's surface as visible light. These rays of sunlight allow for various natural ecological processes to occur once it reaches the immediate biosphere, which include: *heat absorption, reflection, evaporation* and *photosynthesis* (Lyle, 1996). Each of these four ecological processes undergo a series of transformations via which they begin to support living organisms and the biosphere (*fig 22*).

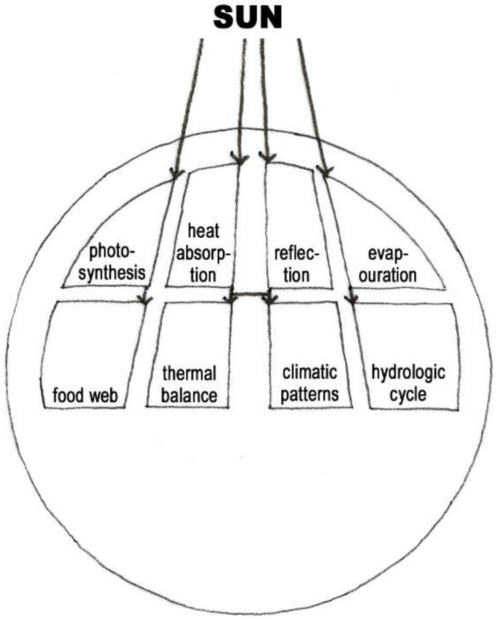


Figure 22: sketch illustrating the natural reactions that occur the moment the "visible sunlight" strikes Earth's surfaces – it is to demonstrate the processes of photosynthesis, heat absorption, reflection and evaporation. (Lyle, 1996: 54). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

The above figure (*22*) gives insight to natural conversions of solar energy that is experienced within the biosphere, where *photosynthesis* creates *food webs* for biological life, *heat absorption* brings *thermal balance* to the atmosphere, *reflection* influences *climatic patterns* and *evaporation* defines *the hydrological cycle*. It is vital that architecture works with these systems, rather than against them. However, in order for an eco – efficient architecture to adopt this notion for the utilization of human ecologies, the solar radiation must be transformed (Gueymard, 2004). With the peak of human creativity and inventiveness of the late 20th century, the transformation of solar radiation was most eminent amongst photovoltaics and heat concentrations. Lyle (1996: 56), suggests that to the above figure, the research may add the following (*fig 23*):

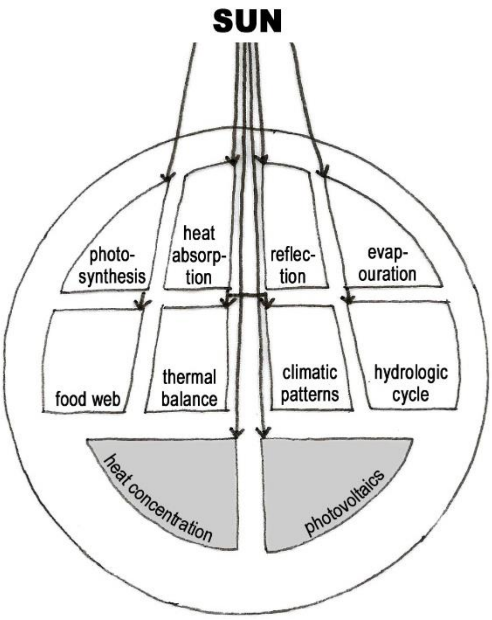


Figure 23: sketch illustrating the addition of man – made utilization of solar radiation to the "whole" system. (Lyle, 1996: 58). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

This exploration unpacks the opportunities of solar radiation which an architecture may adopt and foster to improve its efficiency as an industrial system within the biosphere. Moreover, it ensures an architecture with both *passive* and *active* solar energy that shall facilitate natural and human ecological processes. Passive solar gain will ensure a reasonable amount of natural sunlight (preferably south facing), impacting on the architecture's comfort and sense of *place*, as well as natural heat gain where necessary. As mentioned above, active solar gain then refers to the utilization of photovoltaics and heat concentration systems that have the ability to generate electricity, allowing an architecture to efficiently power spaces, processes and activities. (Lyle, 1996).

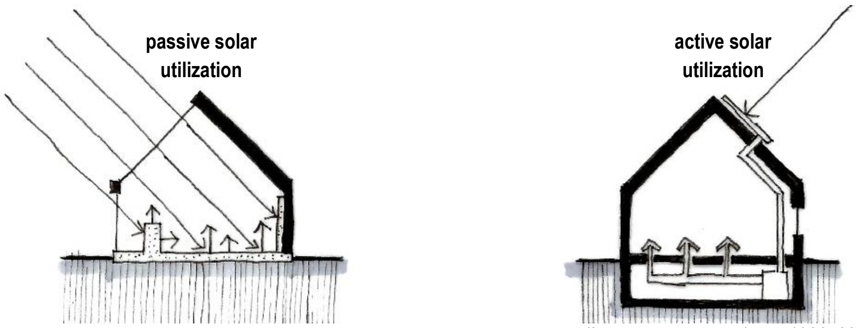


Figure 24: sketch illustrating a **passive solar** and an **active solar** utilization within an eco – efficient architecture. (Lyle, 1996: 60). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

Solar energy, however, does not end here. Consider the chain of events occurring from the Sun's core to food webs created on Earth, similar to the systematic processes of Industrial Ecology - solar energy then allows these processes to transform even further to create greater opportunity for natural, human and architectural ecologies. This can be illustrated below (*fig 25*), where solar radiation allows *photosynthesis* to occur, thus creating *food webs* to which *biomass* and *food* is then created for living organism, etc. Solar energy will therefore influence chapters that follow.

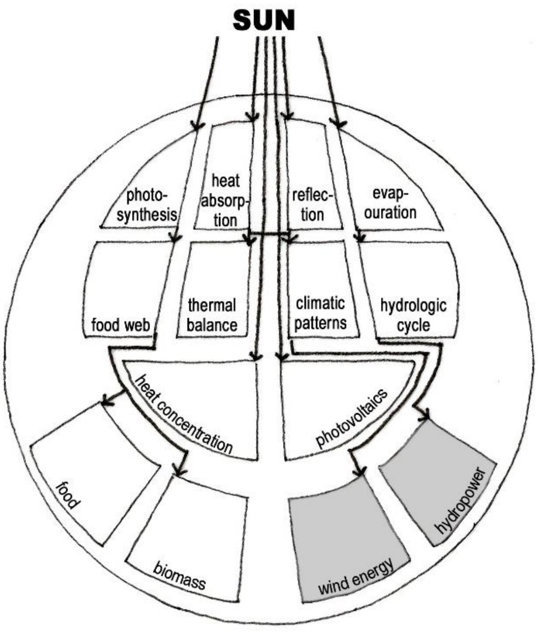


Figure 25: sketch illustrating the growth of the "whole" system when one begins to unpack the chain of events of solar radiation. (Lyle, 1996: 59). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

3.4.3 Wind energy

Drawing an analogy from the above discussion, solar radiation provides the atmosphere with *reflection*, from dense surfaces such land formations and water bodies, which influences *climatic patterns*, inevitably providing wind. Thus, wind is merely a consequence of solar radiation within the Earth's atmosphere (Edelstein and GE R&D, 2003).

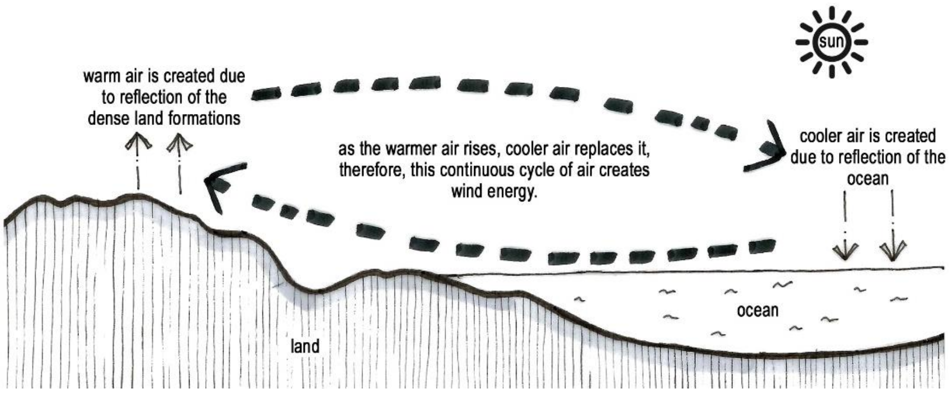


Figure 26: sketch illustrating the exchange of cool and warm air that essentially creates a cycle that influences the motion: called wind energy. 2018, By Author.

Wind energy can then be referred to as "air in motion" (Edelstein and GE R&D, 2003), which is produced by the exchange of cool air replacing rising warm air within the biosphere (*fig 26*). Similar to the concept of Industrial Ecology, both systems of cool and warm air work interdependently. Therefore, should either system overpower the next, the result could be irregular wind speeds and atmospheric pressure.

In contrast to photovoltaics and heat concentrations, transforming wind into a usable energy is not a relatively new phenomenon. Aligned with the conditions of pre – industrial man, earlier societies had converted wind energy for the pumping of water and grinding grain (Burton, Jenkins, Sharpe and Bossanyi, 2011). Dating back to at least 3000 years ago, these conversions were carried out through windmills (*fig 27*), although simpler vertical axis windmills were uncovered in the Persian – Afghan border, which dated back to approximately 200BC (Kaldellis and Zafirakis, 2011). Further evolution of the windmill had been constructed towards the late 19th century, but at this stage, it had the ability to generate electricity - up to 12kw. Although windmills (or wind turbines) offered great opportunity, it fell into disuse, as the cheaper fossil fueled engine took over during the industrial age (Burton, Jenkins, Sharpe and Bossanyi, 2011).

Figure 27: illustrating a 42ft red brick structure built during 1818 known as "Old Buckenham Towermill" – said to be the largest windmill built at the time, (online). 2018.

According to Lyle (1996), wind turbines represent a contemporary take on ancient pre – industrial technology. Therefore, Bjørn and Strandesen (2011) recommend that wind must be utilized within modern processes and activities as its energy is natural, renewable and simple to convert. Aligned with eco – efficiency, the rotary mechanical energy generated when the blades are turned by the wind is converted into electrical power by a generator (Lyle, 1996: 63).

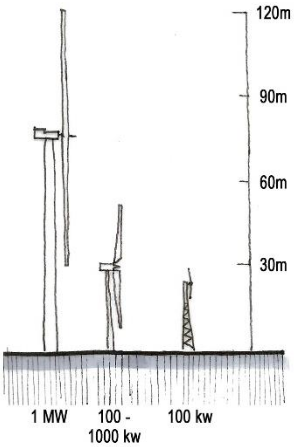


Figure 28: illustrating power – scale ratios of wind turbines. 2018, By Author.

Moreover, for a wind turbine to efficiently produce electricity it will require a minimum wind speed of 11 kilometers per hour (Lyle, 1996: 63). These systems vary in size and height, whereby a taller wind turbine will be exposed to greater wind speeds, thus increasing the power output. However, this does not undermine smaller systems, as they still have the ability to produce up to 100kw of power. Larger systems then have the ability generate over 1 megawatt of electricity (*fig 28*). This proves that there is immense opportunity should this system be utilized within an eco – efficient architectural design.

Beller (2011: 15) stipulates that it is not an uncommon idea, where wind turbines are introduced in buildings and existing urban structures. It is perceived by most industrialist, architects, engineers and designers – that only high-rise buildings accommodate for wind turbines due to their exposure to lateral forces. Contrary to this belief, Beller (2011: 17) suggests that low-rise buildings may utilize the energy of the wind through smaller wind turbine systems, that are often induced by "upwinds" around major obstacles such as bridges or other structures. However, this task may deem to be problematic as wind turbines emit vibrations that could cause fatigue and stress on a building's structural integrity.

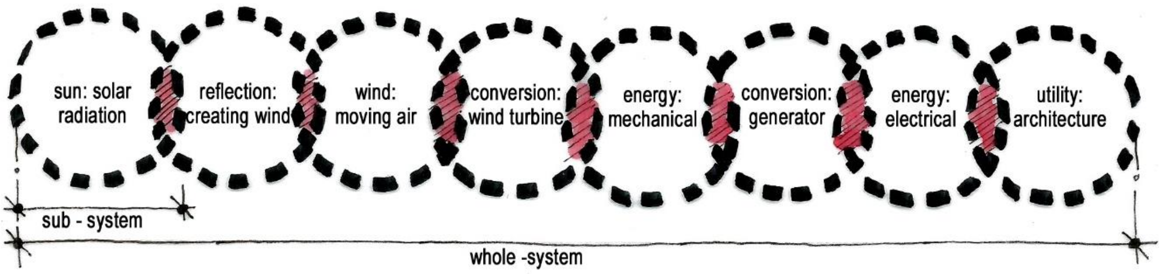


Figure 29: diagram illustrating the analytical unpacking of wind energy processes, similar to that of an efficient industrial system, to which an architecture must adopt and accommodate. 2018, By Author.

The above figure (*29*) defines the processes of wind energy, to which an architecture must accommodate, structurally and aesthetically. Therefore, in order for an eco – efficient architecture to adopt this notion, wind turbines must be designed as an integrated system within the architectural process to achieve efficiency and environmental equilibrium (Beller, 2011).

3.4.4 Water energy and rain water harvesting

Water may be regarded as one of the most vital renewable resources within the immediate biosphere, where 70% of the Earth itself is made up of this precious liquid (Ruhela, Bhutiani and Anand, 2004). Therefore, it is inevitable that this valuable resource and its energy is harnessed within an architecture that is to be efficient within an industrial landscape.

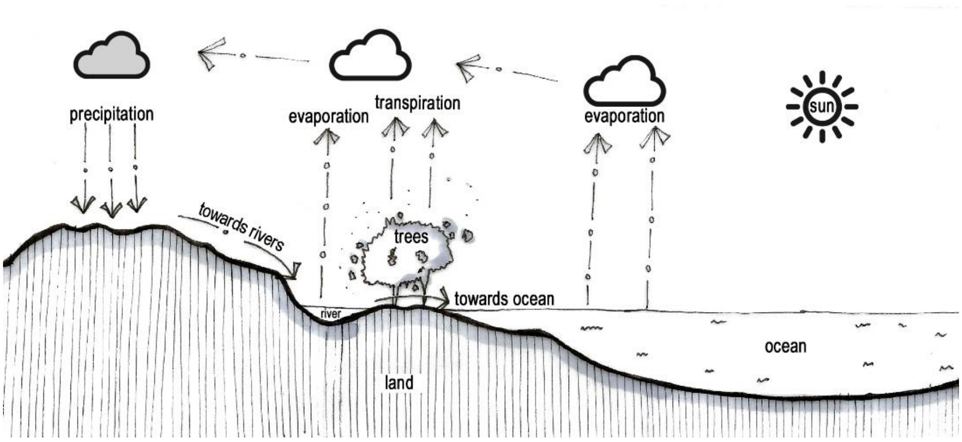


Figure 30: sketch illustrating the hydrological cycle: through solar radiation, the biosphere experiences evapotranspiration, that is cooled and condenses within the atmosphere and is exuded back to Earth, where the cycle continues. 2018, By Author.

Mostly influenced by solar radiation, figure (*30*) illustrates the effective mechanisms of the *hydrological cycle*, where as a result of solar radiation, water is transformed into a gaseous state through *evaporation* and *transpiration*, which when cooled and condensed, then discharged back to the Earth as *precipitation*. This contributes to surface water, such as rivers, streams and lakes that are continuously moving in search of sea level due to gravity (msnucleus, 2018). Thus, the velocity of the water is highly dependent on the terrain, vegetation, rock and soil formation that may obstruct its course.

Similar to that of wind energy, hydro energy then refers to the exchange of the water's velocity falling upon a turbine that causes it to turn. Aligned with pre – industrial society, many of which utilized the system of a water wheel to grind grain (*fig 31*). According to Lyle (1996: 63), unlike wind energy that fell into disuse during the industrial age, water energy had been widely exploited through hydroelectric power stations, more so towards the start of the 20th century. As the demand for electricity grew significantly, this put strain on hydroelectric generators, where the velocity of water varied due to fluctuating tides, winds and hydrological cycles.

Figure 31: illustrating photo capture in 1964 of the Friedesse Mill, in Neer, Germany, (online). 2018.

This resulted in the construction of dam walls, reservoirs and impoundments. Baxter (1977) suggests that these structures can be dated back to pre – industrial man and were probably built for flood control and water supply. However, as with any system developed during the industrial age, these structures were on an entirely larger scale that brought extensive ecological change and destruction to both the natural environment as well as indigenous communities (Lyle, 1996: 64).

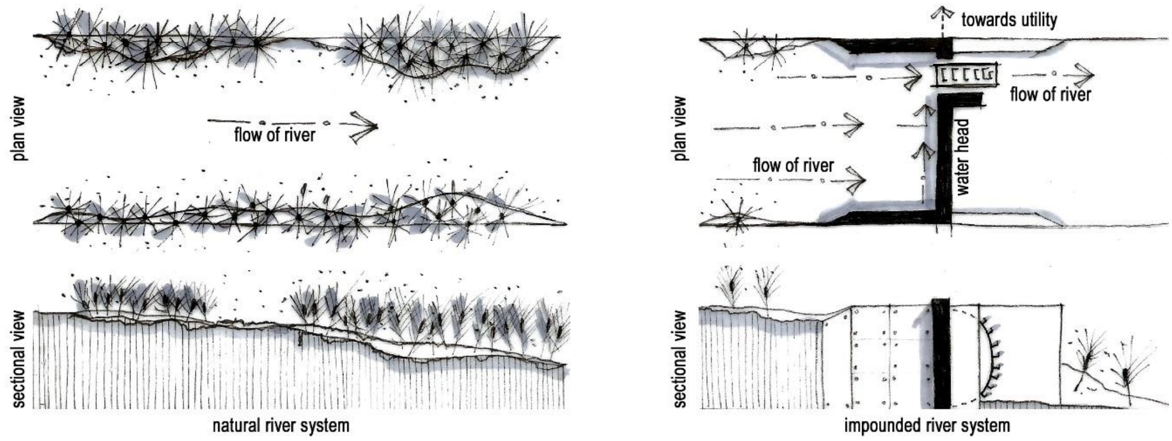


Figure 32: sketch illustrating the consequences of the industrial age: hydroelectrical dams, that alter natural ecosystem. 2018, By Author.

The above figure (*32*) gives insight to the destructive consequences of the hydroelectric concept, however, this research shall not dwell on critiquing the performance of hydroelectrical impoundments, rather, it is to consider the ecological impacts and a change of thinking towards the utilization of water energy. Therefore, a new system has been conceived – hydrokinetic energy. According to Khan, Bhuyan, Iqbal and Quaicoe (2009 :1823), hydrokinetic systems utilize the kinetic energy stored within streams, rivers or tidal currents, via which transform the water's velocity into electricity.

Many believe, it is similar to earlier hydroelectrical concepts, however, the pivotal characteristic of this systems is that it does not require a man – made water head or a redirected stream of water (Khan, Bhuyan, Iqbal and Quaicoe, 2009 :1824). Instead, hydrokinetic systems are submerged within the waterbody which produces between 250w – 2500w of energy depending on the velocity of water that passes through it, with *little to no* environmental impacts (smart-hydro, 2018).

Khan, Bhuyan, Iqbal and Quaicoe (2009 :1824), further stipulate that scalability and modularity are appealing features of hydrokinetic systems. Therefore, as figure (*33*) illustrates, there is ample opportunity for an eco – efficient architecture to exploit the energy imbedded in water, without ecological destruction. However, hydrokinetic systems must be conceived as an integral part of the architectural process as they will be interdependent systems.

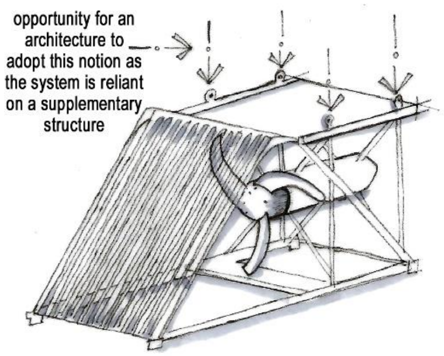


Figure 33: sketch illustrating a conceptual hydrokinetic system. 2018, By Author.

As proclaimed above, Earth consists of approximately 70% of water, of which only 3% of the available water within the biosphere is fresh water. Out of the 3%, only 1% is surface water that can be obtained, the remaining 2% is sealed within glaciers and ice caps located in the polar regions. Thus, the 1% of surface water is often revitalized by rainfall and other forms of precipitation (Ruhela, Bhutiani and Anand, 2004).

According to Maslow's hierarchy of needs (Maslow and Lewis, 1987), *water* is defined as "*physiological needs - basic needs*". Therefore, the research shall exploit water not only for its energy, but as a resource that supports human ecological life. The harvesting of rainwater then becomes eminent within an environment where available surface water is so easily cross contaminated with effluent and harmful toxic waste. Rahman and Jahra (2007) stipulate that rainwater is the lightest form of water in the biosphere because it is naturally transparent, clean and free from bacteria. Moreover, through water quality testing, it has been revealed that rainwater obtained from roof tops are significantly cleaner than other sources, apart from springs and bore holes (Rahman and Jahra, 2007). Rainwater harvesting then refers to the "practice of holding water in a place" (Athavale, 2003).

The harvesting of rainwater for human sustenance can be found in most great pre – industrial societies and offer both simple and complex systems by which water had been contained. According to Boers and Ben-Asher (1982: 151), storage then becomes an essential part of harvesting rainwater. The method in which rainwater is stored should be governed by the way it is intended to be utilized. Helmreich and Horn (2009: 120) suggests that there are two primary methods by which rainwater is stored: figure (*34*) illustrates rainwater storage tanks that are elevated significantly above the ground, in this case, to allow gravity to assist the water supply. Figure (*35*) depicts rainwater storage tanks below the ground, where this system requires a pump to supply water where it may be required. These, storage vessels normally take the shape of a cylindrical or cuboid form, as it prevents heat concentrated evaporation. Where, 1mm of rainwater over $1m^2$ results in approximately a liter of water (Helmreich and Horn, 2009: 120), an architecture must provide the necessary provisions to allow itself to adopt the above notion in creating efficiency towards addressing the basic needs for the sustenance of the end-user.

Figure 35: image illustrating rainwater tanks elevated of the ground: gravity then enhances the water supply, (online). 2018.

Figure 34: image illustrating rainwater tanks stored underground: where pumps would transfer water where needed, (online). 2018.

3.4.5 Architectural form and energy flow

The above discussion gave insight to understanding the impacts of the energy emitted by the sun, providing the biosphere with solar energy, thus creating wind energy and hydrological cycles to which an architecture may adopt or utilize within its programme to ensure ecological efficiency. Based *on Industrial Ecology* (Jelinski, Graedel, Laudise, McCall and Patel, 1992) and *Evolutionary Thermodynamics* (Gu and Evans, 2010) uncovered in Chapter Two, it can then be assumed that an architecture merely extracts energy and resources from an already existing energy flow within the biosphere. As illustrated in figure (*36*), any architectural system effectively redefines or alters natural energy flows through its utilization (Lyle, 1996: 105). This subchapter then aims at investigating architectural forms that provide strategies to correlate with existing energy flows, such as controlling heat balance, reflection, absorption, movement of air and releasing heat. This exploration ensures that architecture is treated as a system in nature, and considers the comfort range of the built environment, whilst maintaining a steady state of equilibrium within its host environment.

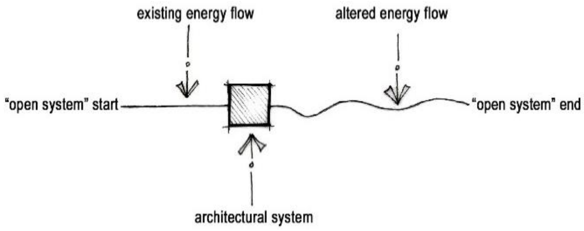


Figure 36: sketch illustrating the energy flow, as an "open system", to which an architectural system clings onto, utilizing its resources and energy, thus altering the flow of energy thereafter. 2018, By Author.

Lyle (1996) suggests that a building could be regarded as a mediator between the Sun and Earth, and for an architecture to align itself with the regenerative thinking of the Next Industrial Revolution, it must be shaped to guide energy flows. Lyle (1996: 105) further proclaims that there are three basic architectural forms that utilize this thinking to guide energy flows, in three significantly different ways. As illustrated in figure (*37*), the first form considers a building on stilts. This allows air (wind energy) to move freely around the building, alleviating pockets of warm air. Moreover, the raised platform creates a shaded living space beneath, which may also foster ecosystems (Lyle, 1996: 105). The second form illustrated in figure (*38*), depicts an earth – sheltered structure that utilizes the earth as a thermal "blanket". Inspired by desert Indians of South America, this type of form uses the constant temperature (heat energy) of the earth to regulate its thermal conductivity, where in extremely hot conditions, it would release heat into the earth, thus cooling the building, and visa versa. The third form illustrated in figure (*39*) depicts a sunspace form, which

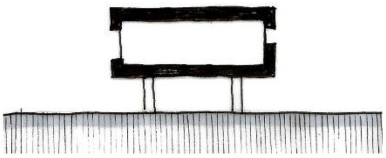


Figure 37: sketch illustrating building on stilts or "pilotis". (Lyle, 1996: 105). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

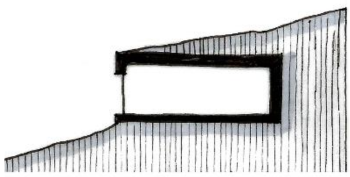


Figure 38: sketch illustrating earth sheltered structure (Lyle, 1996: 105). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

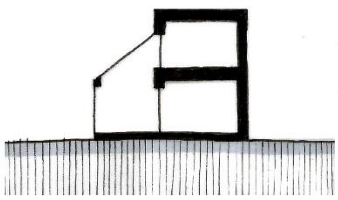


Figure 39: sketch illustrating a "sunspace" building (Lyle, 1996: 106). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

acts like a greenhouse, normally a considerable area that is north – facing allowing short wavelength solar radiation energy flow to penetrate the building, thus warming up interior spaces. Lyle (1996: 106) suggests that in many instances, sunspace forms utilize deciduous trees and vines as natural shading devices when the heat is unwanted.

Although the three architectural forms mentioned above differ in ways that they would control existing energy flows, they may be utilized in a single design (Lyle, 1996: 106). Furthermore, the three concepts of energy – earth forms may be utilized in various ways and combinations to achieve ecological architecture that conserves both human and natural ecological processes. However, this does not investigate interior energy flows.

Lyle (1996: 106) then argues that controlling the energy flow within a building is vital, as the materials and details must supplement the architectural form. Thus, five key elements are important for an architecture's ability to maintain its interior thermal capacity. These refer to: *insulation, transparent surfaces, thermal mass, shading* and *openings* (Lyle, 1996).

Insulation: human activities and processes often require cooler or warmer spaces than the outside air. Aligned with the 2nd law of Thermodynamics, warm air always tries to exude its heat to the cooler air, effectively bringing them both to a state of equilibrium. Insulation then refers to a material that will slow down this process, either to maintain heat in a room, or prevent heat from entering (Lyle, 1996: 106). Therefore, insulating materials are the most efficient energy - conserving details within an architectural process, where it is necessary to thermally separate two areas.

Transparent surfaces: within an architecture that chooses to maximize solar radiation, energy flow through a transparent surface is then critical to thermal comfort. Lyle (1996: 107) suggests that transparent materials are poor insulators as they readily lose or gain heat at an unstable rate. Therefore, as illustrated in figure (*40*) careful placement and sizing of transparent surfaces are to be considered, whilst being exposed to maximum solar radiation: south in the northern hemisphere and north in the southern hemisphere.

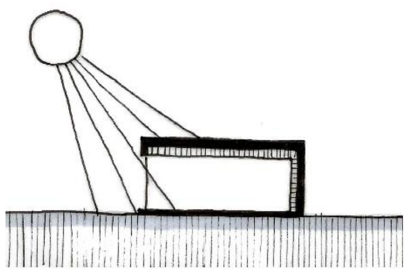


Figure 40: sketch illustrating a transparent surface facing "south" to which it is maximizing solar radiation (Lyle, 1996: 106). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

Thermal mass: solar energy can be easily maintained within a structure through a transparent surface, provided there is a constant exposure to the sun. Therefore, the process for storing heat when there is little to no solar exposure is regarded as a "thermal mass". Lyle (1996: 106) proclaims that should an architecture seek to maintain thermal energy within its interior space, thermal massing would be the most efficient solution. As illustrated in figure (*41*) a thermal mass could be any material that is heavy, dense or bulky, which its main objective is to rapidly absorb large amounts of heat and then release it at a slow rate. Materials such as stone, brick and water share these properties and therefore are excellent for storing heat energy. However, for this process to work effectively, the size of the thermal mass should be 1/3rd of the total area of the transparent surface. Lyle (1996) suggests that this ratio will ensure that thermal storage is then diurnal which is the main goal for passive solar design.

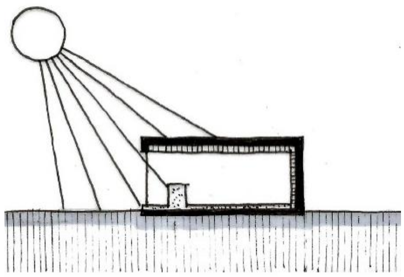


Figure 41: sketch illustrating thermal mass exposed to solar radiation (Lyle, 1996: 106). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

Shading: as depicted in figure (*42*) this refers to an architecture's ability to allow solar radiation into a building during the winter, whilst shading interior spaces through fixed overhangs or shading devices during the summer (Lyle, 1996: 108). Similar to that of eco – effectiveness, Lyle (1996: 108) suggests that a building is to consider responsive and flexible shading devices that change with the seasons and existing energy flows. In addition, "live" shading could come from deciduous plants and trees.

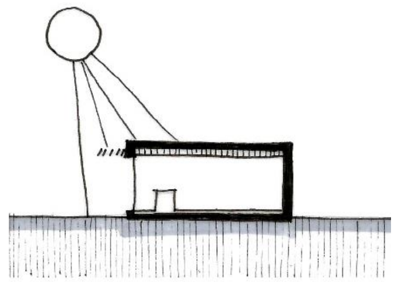


Figure 42: sketch illustrating thermal mass exposed to solar radiation (Lyle, 1996: 106). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

Openings: openings refer to an architecture's control of air (wind energy), thus influencing the thermal comfort of space. According to Lyle (1996, 108), cross ventilation is then, the most common ideology of interior air movement. As illustrated in figure (*43*), the movement of air is conceived through an inlet towards an outlet (*fig 43.1*), therefore, by altering the position (*fig 43.2*) or size (*fig 43.3*) of either, may improve the amount of air moving through the space. However, the placement of the inlet is of more importance as it dictates that amount of pressure regulated when air enters a building. Thus, overhangs are introduced above inlets to enhance pressure build up, inevitably creating a greater air flow through the structure (Lyle, 1996). Figure (*43.4*) illustrates another condition with regards to air movement: *rising warm air*. Similar to the creation of wind energy explored earlier, this investigates the replacing rising warm air by cool air which allows for an interior that is thermally balanced. This system depends on a low

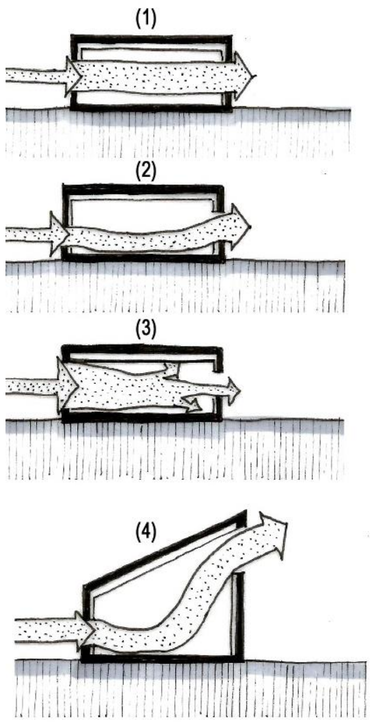


Figure 43: sketch illustrating air flow movement within a structure (Lyle, 1996: 108 - 109). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

inlet and a high outlet, thus the greater the distance between the two, a greater amount of air flow may pass through the space.

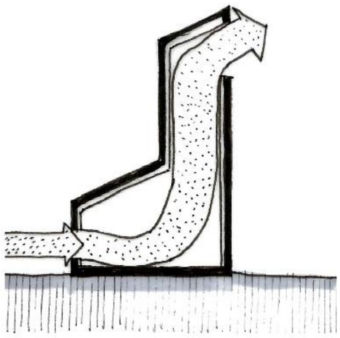


Figure 44: sketch illustrating air flow within an industrial structure (Lyle, 1996: 112). Regenerative Design for Sustainable Development (Adapted by Author, 2018).

According to Lyle (1996: 112), a similar principle may be investigated within an industrial structure, where continuous heat is radiated by activities and processes. Therefore, thermal chimneys may be exploited as they offer enhanced air in motion, due to distance between the inlet and outlet. The fundamental attribute within a thermal chimney is that it uses its form to achieve thermal equilibrium. Moreover, South facing glass is then introduced at the top of the form, which further induces heat, essentially creating a more drastic flow of air.

The above subchapter provides the research with the possibilities of resources and energy that can be utilized by an eco – efficient architecture from the biosphere. Moreover, it put emphasis on the importance of the Sun's energy providing the planet with solar and wind energy, as well as hydrological cycles. Thus, Industrial Ecology formed the lens that ensured that architecture is not viewed in isolation but as an integral system within nature, that must utilize these energies provided by the sun.

Therefore, an architecture may efficiently facilitate activities and processes whilst considering the sensitivity of the natural ecologies and the comfort of human ecologies.

It can then be assumed that the above investigation gives insight to "high – tech technology". However, this does not undermine "high – tech thinking" with "low – tech technology", which refers to ecological processes found within the biosphere. The next chapter will then explore nature's technologies that may inform an architecture's response to dealing with forms of waste and ecosystem decay.

"The idea that human industry destroys the natural world, or that excessive demand causes environmental ills, is a simplification. Nature - industrious, creative, even wasteful - is not efficient but effective" (McDonough and Braungart, 1998)

3.5 NATURE AS SYSTEM IN ARCHITECTURE

The above statement stipulates that human industry is depletive, yet nature's industry is regenerative. Therefore, this section of literature review is to investigate Natural Ecology through the Theory of Ecology: where the research shall uncover regenerative ecological processes in nature. Considering that architecture is merely an extension of its host environment, the aim of this study is then to incorporate these ecological processes within an architecture to foster human activities and processes, whilst conserving natural ecosystems that coexist within an industrial landscape.

3.5.1 [Eco – effectiveness]: utilizing the biosphere's ecological processes

As discussed earlier, McDonough and Braungart (1998) suggested that "*the concept of eco – effectiveness can be defined by Industrial Ecology… where human industrial activities and processes are to be regenerative as opposed to depletive, which proposes a "cradle to cradle" cycle of life…"*. To fully understand this thinking, as illustrated in figure (*45*) the research had considered man's (the end – user's) basic needs towards his livelihood within the biosphere, in order to unpack specific ecological processes that may deem to be beneficial. More so, this exploration is to align itself with the problem statement, as these ecological processes may give insight to ecosystem conservation and awareness for the uMngeni precinct. Therefore, through the lens of the Next Industrial Revolution, the research shall dwell on the processes of*: photosynthesis, constructed treatment wetlands, solar aquatic treatment* and *sludge disposal and by products* towards an eco – effective architecture.

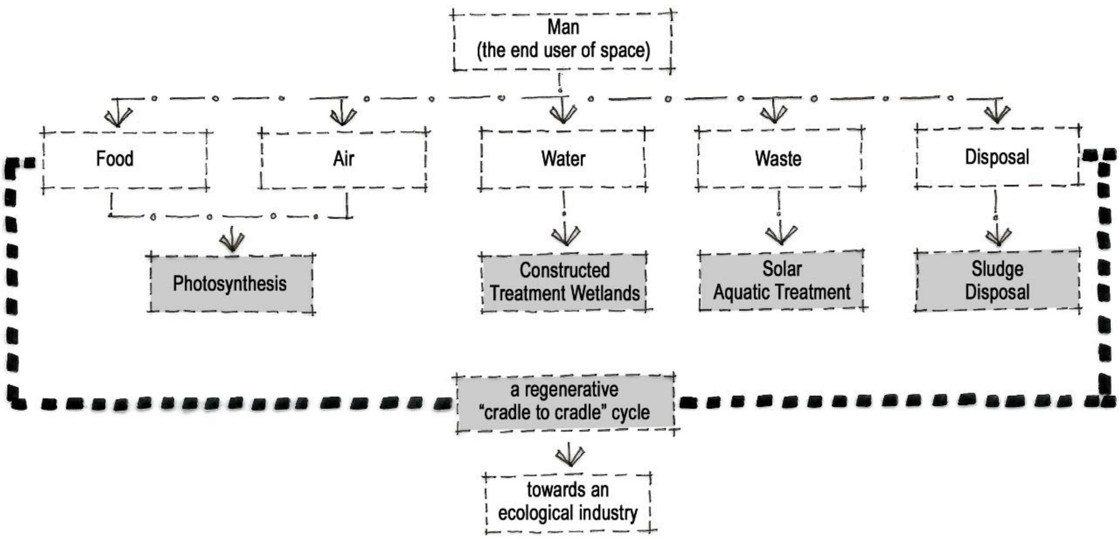


Figure 45: sketch illustrating the understanding of man's basic needs to which ecological processes may foster towards ensuring an eco – effective architectural design. 2018, By Author.

3.5.2 Photosynthesis: food webs and air purification

Photosynthesis could be regarded as one of the most vital ecological processes that occurs within the biosphere (Gust, 2006). As discussed earlier, this ecological process is induced by *solar radiation*, whereby photons entering the immediate biosphere strike the green surfaces of plant life (Lyle, 1996: 54). Therefore, photosynthesis refers to the process by which plant life convert light energy into chemical energy that is stored for later use. Moreover, Gust (2006) states that tiny units located on the leaves of plant life, termed – "photosynthetic reaction centers", are responsible for harnessing the energy of solar radiation to convert carbon dioxide from the atmosphere into starch, sugar and other carbohydrates, thus releasing oxygen in the process.

As mentioned in the previous subchapter, Lyle (1996) gave insight to the impacts of solar radiation upon photosynthesis. Thus, this investigation will be a continuation of this thinking, where the process of photosynthesis provides the biosphere with food webs. Aligned with the Theory of Ecology, food webs then refer to the interrelated ecosystems in all their spatial scales that result in diversity, stability and productivity (Worm and Duffy, 2003). Therefore, through the ideology of photosynthesis, food webs provide a platform for organisms to flourish so that they may be converted into edible plants (Gómez-Baggethun and Barton, 2013). It can then be assumed that photosynthesis provides the biosphere with an "ecosystem service": *food*, sustaining all organisms including mankind. Gómez-Baggethun and Barton (2013: 237) suggest that the process of photosynthesis is the fundamental component to the planet's food supply and production and should be celebrated within an urban context.

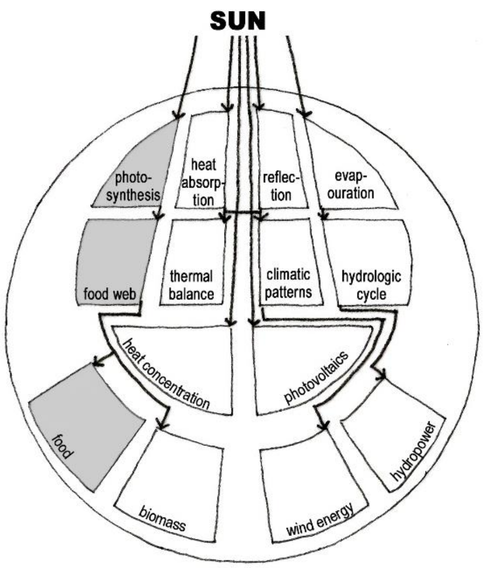


Figure 46: sketch illustrating photosynthesis impacts on food webs, thus creating food to sustain life within the biosphere. (Lyle, 1996: 58). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

Apart from *food*, photosynthesis provides the biosphere with another vital "ecosystem service": *oxygen*. According to Gómez-Baggethun and Barton (2013: 237), with the rise of industry during the last decade, air pollution from these industrial processes and activities is accountable for the increase in cardiovascular and respiratory diseases within urban fabrics. Thus, this study is to investigate photosynthesis as a fundamental system in an eco – effective architecture that provides not only a source of *food*, but the *purification of air* within an industrial landscape.

The utilization of plant life to control air pollution has been in practice since the 17th century, where large plantings of trees and shrubs were said to cleanse polluted air in London. The purification process begins with air moving through dense plant life, leaving behind dust and other pollutants trapped on leaves and stems. During precipitation, these dust particles are washed from the plant life and returned into soil (Lyle, 1996: 104). According to a study carried out in Germany, a 10 000m^2 plot of beech trees could effectively remove 4 tons of dust per year (Meldan, 1959).

Moreover, through the ecological process of photosynthesis, plant life consumes other pollutants, such as: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) (Gómez-Baggethun and Barton, 2013: 237). However, the reliance of plant life for air purification within an industrial setting is heavily dependent on the species, form and density of the plantation, as well as the conditions established by human ecologies. Lyle (1996: 104) stipulates that air pollution in an industrial landscape may cause stress to plant life, where pollutants may congest photosynthetic reaction centers on leaves and stems. Thus, as illustrated in figure (*47*) some deciduous trees and plant life with closely grouped - tough leaves are remarkably resistant, these refer to: beech (*Fagus*), elm (*Ulmus*), mountain-ash (*Sorbus*), plane (*Plantanus*) and gingko (*Ginko*). As with most cities, the greatest need for cooling and pollution reduction is during the summer, therefore deciduous plant life is an ideal system for the purification of air that is to be integrated within an eco – effective architecture.

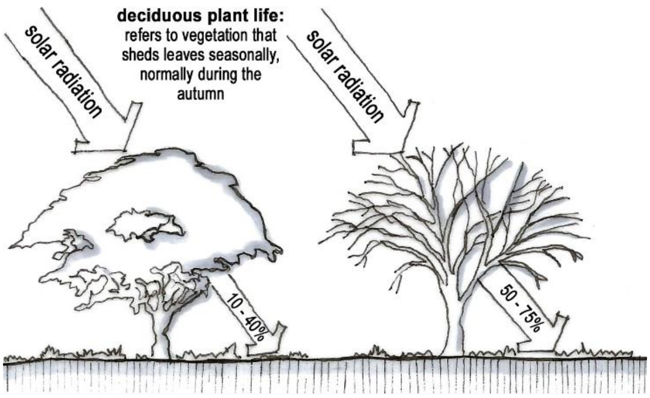


Figure 47: sketch illustrating a deciduous tree that provides enhance photosynthesis during the summer. (Lyle, 1996: 103). Regenerative Design for Sustainable Development (Adapted by Author, 2018)

Lastly, Lyle (1996: 57) suggests that another biological utility of photosynthesis is waste treatment, thus the research will explore these strategies below.

3.5.3 Constructed treatment wetlands: water purification and filtration

Ruhela, Bhutiani and Anand (2004) previously revealed, that only 1% of all fresh water within the biosphere is accessible to humans and most living organisms as surface water. Wetland ecosystems then play a vital role in the quality and quantity of surface water within urban landscapes, through filtration, retention and decomposition of effluent and organic waste (Gómez-Baggethun and Barton, 2013: 236 & 237). However, due to rapid industrial development, most wetlands had been destroyed, leaving surface water bodies vulnerable to toxic effluent and other pollutants.

According to the South African National Water Act (No 36 of 1998), a wetland refers to: land that is transitional between terrestrial and aquatic systems, where the water table is usually near the surface, or where the land is submerged in shallow water which would normally support vegetation and other living organisms typically adapted to life in the marshlands. Therefore, this study is to investigate the biological purification and filtration of water through the concept of constructed treatment wetlands. Ramjohn (1999: 27) suggests that nature deals with wastewater effectively, instead man ignores the power of natural ecologies, pushing technical boundaries trying to deal with the same problem.

A *constructed wetland* can then be referred to as an ecologically engineered system that is to mimic a *natural wetland* (Ramjohn, 1999: 34). This simple ecological system utilizes plant life or vegetation for the treatment of water. Aligning itself with the Theory of Ecology, and the Next Industrial Revolution – "*waste equals food"*, the vegetation within this system absorbs waste and contaminants in the of flow water that passes through it (Ramjohn, 1999: 35). Therefore, the species of plant life utilized within this process is vital as they are placed under continuous shock dealing with various forms of waste.

Ramjohn (1999: 35) suggests that species such as cattail (*Typha*), sphagnum (*Sphagnum*), water hyacinth (*Eichhomia crassipes)* and other mosses contain remarkable properties that absorb contaminants through a progression of biochemical reactions (redox) and physical processes of sedimentation of solids. Figure (*48*) then illustrates a similar small-scale model using water hyacinth plants and algae to purify wastewater. Together, these plants have the ability to reduce bacteriological elements and chemicals such as: biochemical oxygen demand (BOD), chemical oxygen demand (COD), acidity, oxido nitrate (NO_4), phosphate ion (PO_4) and coliform. Constructed treatment wetlands then pose as an ideal system to deal with municipal storm water, agricultural runoff and industrial wastewater (Gómez-Baggethun and Barton, 2013: 237).

Figure 48: image illustrating small scale apparatus of hyacinth and algae to purify water, (online). 2018.

Ramjohn (1999: 35) further justifies that a critical benefit for the utilization of constructed treatment wetlands is that it can be established in close proximity to the source of the pollution. In addition, Lyle (1996: 243) supports this notion, suggesting that depending on the location, the design of well-constructed wetlands could not only offer the means to purify and filter surface water, but it begins to conserve, revitalize and shape riparian ecosystems.

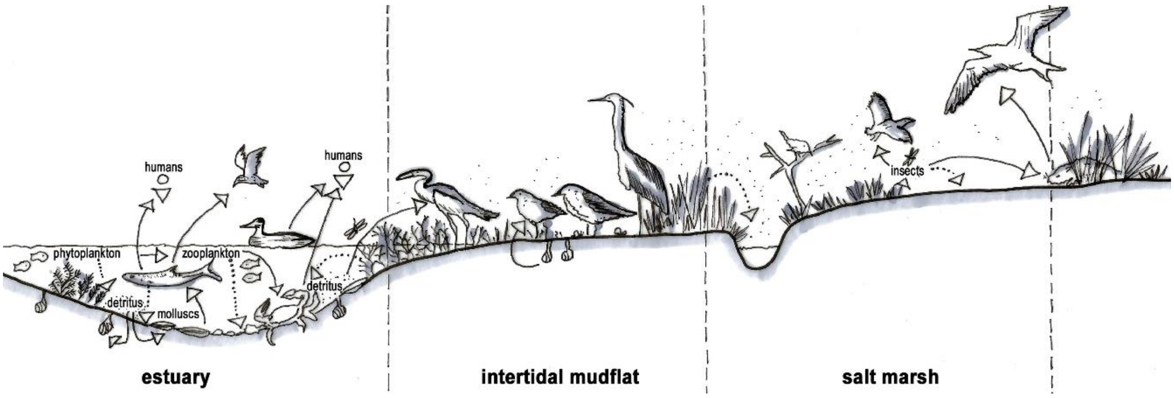


Figure 49: sketch illustrating the interdepend ecological processes that occur within a riparian ecosystem that a constructed wetland may support (Lyle, 1999: 175). Design for Human Ecosystems (Adapted by Author, 2018)

As illustrated above in figure (*49*), by the design of constructed treatment wetlands, there will be an effective influence on riparian ecosystems. Thus, aligning the research with the rich biodiversity of the lower uMngeni River.

Despite the many beneficial attributes of the constructed treatment wetlands concept, this system does experience restrictions to the environments it may be adopted within. The first restriction refers to the amount of effluent or contamination entering the constructed wetland that must be established in order for the plant life to break it down successfully without placing strain on the system. There should be great care taken in monitoring the initial process, thus ensuring the water discharged later, is of a determined quality (Ramjohn, 1999: 35). The second constraint refers to the scale of the system, where large scale applications may not be feasible. The third restriction refers to the host environment, as constructed wetland designs function well in mostly warmer tropical climates (Ramjohn, 1999: 36).

Constructed treatment wetlands begin to give insight towards the purification and filtration of water within industrial – urban landscapes, as well as the development of riparian ecosystems. Therefore, for this notion to be adopted within an eco – effective architecture, the built form must be aligned with all its requirements and restrictions. Ramjohn (1999, 35) suggests that constructed treatment wetlands mostly focus on wastewater, as sewage is often avoided, due to odour, unsightliness and risk of ecosystem failure. Thus, the research shall now explore solar aquatic treatment for sewage wastewater.

3.5.4 Solar aquatics: wastewater treatment

Ever since the invention of the water closet by Thomas Crapper during the industrial era of the 19th century, human excrement had been primarily dealt with by mixing it with water, which is then discharged through a series of underground pipes to the closest body of water, normally a bay or river (Lyle, 1996: 227). Solar aquatic treatment is then an ecologically engineered system, similar to that of constructed treatment wetlands investigated above. However, the fundamental difference is that solar aquatics is an intensified biological treatment system that is capable of handling sewage wastewater. Therefore, this study is to investigate the biological treatment of sewage wastewater through the ideology of solar aquatics that shall inform an eco – effective architecture towards dealing with waste and pollutants.

According to Stephen (1998: 165) the technology behind Solar Aquatic Systems (SAS) had been developed during the 1980's by Dr. John Todd. The technology patented under the commercial name - "*Living Machine*", had been sold to the Ecological Engineering Associates (EEA), who were responsible for the development of the solar aquatic technology for industries and communities in need of new ways to deal with sewage wastewater.

Wastewater within a solar aquatic system is circulated through a series of translucent tanks, each hosting aquatic environments and constructed marshes (Stephen, 1998: 164). The circulation of wastewater occurs mostly in the confinements of a greenhouse, which enhances and intensifies biological processes. Moreover, the greenhouse regulates the conditions for bacterial function, including temperature, humidity, habitat, pH, oxygen availability, evapotranspiration and light. Stephen (1998: 164) suggests this system then relies on the ecologically diverse constructed aquatic environments that maximize biological deterioration of sewage wastewater. Todd's design of solar aquatics – the Living Machine, had been divided into three primary sections, as illustrated in figure (*50*) below:

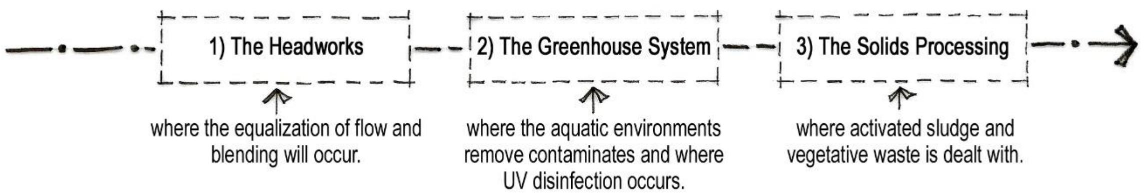


Figure 50: sketch illustrating the flow of the three primary sections of Living Machine by developed by Todd (1994). 2018, By Author.

Ramjohn (1999: 38) then states, to fully understand the ecosystem service provided by utilizing biological wastewater treatment, it is essential to unpack primary principles of this process that occurs within the system. Aligned with the Theory of Ecology, Todd (1994) had considered nine principles that formed the basis for the design of Living Machine or Solar Aquatics. These are as follows:

Microbial Communities: the first principle refers to the foundation of the Living Machine or Solar Aquatics which is based upon bacteria. The system utilizes species from freshwater, marine and terrestrial settings. However, other species are then utilized, merely as a food source for other organisms higher up in the food chain.

Photosynthesis: aligned with the earlier subchapter, the second principle refers to photosynthesis as the primary source of energy within the system. Ramjohn (1999: 39) suggests that it is vital for solar aquatic systems to use a diversity of vegetation, plant life and moss to ensure overall efficiency.

Sub - ecosystem: Todd (1994) suggests the third principle is the use of three to four sub – ecosystems that form part of the living machine, to which they are divided in physical space but connected through the flow of effluent.

Pulsed Rate Exchanges: similar to contingencies investigated in Theory of Ecology, the fourth principle discusses the intended stress or disruptions introduced to the system. This is to mimic the unpredictability of nature, allowing the constructed environments to "learn" and adapt to change and stress.

Nutrient and Micronutrient Reservoirs: the fifth principle refers to supply of mineral nutrient that must be in equilibrium within the flow of wastewater (nitrogen, carbon, etc.)

Geological and Mineral Diversity: the sixth principle looks into utilizing bacteria and mineral content that is obtained from metamorphic, sedimentary and igneous rock.

Steep Gradient: aligned with the third principle, this principle refers to rapid or sudden change in the solar aquatic system, where species are re-introduced into previous tanks ensuring a closed loop cycle.

Phylogenetic Diversity: the eight principle refers to Todd's (1994) understanding of phylogenetic levels, where according Ramjohn (1999: 39) species are often underestimated relative to their role within the biosphere, more so towards enhancing the effectiveness in solar aquatic systems.

The Microcosm - Macrocosm: the final principle refers to the Living Machine's ability to mimic the ecological processes that occur within the biosphere.

Therefore, based on the above principles, the following figure (*51*) depicts the technical description of the processes within a Living Machine or Solar Aquatic System:

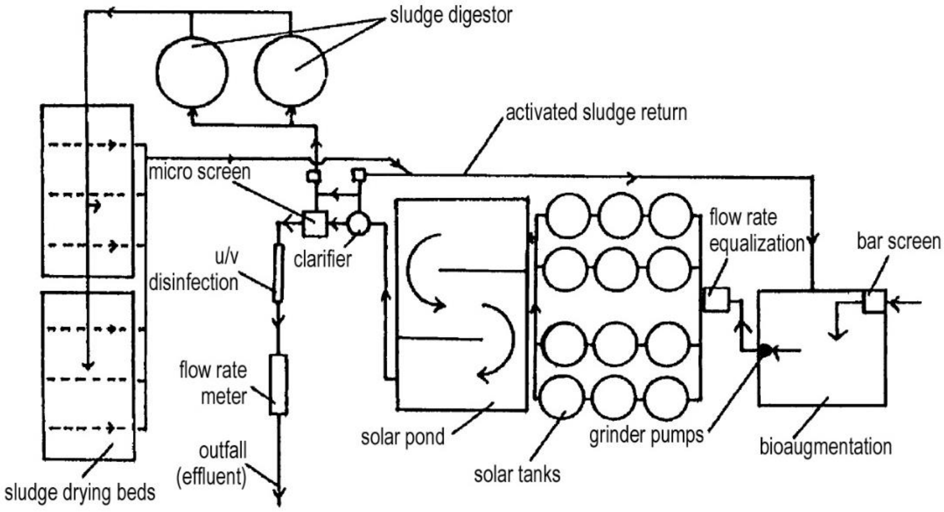


Figure 51: diagram illustrating the technical layout within a solar aquatic sewage waste water system – example taken from Bear River Solar Aquatic System setup. (Ramjohn, 1999: 47). The Use of Solar Aquatic Biological Wastewater Treatment System in Sustainable Community Design.

Together, the intensified ecological processes presented above reduces the sewage wastewater of - biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphorus (P), Nitrogen (N) and substantially reduces the level of total suspended solids (TSS) (Ramjohn, 1999: 44).

Solar Aquatics – Living Machine then provides a means for the treatment of sewage wastewater, whilst providing habitats for an array of species. In addition, Stephen (1998: 165) states that a pivotal aspect of a solar aquatic facility is that it poses as a natural, pleasant, odor-free space within a greenhouse. Thus, suggesting that the attractiveness of the ecological technology encourages awareness associated with nature, ecosystem conservation and construction, waste reuse and wastewater treatment. The formula for utilizing ecological processes within the biosphere to effectively foster human – industrial processes and activities then begins to draw links towards the research. Furthermore, by understanding the programme and spatial requirements (*fig 51*) of a solar aquatic facility, it then becomes a notion that can be easily integrated as a natural system within an architecture.

As with any process or activity, the output is normally waste. Therefore, the research shall now explore the possibilities of waste byproducts exuded by the above biological wastewater treatment systems.

3.5.5 Activated sludge: disposal and other byproducts

As discussed above, both biological wastewater treatment systems offer immense ecosystem services. This investigation is then aligned with Industrial Ecology: Next Industrial Revolution and the "cradle to cradle" concept, towards understanding the possibilities of the waste exuded by the biological wastewater treatment systems that could be a resource for other living organisms, or a byproduct for other processes.

According to Ramjohn (1999: 138), water and activated sludge are two of the most common waste products that are discharged at the end of both biological wastewater treatment processes. Water being more attainable of the two, therefore has a significant commercial value and is often sold for irrigation purposes or specific industrial activities. However, discharging the water product into surface water bodies is not an uncommon sight.

Activated sludge then refers to the sludge that is removed from the sewage effluent by bacteria and microorganisms. Therefore, activated sludge is a combination of sludge and bacteria (Ramjohn,1999: 138). This form of waste is the more versatile product, due to the high level of pollutants that had been effectively removed. In some cases, the activated sludge product is further utilized by solar aquatic facilities, by reintroducing the mixture into the system, should there be a need to increase bacterial entities. Lyle (1996: 61), suggests that activated sludge can be discharged into an anaerobic digestion process, which allows the sludge to mix with methane forming bacteria. Thus, converting the residual waste into a biogas, later becoming a source of power and fuel. Furthermore, due to the intensity of the bacterial makeup of the sludge and the lack of contaminants, the waste then serves as a rich fertilizer to build agricultural soil and ecosystems. However, oppose to that of constructed treatment wetlands, solar aquatics utilized a higher level of species, that thrive of the activated sludge, providing two more byproducts: animals and plants (Ramjohn, 1999: 139).

With the continuous flow of nutrients and food, animal species mature at an extensive rate, thus allowing them to be harvested at relevant intervals. Larger fish species introduced into the ecosystems to regulate the food chain have potential commercial value. Tilapia, a common species utilized within solar aquatics is proven to be in demand for human consumption (Ramjohn, 1999: 139). Similarly, Grass Carp, Flathead Minnows and Golden Shriners have become a food source for humans, but at a lesser value. Ramjohn, (1999: 139) suggests that mollusks, such as mussels, snails and crayfish may also be harvest by local communities and restaurants as they hold great commercial and culinary value. As with the diverse animal species, solar aquatics utilizes a host of plant life - from trees, shrubs, flowering plants to foliage and vascular vegetation. Therefore, developing organic gardens that produce herbs, vegetables and other edible plants then become a source of food for local communities and restaurants.

This exploration gives insight to the many opportunities that are offered by nature's regenerative industry, where it begins to facilitate human ecological activities and processes. Moreover, it provides a tangible understanding of this and allows for nature systems to be integrated with an architecture.

3.6 CONCLUSION

Chapter Three has unpacked existing knowledge that is to inform an ecological architecture towards an industrial symbiosis within its host environment.

From this exploration, Industrial Ecology gave insight to the rethinking of the current industrial revolution. Where, architects and designers are to consider an eco – effective, "cradle to cradle" ideology towards products, processes and activities that are to flow in nature or as an independent metabolism. Moreover, this led the research to investigate the idea of "waste equals food" that provided the understanding of the closing of material loops. Thus, informing a regenerative architecture that is to utilize the biosphere in an effective and efficient manner.

It can be assumed that architecture is merely an arrangement of space that creates place, addressing the needs of society. Therefore, Human Ecology through Place Theory gave insight to pre – industrial society's connection with the natural world, despite their shallow ecological thinking, nature had been a formidable part of their livelihoods. Industrial society then lead the research to the fundamental issues that mankind faces today, the environmental destruction that is driven by equity and commerce. Moreover, post – industrial impacts then aligned this thinking with architecture, where man's reliance on the machine began to inform his architecture that is immensely disconnected from that of the natural world.

Following from this, Architectural Ecology through Industrial Ecology provided an understanding of the existing systems within biosphere, and methods in which an architecture could integrate these processes to improve on its efficiency. Thereafter Natural Ecology through the Theory of Ecology gave insight to ecological processes in nature that shall foster human ecological processes, whilst forming as an integral part of architecture.

In the next chapter the research will explore precedent studies that aim to investigate existing architectures. The studies are to be critically unpacked towards understanding of an ecological architecture through lens of the above literature reviews, as well as the theoretical framework. These architectures refer to the Aquaterra Environmental Centre – France and the Water Treatment Plant (WTP) – France.

CHAPTER FOUR: PRECEDENT STUDIES

4.1 INTRODUCTION

The following chapter investigates precedent studies that deal with buildings which are informed by "ecological architecture" and "industrial ecology" as discussed above. These two examples will be critically unpacked through the theoretical framework instated in Chapter Two and research questions established in Chapter One to ensure a clear link to the research problem. Moreover, each study will be explored through the principles of *Natural Ecology*, *Human Ecology*, *Architectural Ecology* and the concept of *Industrial Ecology.* The studies explored below can be located within an industrial landscape and are affiliated with water bodies and natural ecosystems, reinforcing the contextual link towards the uMngeni precinct. The overall aim of this analysis is to investigate and compare the understanding of ecological architectures that is in industrial symbiosis with its host environments towards the ideologies of environmental awareness and conservation.

4.2 AQUATERRA ENVIRONMENTAL CENTRE – [HÉNIN-BEAUMONT, FRANCE]

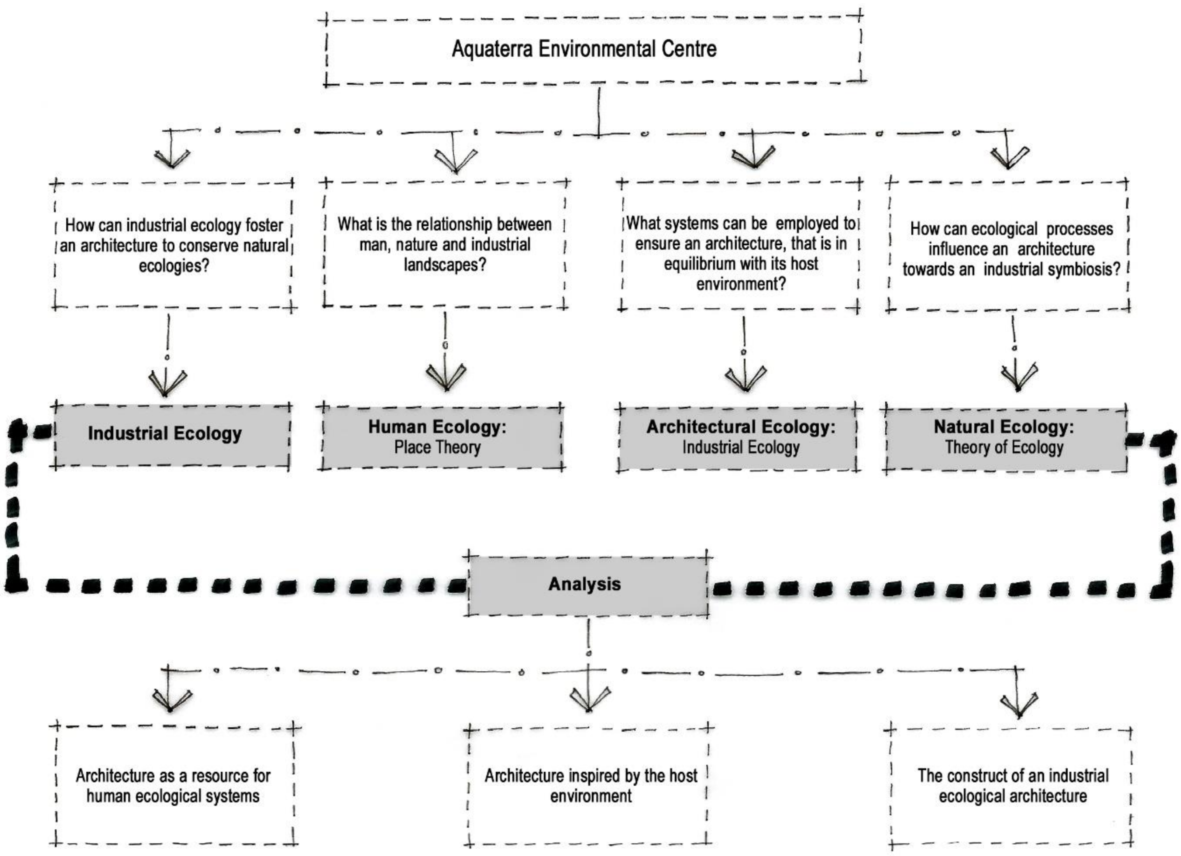


Figure 52: diagram illustrating the critical unpacking of the Aquaterra Environmental Centre – where the architecture will seek to answer questions pertaining to the research, followed by being investigated through the relevant theories and concepts towards understanding the building through the key principles of Human, Natural and Architectural Ecology. 2018, By Author.

4.2.1 Introduction

The Aquaterra Environmental Centre is situated in Hénin-Beaumont, France. The building had been constructed upon the former Drocourt coking plant, also recognized as one of the largest coke production facilities in Europe since the 1920's (Archdaily, 2018). However, due to drastic change in the steel and coal industries during the late 20th century, the plant had closed its doors in 2002. Most of the plant's developments were demolished leaving behind polluted soils and slag heaps that resembled emblematic hills and mountains within a relatively flat industrial landscape. Thus, the Aquaterra Environmental Centre had been conceived as a call for the preservation and restoration of local memory and heritage. As figure (*53*) illustrates, Tectoniques Architects were responsible for the building and utilized the concept of ecological architecture and industrial ecology to resuscitate the love between local people and nature (Tectoniques, 2014). Justification for this study then stems from the building's aspirations towards creating environmental awareness for the end – user, as well as the understanding of an architecture as a demonstrational scheme.

Figure 53: image illustrating site plan of the Aquaterra Environmental Centre, where the scheme resides within a mostly industrial landscape surrounded by slag heaps, (online). 2018.

4.2.2 Architecture as a resource for human ecological systems

According to the architects, the project brief had to consider an architecture that serves as a resource for raising awareness and educating local communities, predominantly the youth. Thus, the Aquaterra Environmental Centre would address questions pertaining to environmental destruction and conservation (Tectoniques, 2014). Moreover, the building encourages the application of modern efficient and effective practices that explore sustainable housing, waste sorting and the idea of material metabolisms.

Figure 54: image illustrating plant life introduced within the building's awareness programme, (online). 2018.

Figure 55: image illustrating plant life introduced around the building's exterior fostering ecosystems, (online). 2018.

As illustrated in figure (*54* and *55*) a significant part of the awareness programme is influenced by ecosystem decay - similar to the impacts of the Industrial Revolution (McDonough and Braungart, 1998), which is demonstrated by various exotic plant life, trees and shrubs, both internally and externally.

Through the lens of Place Theory, the Aquaterra Environmental Centre begins to highlight the pitfalls of Industry, in this case the former coking plant, as well as the destructive livelihood of industrial man. Thus, the building serves as an educational catalyst to stimulate man's once profound connection with that of the natural world, allowing postindustrial locals of the immediate precinct to establish a much more effective place within the biosphere.

4.2.3 Architecture inspired by the host environment

The building forms part of a larger urban scheme, as illustrated earlier in figure (*53*), designed and conceived by the Ilex Landscape Design firm (Tectoniques, 2014). Thus, depicted in figure (*56*) the 45-hectare site had been arranged around playful esoteric islands and artificial lakes providing a new layer of ecosystems that are interconnected through primary and secondary linkages. The design of the scheme had been influenced by the second principle of the Theory of Ecology, where the interconnectedness of processes will result in an outcome that is rich in diversity (Scheiner and Willig, 2008). Therefore, the organic structure was to reverse the image of the former harsh industrial coking facility that had caused environmental decay.

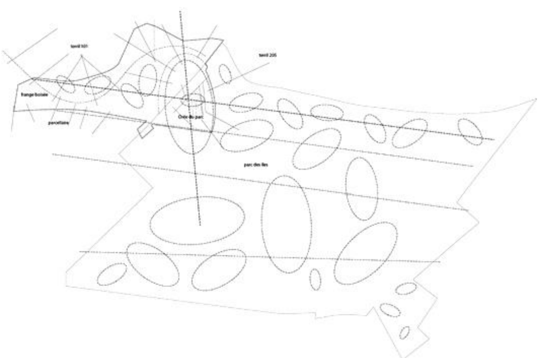


Figure 56: image illustrating urban schematic of the 45-hectar industrial site, (online). 2018.

The new urban scheme had then redefined the host environment that inevitably inspired the building's architecture. According to Tectoniques' (2014) design principle - *architecture must follow the landscape as much as the landscape accompanies the building*, which suggests that the built form takes inspiration from the articulated islands and artificial lakes. Thus, justifying the building lens – shape formation, that naturally fits within the site, to which it forms its own island.

As figure (*57*) depicts, the building's structure stays true to the form - where the structural grid provides the platform for the elliptical form to be achieved. Moreover, a rigid grid system is introduced within the building to further support the roof covering over larger spans.

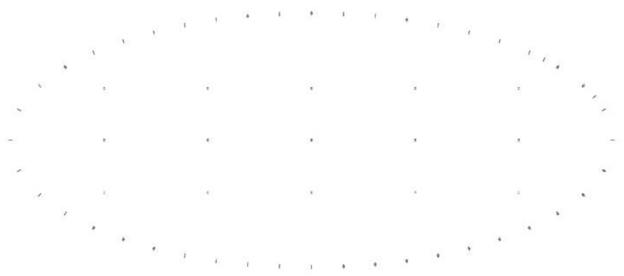


Figure 57: image illustrating the building's structural grid, (online). 2018.

The structural grid allowed for the building's enclosure to emphasize the elliptical form that can be portrayed as universal and generous. As figure (*58*) illustrates, this then allowed the building to achieve a pleasant interface between exterior and interior spaces, as the panoramic façade had been designed to offer transparency and openness.

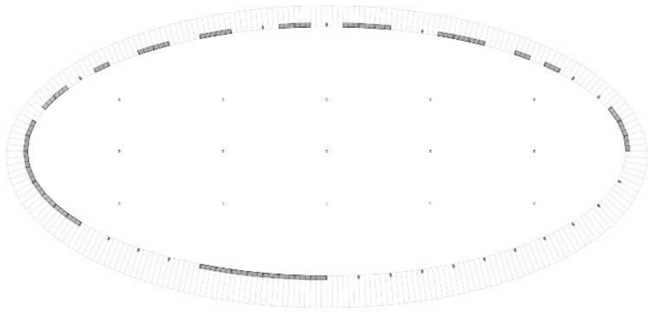


Figure 58: image illustrating the building's enclosure and indoor – outdoor interface, (online). 2018.

The building could then begin to establish its interior spaces. As figure (*59*) depicts, the building had been separated into two zones – the north side had been utilized for office spaces and services, whilst the south side had been implemented as the open – public domain. Thus, the more public zone consists of temporary and permanent exhibition spaces that are linked to a greenhouse, which hosts various environmental features that will be explored in "investigating [eco – efficiency]" in the next subchapter within this study (Tectoniques, 2014).

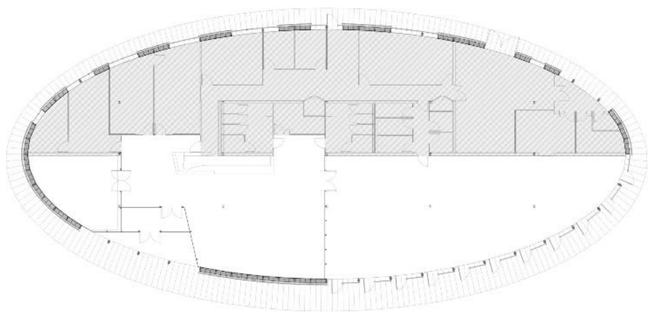


Figure 59: image illustrating the building's floor plan – internal spaces, (online). 2018.

This investigation then gives insight to the artificial implementation of ecosystems, where through the Theory of Ecology, the lakes and islands would begin to foster new or existing organisms. Therefore, it can be assumed that the redefined host environment and its ecosystems had influenced the building's architectural language. Aligned with the thinking of Gu and Evans (2010), the building then serves an evolutionary paradigm that fosters the relation between people and nature, industrial history and the future, as well as architecture and the industrial landscape.

4.2.4 The construct of an industrial ecological architecture

4.2.4.1 investigating [eco – efficiency]

This section shall investigate the Aquaterra Environmental Centre's eco – efficient architecture, that encourages the building's awareness programme. Therefore, this exploration shall dwell on: *rainwater harvesting, two-way ventilation, passive solar gain and control, wind energy and activate solar gain.*

The building's roof structure had to be considered as a rainwater harvesting device (Tectoniques, 2014). Thus, as figure (*60*) illustrates, the roof successfully captures rainwater runoff into harvesting tanks, that is later used for the sustenance of plant life within the greenhouse and the flushing of toilets.

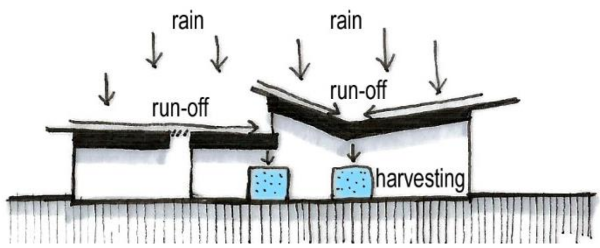


Figure 60: illustrating the Aquaterra Environmental Centre's rainwater harvesting system. 2018, By Author.

The arrangement of the built form also allows for cross ventilation and air – exchange. Depicted in figure (*61*) and aligned with the thinking of Lyle (1996), the building utilizes lower air inlets and higher outlets to induce the movement of air to ensure thermal equilibrium.

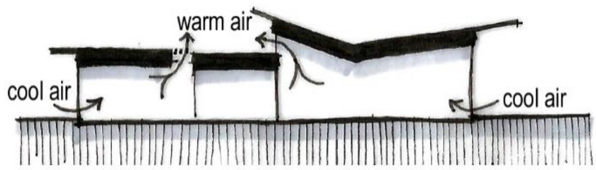


Figure 61: illustrating the Aquaterra Environmental Centre's two – way cross ventilation. 2018, By Author.

Similarly, the building's form promotes passive solar radiation through transparent surfaces and openings, illustrated in figure (*62*). Thus, fixed overhangs and moveable shading devices are implemented to control harsh radiation during the summer. This eco – efficient technique is not only vital for thermal comfort of the end - user, but it is to support the plant life within the building's greenhouse facility.

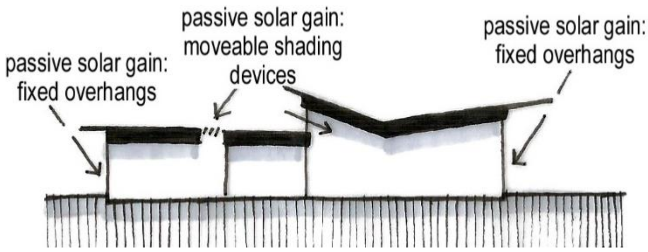


Figure 62: illustrating the Aquaterra Environmental Centre's passive solar gain and control. 2018, By Author.

Aligned with the Next Industrial Revolution, the building utilizes the biosphere's energy. Illustrated in figure (*63*), wind turbines and photovoltaic panels convert natural energy into stored electricity to support various activities and processes within the building's programme.

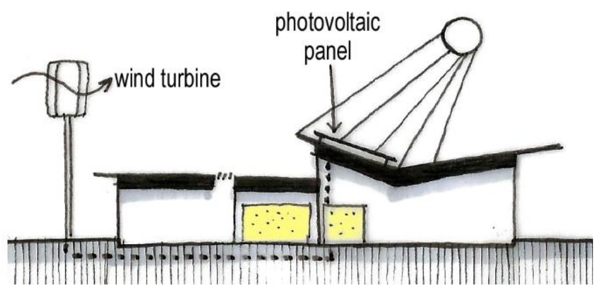


Figure 63: illustrating the Aquaterra Environmental Centre's active solar gain and wind energy. 2018, By Author.

The above analysis then gives insight to the Aquaterra Environmental Centre's eco – efficient techniques. Moreover, it has highlighted the building's roof structure that is to be treated as an educational fifth façade that allows for extensive planting, rainwater harvesting, the housing for photovoltaic panels as well as its arrangement to allow for passive solar radiation and induced air movement. However, to fully understand the building's aspirations towards achieving environment awareness through Ecology and Industrial Ecology, the research shall dwell deeper into the building's eco – effectiveness.

4.2.4.2 investigating [eco – effectiveness]

This section will then critically unpack the building's composition as a system that may flow within the biosphere as a nutrient or something that can contribute to an already existing material metabolism. Therefore, this study will explore the following: *dry construction, bio – sourced materials, permeable façades* and *the tectonics of an effective architecture.*

The building's construction method stays true to Tectoniques' design principles, where for an effective architecture to be conceived, there should be a certain level of quality and care taken to the treatment of the host environment (the site). Thus, the building is constructed mostly with a dry construction technique, that utilizes a combination of steel and timber (Tectoniques, 2014). Aligned with the concept of Industrial Ecology – where an industrial system is not viewed in isolation, rather in relation to its context. This suggests that the building's architecture is inspired by existing structural elements found within the host environment: large steel portal frames and standardized industrial steel sections.

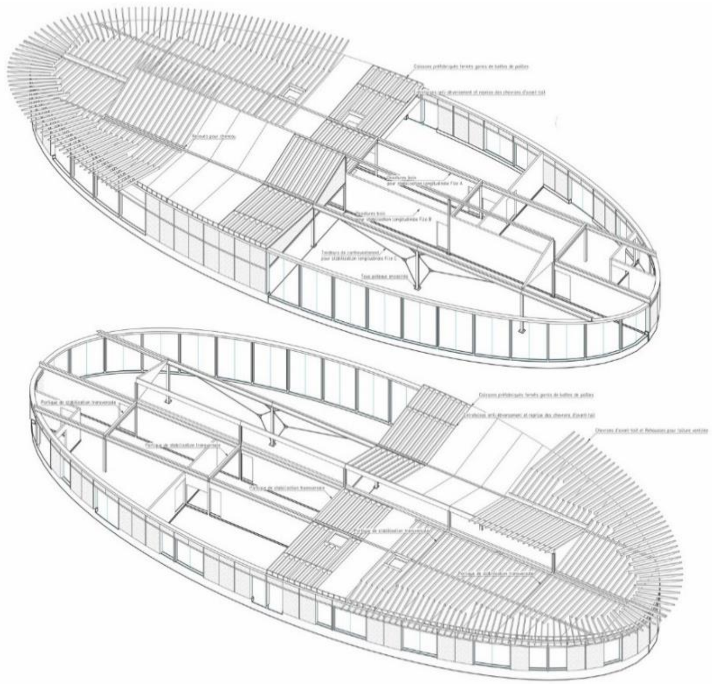


Figure 64: image illustrating the building's structural layout, (online). 2018.

As figure (*64*) illustrates, the Aquaterra Environmental Centre is built around three primary steel portal frames, with various secondary steel sections that are to accommodate for the roof's formation. Therefore, these steel structures can then be regarded as technical nutrients that may continuously flow as steel within both the industrial or construction industries. Moreover, the modularity and standardization of the steel elements ensures that it can be prefabricated, lowering the amount of energy spent in the development of the building whilst causing less environmental damage to the host environment.

The building's secondary structure then considers load bearing walls and roof, which consists of timber – boxed elements (*fig 65*) that are packed with straw bales (*fig 66*). Thus, the utilization of bio – sourced materials led the architects to use timber for the primary walling structures and finishes, insulated by straw bales, as both materials are of plant life origin and are produced locally (Tectoniques, 2014).

Figure 65: image illustrating the building's prefabricated timber – boxed enclosures, (online). 2018

Figure 66: image illustrating the building's straw bale insulation packed within the cavity of the timber – boxed enclosures, (online). 2018.

This proposes that the building's enclosures can be conceived as both technical and biological nutrients. Similar to that of the steel structure, the timber elements may flow as technical nutrients throughout its life cycle, whilst the straw bale elements may then flow as a technical nutrient should there be a greater utility for it, or it can be returned to the biosphere safely as a biological nutrient that offers nourishment to the soil. Aligned with *Economy* and *Equity* within the Next Industrial Revolution, the straw bales then offer an affordable yet effective insulation for the built form that does not intend to harm the end – user nor natural ecosystems.

As a continuation of the bio – sourced structure and insulation, the building's façade is then completed through a succession of wood brick elements that makes reference to local memory and preindustrial building techniques (Archdaily, 2018). As figure (*67*) depicts, this permeable façade is then arranged through interlocking bricks fixed to steel framework rods. This allows the wall to be perceived in two ways: from a distance it resembles an ordinary brick wall, however, close up – it can be seen as a light skin curtain that is permeable and transparent. The modularity of each brick then allows it to be

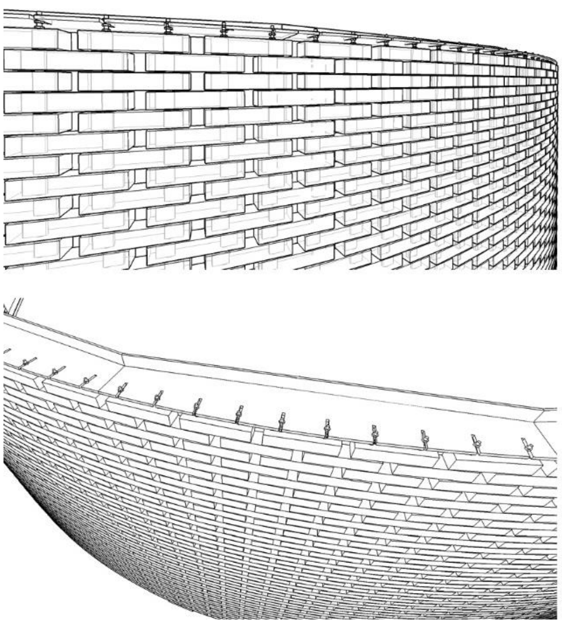


Figure 67: image illustrating the building's permeable facade, (online). 2018.

conceived as a technical nutrient that may be utilized as a wood brick throughout its life cycle, or depending on the brick's finish and protective coating, it may be returned to the soil as a biological nutrient which poses the idea of a biological façade.

Lastly, this investigation examines the tectonics of an effective architecture, which considers the way in which the above materials are brought together to supplement the built form's programme. Figure (*68*) illustrates the arrangement of the various materials that contribute to a structurally sound building. However, the materials stay true to their form and are expressed to the end – user, as tangibility is a key factor in the creation of awareness. Moreover, the tectonics address human scale and do not intend to overwhelm the end – user.

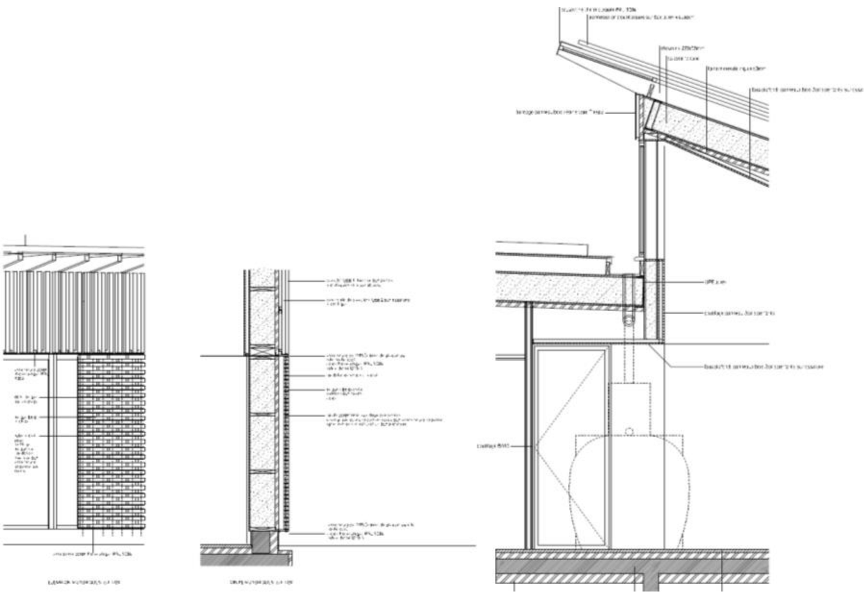


Figure 68: image illustrating the eco - effective tectonics of the Aquaterra Environmental Centre, (online). 2018.

4.2.5 Sub – conclusion

The Aquaterra Environmental Centre provides the research with the understanding of an architecture that is a direct consequence of industry, where it is to raise awareness around the destructive industrial history, as well as the ecological future of the precinct through memory and tangibility. Aligned with Industrial Ecology, the architectural formation had been influenced by the host environment and its context which further instated the building's sense of contextual identity.

Similarly, the building's formation had to consider the utilization of the biosphere's energy, ensuring its ability to efficiently foster processes and activities. Unpacking the materiality of the built form, it then poses as a system than can flow within the biosphere as either a technical or biological nutrient, ensuring that the building's materials can be adaptively reused or returned to the earth safely.

The next precedent study will explore the relationship between man, nature and hydrology, where the treatment of water forms part of the main component in creating environmental and ecological awareness.

4.3 WATER TREATMENT PLANT – [ÉVRY, FRANCE]

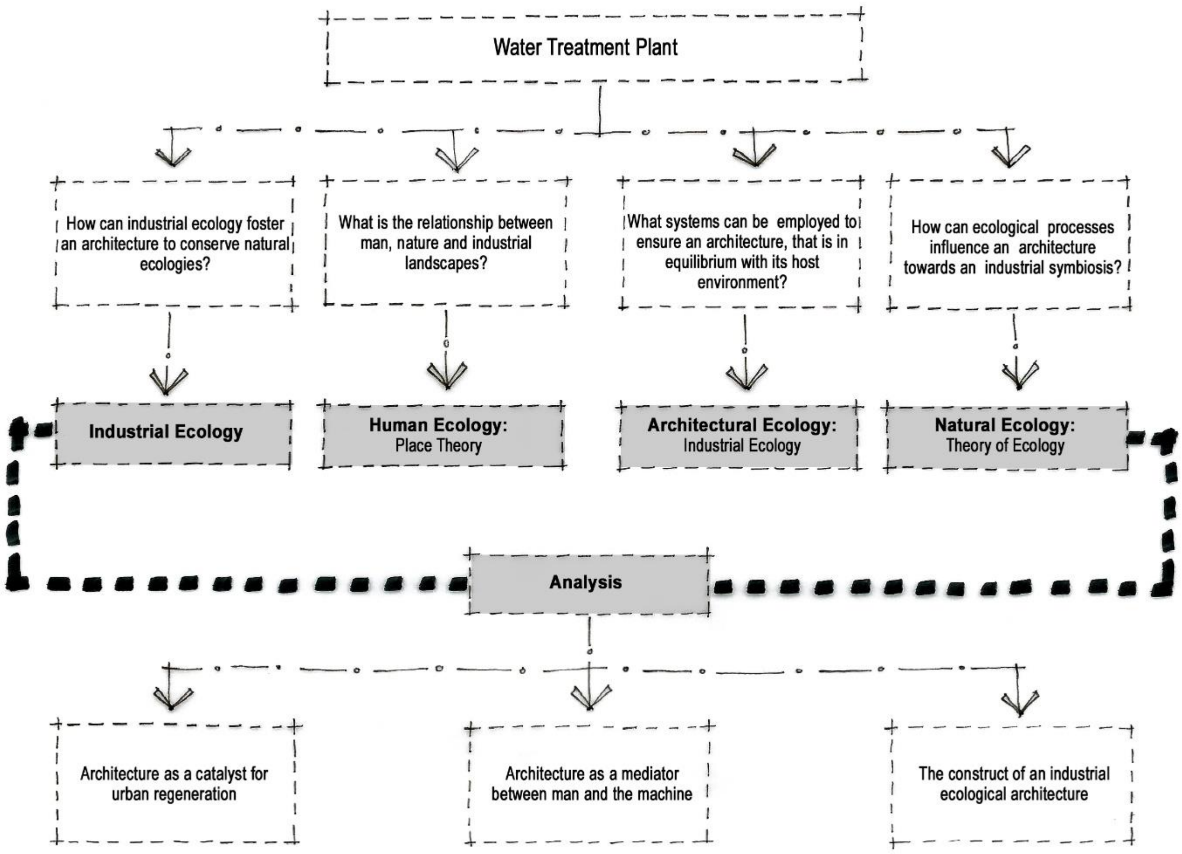


Figure 69: diagram illustrating the critical unpacking of the Water Treatment Plant – where the architecture will seek to answer questions pertaining to the research, followed by being investigated through the relevant theories and concepts towards understanding the building through the key principles of Human, Natural and Architectural Ecology. 2018, By Author.

4.3.1 Introduction

The Évry Water Treatment Plant can be located along the edge of the Seine River, France (Archidose, 2018). The original plant had been constructed during the 1970's, mostly dealing with the purification of wastewater for local suburbs. However, rapid urbanization of the late 20th and early 21st centuries began to inundate this industrial process, placing the immediate biosphere under immense strain. Thus, AWP had successfully won a bid in 2003 to which the team of professionals had to upgrade and revitalize the old 1970's facility, whilst doubling the plant's treatment capacity, propose four new buildings and drawing in a public route through the site.

AWP (Miesharch, 2018) suggests the treatment of wastewater had been a previously rejected and hidden notion. Thus, the architectural response then utilized this infrastructure as a new form of prominence within the urban fabric – where it transforms the built form from a functional building into a symbol that celebrates the ideologies of man, nature and hydrology through an industrial lens.

Justification for this study originates from the building's aim in creating a local landmark within an already established industrial landscape, through the concept of industrial ecology towards the awareness of natural ecosystems. As illustrated below in figure (*70*) the built environment clings onto its host environment mediating between dualistic settings: river/city, machine/man and industry/nature.

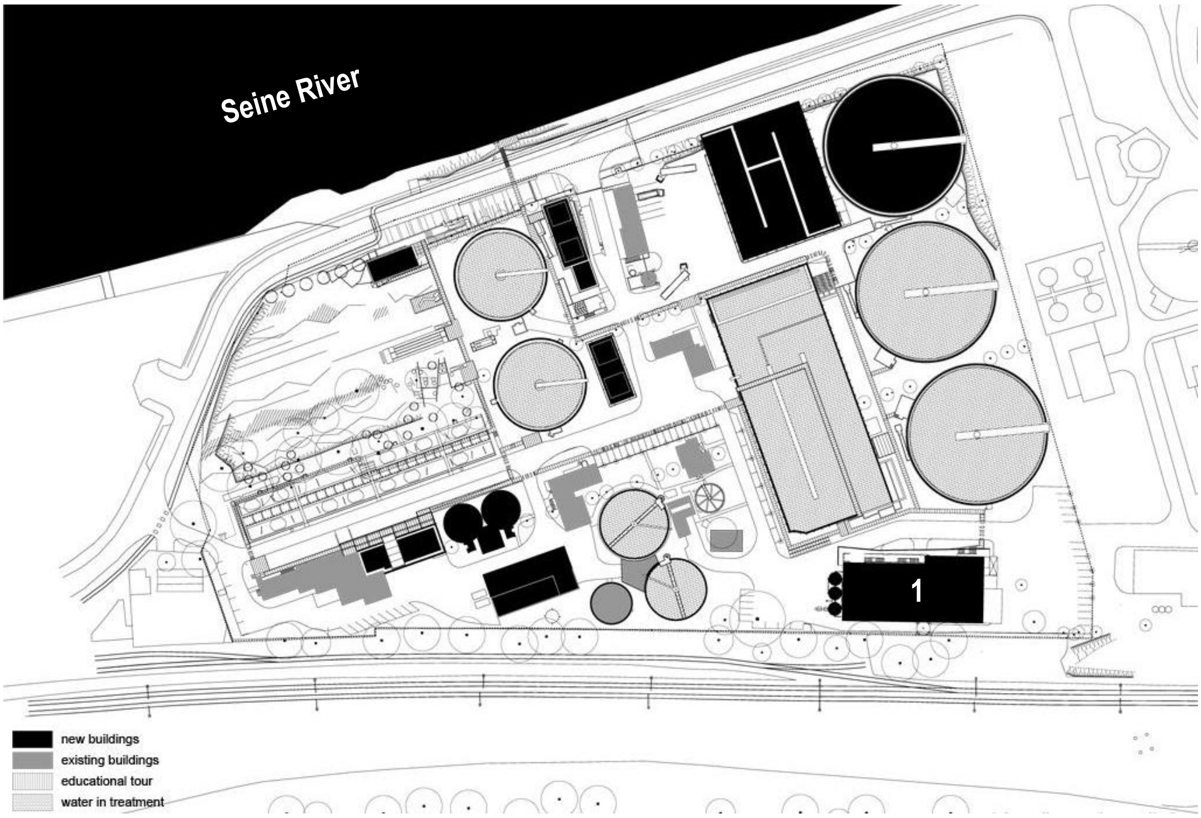


Figure 70: image illustrating site plan of the Évry Water Treatment Plant – where building (*1*) will be explored in more detail below, (online). 2018.

4.3.2 Architecture as a catalyst for urban regeneration

As previously mentioned, the new architectural response then had to serve as a catalyst for change on both the micro (host environment) and macro contexts. Aligned with the concept of Industrial Ecology, the architecture stays true the site's post – industrial history, maintaining the modular, open – plan arrangement. As figure (*71*) illustrates, machinery and services are placed within strategic spaces to allow visitors to permeate through the building, experiencing various hydrological processes.

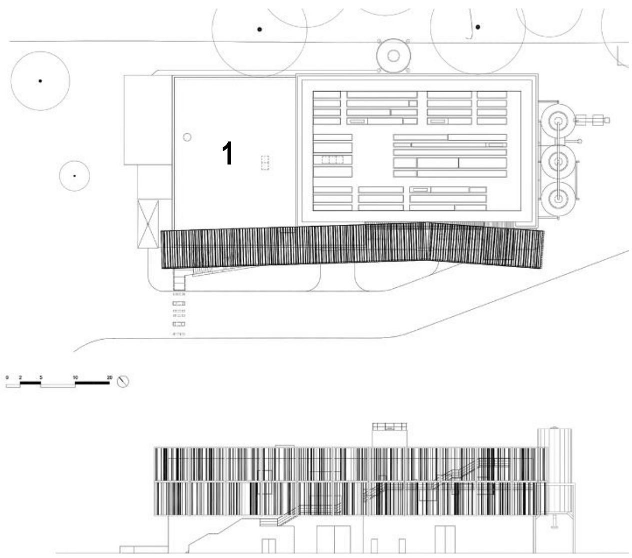


Figure 71: illustrating the plan and elevation of building (*1*), (online). 2018.

Figure 72: illustrating external view of Water Treatment Facility, (online). 2018.

Where the project brief had suggested that a part of the plant's renovations should consider a public component, AWP then had to explore the ideas of identity and way finding through the architecture. As figure (72) depicts, the architects had utilized wooden screens, or as AWP (Archidose, 2018) suggests – "urban scale filters", that softens the harshness of the mostly concrete plant. This design criteria further highlights the old and the new, creating an architectural language throughout the site and establishing a sense of place. Moreover, the wooden screens bring a sense of human scale to the vast buildings, also illustrating parts of the plants that are open to the public.

4.3.3 Architecture as a mediator between man and the machine

According to AWP (Archidose, 2018) the project brief had further required the architectural response to treat the design as a park, based on a water filtering theme, encouraging the idea of "useful infrastructure". This suggests that the architects densified the host environment through buildings and structures, whilst any remaining spaces were transformed into small gardens that are accessible to the public. Aligned with Place Theory explored in Chapter Two, this notion suggests that architects had created a platform through which man may reconnect to the natural world within the parameters of industry. As figure (73) illustrates, public gardens and greenery then become the metaphorical bridge that allows architecture to mediate between man and industry – often changing society's negative perception on industrial landscapes.

Figure 73: illustrating the Water - Plant from a garden view, (online). 2018.

Furthermore, by introducing gardens and natural fabrics, this proposes that the design began to extend and reconnect natural ecosystems which may have been lost due to urban sprawl. Aligned with the Theory of Ecology, this creates an enhanced platform for biodiversity to manifest, essentially exposing the public to long lost natural environments. Thus, creating awareness around hydrology and natural habitats, whilst celebrating man and industry.

In support of this, the design had then to consider public routes in and around the site. However, to further support the hydrological awareness and educational component, designers had introduced elevated public walkways through the plant. As figure (*74*) illustrates, the walkways share infrastructure with the public, whilst creating connectivity and convenience for pedestrians and visitors.


Figure 74: illustrating the elevated public walkway in the Plant, (online). 2018.

4.3.4 The construct of an industrial ecological architecture

4.3.4.1 investigating [eco – efficiency]

This section is a critique of the Évry Water Treatment Plant's eco – efficient architecture that shall inform the architectural response within this study. Therefore, this analysis will uncover the following attributes: *passive solar gain and control, as well as wind energy.*


Figure 75: illustrating the passive solar gain, (online). 2018.

The reconstruction of Évry Water Treatment Plant allowed the proposed administrative and public spaces to utilize passive solar gain. Aligned with the thinking of Lyle (1996), the buildings maximize solar radiation through full – height transparent surfaces. As figure (*75*) illustrates, public walk ways and passages are naturally lit as they are arranged along the Southern axis to exploit solar radiation techniques (Archdaily, 2018).

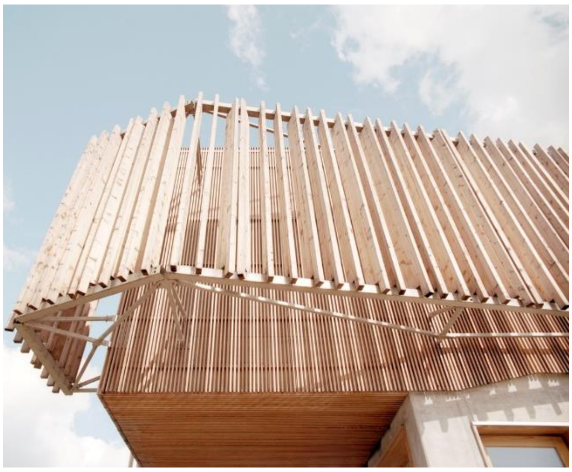


Figure 76: illustrating solar control, (online). 2018.

As with any industrial building, specific activities or processes may require cooler spaces than that of the building's exterior (Lyle, 1996). Therefore, the buildings utilize shading devices to assist with passive solar control. Apart from the "urban scale filter" design ideology, the individual slats of timber are able to move independently, suggesting that designers had paid careful attention towards the movement of the sun and seasonal change.

Figure 77: illustrating the utilization of wind energy, (online). 2018.

As the Next Industrial Revolution suggest, a building must maximize solar gain and any energy created within the biosphere. Thus, the Évry Water Treatment Plant further utilizes energy generated by the wind. Similar to the ideologies provided by Bjørn and Strandesen (2011) – the scheme simply converts wind energy into stored electricity for smaller buildings through small to medium size wind turbines.

4.3.4.2 investigating [eco – effectiveness]

This section aims at analyzing the Water Treatment Plant's eco – effective architecture, whereby the composition of the buildings within this scheme could be categorized as either a biological or technical nutrient that may contribute to either the biosphere or an existing metabolism. This study will therefore explore the following: *timber screens, prefabricated steel structures and the continuation of the hydrological cycle.*

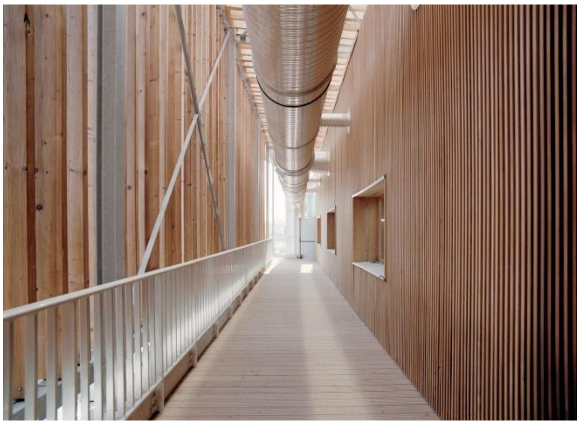


Figure 78: illustrating timber and steel components, (online). 2018.

Figure 79: illustrating extension of the hydro - cycle, (online). 2018

Figure (*78*) illustrates the combination of timber and prefabricated structural steel that is utilized within the plant's architectural arrangement. This proposes an architecture that is simple in its form but high – tech in its thinking, where the timber components may then fade due to time and exposure to the elements, whilst breaking down and releasing its nutrients back into the soil. Therefore, the timber slates can be considered biological nutrients, and easily replaced as their life cycle's come to an end. Similarly, the structural steel components are designed and arranged as modular sections, allowing them to be flexible and adaptive. This proposes that the structural steel components can be considered as technical nutrients, as they can easily and effectively be upcycled or adaptively reused within its next life cycle. Figure (*79*) illustrates the scheme's ability to continue the hydrological cycle. According to AWP (Archidose, 2018) excess rainwater or water byproducts are then discharge at a slow rate into reflective ponds and constructed wetlands. Aligned with the Next Industrial Revolution, it ensures that excess water is not treated as waste, but rather it is returned to the atmosphere through evaporation.

4.3.5 Sub – conclusion

The Évry Water Treatment Plant provides the research with the understanding of an architecture that has the ability to serve as a catalyst for change on a macro and micro level. Thus, the architectural response defined by AWP suggests that industrial processes and activities within the 21st century are to utilize its infrastructure to mediate among man, nature and industry.

Furthermore, the plant's design gives insight to public and visitor permeability, where the buildings are arranged and designed around human scale and public convenience, inevitably supplementing the awareness of hydrological processes. Aligned with "eco – efficiency" and "eco – effectiveness", the plant houses buildings and structures that can easily flow in the biosphere as either technical or biological nutrients.

4.4 CONCLUSION

This chapter unpacked precedent studies that deal with ecological architecture and industrial ecology. Aligned with the Theoretical Framework, Research Questions and Literature Review, this investigation provides the research with the understanding of an architecture that is a direct consequence of the harsh fragmentation created by industrial processes of the 20th century.

Similarly, research further gained understanding of how architecture may then serve as a catalyst for change and as a point of insurgency to reintroduce man to that of the natural world within an industrial landscape. Therefore, it can be assumed that the built environment may act as a mediator between natural and man-made environments.

The research will now explore a case study within the uMngeni Precinct, that is to inform ecological architecture within an industrial landscape, as well as provide the means via which primary data can be obtained.

CHAPTER FIVE: CASE STUDY

5.1 INTRODUCTION

The following chapter shall investigate a case study that intends to inform an ecological architecture that is in an industrial symbiosis within its host environment. As illustrated below in figure (*80*), the uMngeni Green Hub: Ecotourism Centre will be critically unpacked through the research questions established in Chapter One and the theoretical framework employed in Chapter Two. In addition, the analysis will consider personal observations and interviews where possible. Thus, the case study will seek to answer questions pertaining to the research, whilst being analyzed through Place Theory, Theory of Ecology and Industrial Ecology.

This allows the investigation to draw an analogy towards the principles of Human Ecology: *fostering a human ecological support system*, Natural Ecology: *the host environment as a generator for ecological architecture* and Architectural Ecology: *towards an industrial ecological architecture.* Therefore, the overall aim of this study is then to understand these attributes towards the ideologies of environmental awareness and conservation.

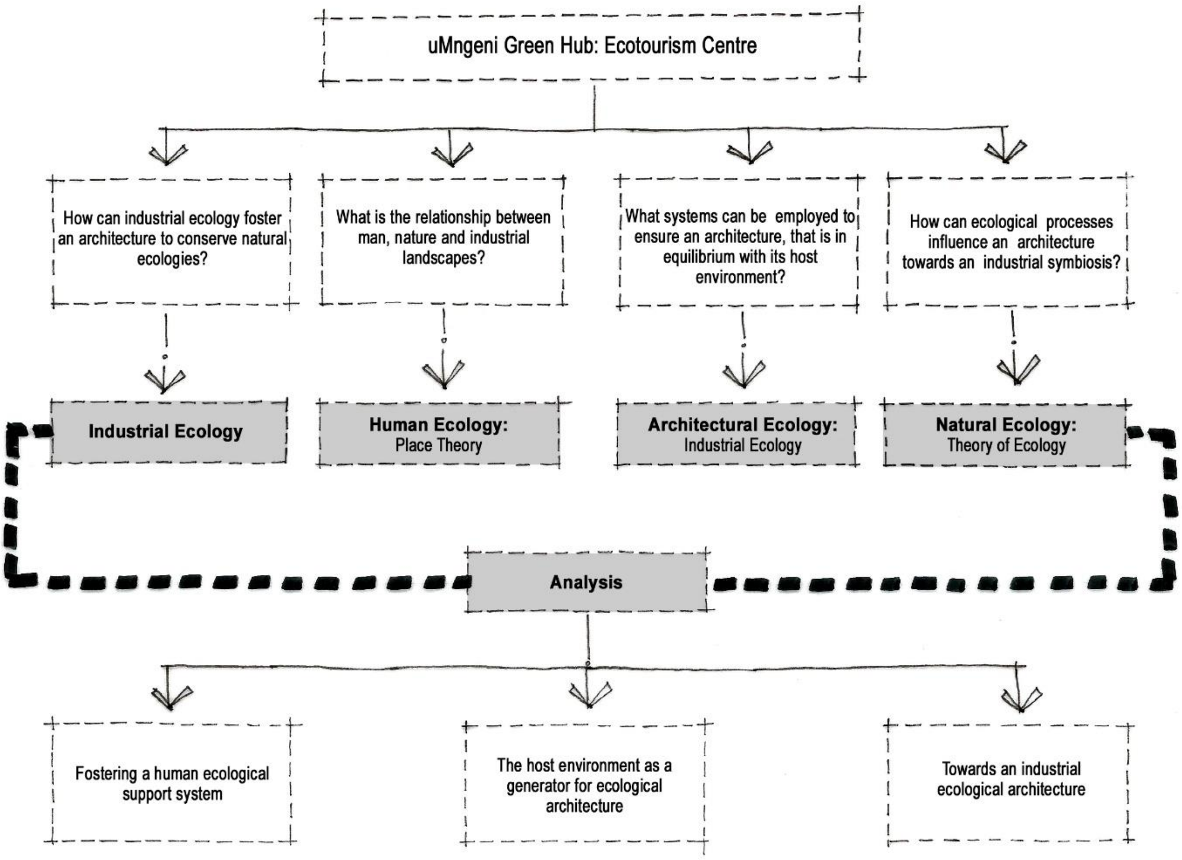


Figure 80: diagram illustrating the critical unpacking of the uMngeni Green Hub: Ecotourism Centre – where the case study will seek to answer questions pertaining to the research, followed by being investigated through the relevant theories and concepts towards understanding the building through the key principles of Human, Natural and Architectural Ecology. 2018, By Author.

5.2 UMNGENI GREEN HUB: ECOTOURISM CENTRE – [DURBAN, SOUTH AFRICA]

5.2.1 Introduction

Established in 2010, the Green Hub can be located alongside the uMngeni River estuary, in Durban, South Africa. Justification for this study is a direct consequence of how the building had been conceived. Owned by the Parks, Leisure & Cemeteries Department, the architectural brief of the project was to provide a space for environmental awareness and ecosystem conservation (Durban.gov, 2018). Budgets for the building was a result of carbon – offset funds linked to the city hosting the 2010 world cup. Thus, the eThekwini Municipality City Architects were responsible for the building's design and had to align their thinking with an eco - friendly concept, as the building had to then host the 17th Annual United Nations Climate Change Conference the following year, in 2011 (Durban.gov, 2018). With multiple environmental influences, the building now serves as a tourism information centre for the greater Durban area (Opengreenmap, 2013). Therefore, as illustrated in figure (*81*) below, further justification for this investigation comes from the building's close proximity to the uMngeni River and Beachwood Mangroves as it would begin to contextually inform the principles of Human, Natural and Architectural Ecology.

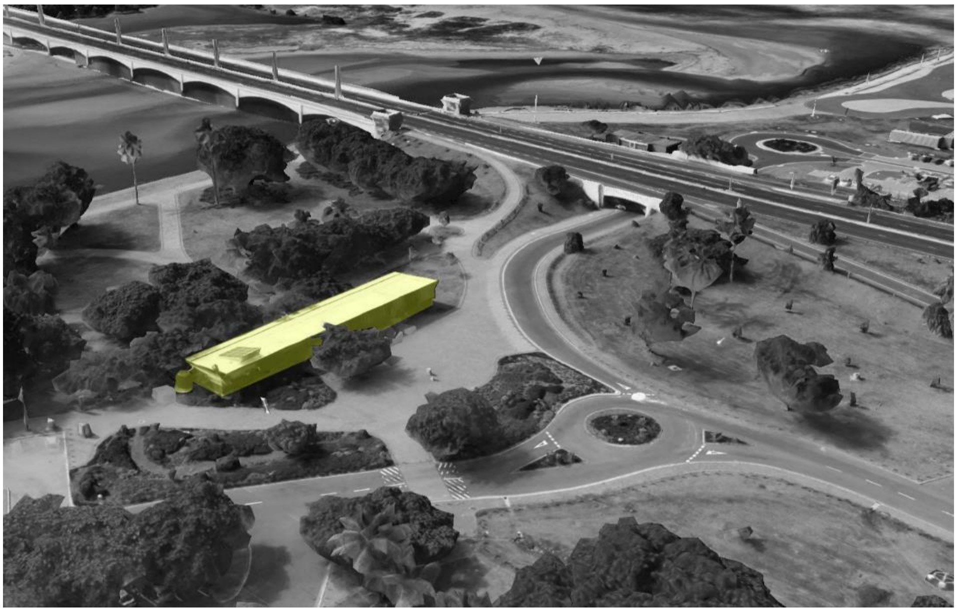


Figure 81: illustrating aerial view of uMngeni Green Hub: Ecotourism Centre, Durban, South Africa – and its interface with the estuarine body of water, (online). 2018. (Adapted by Author, 2018)

5.2.2 Fostering a human ecological support system

The Green Hub now hosts "Durban Green Corridors" - an organization that acknowledges the deep ecological meaning of nature in relation to society. Therefore, the building then serves as a support system for socio – economically excluded communities through skills development and job creation (Durbangreencorridor, 2016). This is accomplished by informal green hubs that operate within the areas of Inanda, Kwamashu and Kwadabeka that rely on the Green Hub as a central node for resources and infrastructure. Moreover, the Green Hub then ensures that all skills that are obtained by local communities to improve their livelihoods are based around their local landscapes. Aligned with Place Theory, this practice ensures that people exploit their environments in an efficient and effective manner, more so, helping them establish themselves within the biosphere (Durbangreencorridor, 2016). As illustrated by figure (*82*), a lady being trained to grow and harvest her own food, this however, does not only ensure communities of a food source, but a greater understanding of the always changing environment, as well as the monetary value of a successful agrarian lifestyle. Similarly, figure (*83*) depicts a local tourism trainee being taught about establishing successful hiking trails around serene ecosystems, that is normally done by them removing alien plant life and shrubs. This ensures that locals are aware of the rich biodiverse value of their landscapes that could improve on their livelihoods. Thus, linking the analysis towards *equity: social justice*, described within the Next Industrial Revolution.

Figure 82: illustrating local lady being taught by a Durban Green Corridors member how to successful plant and harvest their own food, (online). 2016.

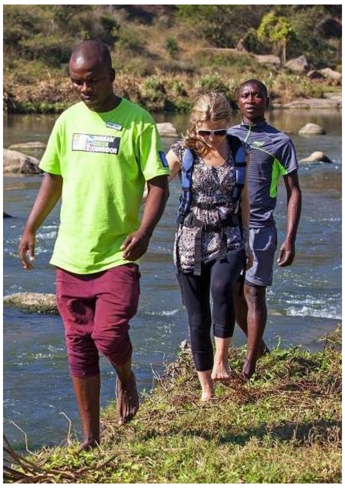


Figure 83: illustrating local man being taught by a Durban Green Corridors member on how to develop their own tourist trails, (online). 2016.

5.2.3 The host environment as a generator for ecological architecture

Considering the above discussion, it can then be assumed that the Green Hub had been conceived through environmental awareness and conservation. According to Habbib (2016), plastics and pollutants were the main cause for ecosystem decay along the uMngeni River and had major impacts on animal and plant life, illustrated in figure (*84*). Aligned with the Theory of Ecology, with emphasis on the distribution and abundance of organisms, the building had then begun to support this notion and adopted various organizations that would facilitate in the rehabilitation of ecologically strained ecosystems (Durbangreencorridor, 2016). These included: Durbanites

Figure 84: illustrating Beachwood Mangroves Nature Reserve manager, Basil Pather displaying plastics and waste products trapped within the mangroves, (online). 2016.

Against Plastic Pollution (DAPP) (*fig 85*) and Duzi uMngeni Conservation Trust (DUCT) (*fig 86*). Thus, the Green Hub's programme had been transformed into a common gathering facility for organizations and volunteers that shared the same passion, resulting in the removal of plastics and maintaining clean surface water.

Figure 85: illustrating DAPP cleaning up the uMngeni River and surrounding ecosystems, (online). 2016.

Figure 86: illustrating DUCT with a "litter boom" that they have erected - as well as sewage effluent on the water's surface, (online). 2018.

As per the Theory of Ecology established in Chapter Two, it described processes that are to be flexible and resilient within the biosphere whilst conserving ecosystems in all their spatial scales. It is evident that the architecture of the Green Hub adopted this notion as it had been influenced by an array of fluctuating environmental factors which adapted to change and provided a platform for new activities and processes, thus giving insight to the beginning of an ecological architecture, that is influenced by its host environment. The next subchapter shall dwell on the Green Hub: Ecotourism Centre's eco – efficiency and eco – effectiveness.

5.2.4 Towards an industrial ecological architecture

5.2.4.1 investigating [eco – efficiency]

This section is a critique of the Green Hub's aspiration towards an eco – efficient architecture, that begins to inform the architectural response within this research. Therefore, the study shall uncover the following attributes: *rainwater harvesting, solar energy, natural lighting, natural ventilation, architectural form* and *indoor and outdoor interfaces*.

As illustrated in figure (*87*), a prominent feature of the Green Hub's design is two large rainwater harvesting tanks that rest upon meticulously off shuttered concrete plinths (Opengreenmap, 2013). It is there to display the building's "sustainable" consciousness. Moreover, with similar thinking to Rahman and Jahra (2007), water is obtained from the building's roof structure as it is the most hygienic platform for capturing rainwater runoff.

Figure 87: illustrating rainwater harvesting tanks. 2018, By Author.

The primary use of the harvested rainwater is for the flushing of ablutions and sanitation purposes, as the building is presently not properly equipped with water purification technologies yet.

The architect's deep ecological thinking becomes apparent, where the Green Hub is not designed in isolation, but rather in relation to its host environment. This can be identified through the manipulation of the rainwater harvesting tanks. As illustrated in figure (*88*), the tanks then act as an integral part of the Green Hub's architecture towards an inclusive design in a mostly public domain. Firstly, the designers recognized socio – recreational activities within the immediate context (for example: outdoor grilling) thus, the tanks allow the public to access its stored water to supplement their activities. The second attribute illustrated in figure (89) then refers to the design of the water source as a central gathering space often affiliated with local landscapes (Rahman and Jahra, 2007). This is emphasized by the plinth that allows for gravity to transfer water, more so, towards its design where it becomes a part of the urban furniture, in this case – a seating platform. This begins to highlight the importance of rainwater harvesting, as an eco – efficient technology as well as a source of sustenance for the end – user.

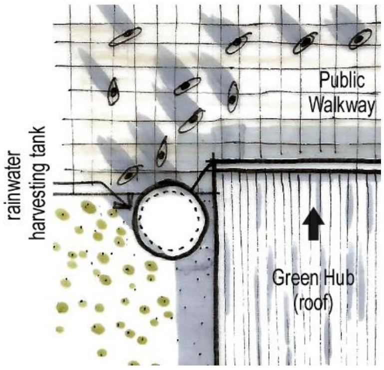


Figure 88: illustrating an urban plan – view of the rainwater harvesting tank as an integral part of the architectural design. 2018, By Author

Figure 89: elevation of a rainwater harvesting tank as a both a "green" technology, as well as urban furniture. 2018, By Author.

The building's design demonstrates another eco – efficient technique, generating its own energy through active solar radiation (Durban.gov, 2018). This is predominantly achieved by 12 photovoltaic panels that transform solar radiation into useable energy for the building's utilization. Each panel generates approximately 200w of energy that ensures 6% efficiency (Solartechnology, 2018). Therefore, the Green Hub boasts up to 72% efficiency, providing its own electricity.

As with any eco – efficient architecture, designers paid careful attention to building orientation, which inevitably supports the photovoltaic panels. As illustrated in figure (*90*), the panels are fixed upon the roof structure that ensures a vast amount of sun exposure over the Northern axis. To further support this technique, the photovoltaic panels are able to tilt according to seasonal changes, described in figure (*91*).

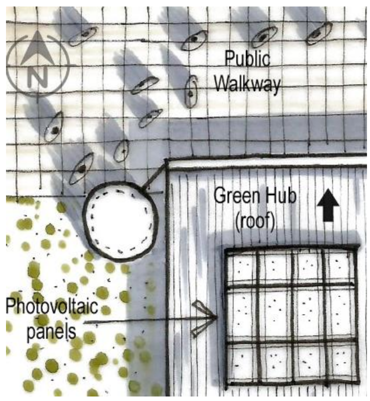


Figure 90: illustrating pv panels upon the Green Hub's roof. 2018, By Author.

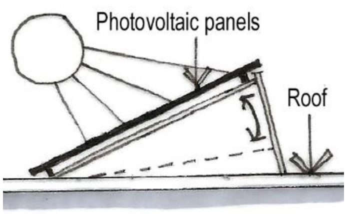


Figure 91: illustrating pv panel inclination. 2018, By Author.

Aligned with the fourth principle of the Theory of Ecology and one of the early traits uncovered towards an ecological architecture within this study, designers acknowledged seasonal change (Scheiner and Willig, 2008). Therefore, the simplistic design of the photovoltaic panels allows it to be flexible in nature, working with geographical contingencies instead of manipulating the natural environment to suite human demands.

In support of the photovoltaic panels, the building utilizes passive solar radiation techniques towards minimizing the need for artificial lighting (Opengreenmap, 2013). As illustrated below in figure (*92*), the building achieves this through large facing North – South elevations. Moreover, figure (*93*) then illustrates a substantial amount of glazing that allows for natural light to permeate into the built form. Thus, giving the interior space a sense of openness and defining a comfortable place for the end – user.

Figure 92: sketch illustrating site plan (orientation plan) of the Green Hub: Ecotourism Centre within its host environment. 2018, By Author.

Figure 93: illustrating naturally lit interior of the Green Hub. 2018, By Author.

To further support the notion of passive solar radiation, the building utilizes existing deciduous trees located on the Northern elevation, depicted in figure (*92*) to act as a "living" shading device during the summer (Lyle 1996: 108). In addition, towards an ecological architecture, designers had recognized the effectiveness of the vegetation, which sheltered the Green Hub from dust and sand, also serving as a form of air purification.

The movement of air through the built form then becomes the next eco – efficient technique explored within this study. Similar to that of natural lighting, the Green Hub's architecture utilizes a series of design principles to achieve natural ventilation (Opengreenmap, 2013). Thus, creating an architecture that's thermally comfortable for the end – user, whilst eliminating any mechanical or artificial aeriation. Aligned with the thinking of Lyle (1996, 108) the building utilizes cross ventilation; whereby the inlet and outlet openings are parallel and are further induced by large over-hangs, illustrated in figure (*93*).

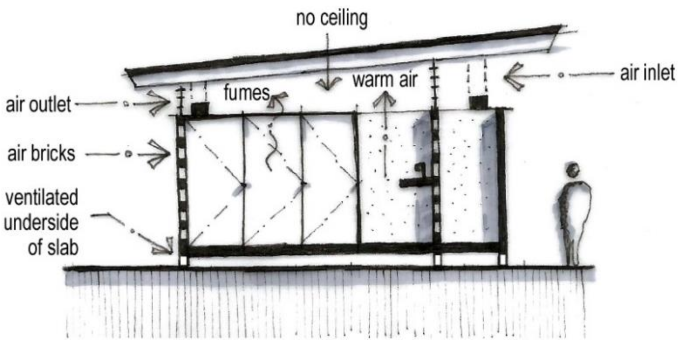


Figure 94: illustrating natural air ventilation techniques utilized within the Green Hub's eco – efficient architectural design towards an ecological architecture. 2018, By Author.

It then becomes evident that the Green Hub functions with existing energy flows to facilitate its programme. However, to fully understand this efficient technique, the research shall dwell deeper towards the building's more public facilities: the restrooms. As figure (*94*) illustrates, designers utilized the movement of air to naturally ventilate the restrooms by not implementing a ceiling, which ensures that any form of odor and warm air may be easily discharged by induced winds beneath the roof cavity. Airbricks are then introduced as a permeable enclosure, that allows for enhanced ventilation and natural light to occur within these spaces. Similar to the thinking of Lyle (1996, 105), the building also utilizes an elevated slab that allows air to move freely around the structure, alleviating pockets of warm air, maintaining a thermally balanced interior space.

This thinking begins to uncover another trait towards an ecological architecture, where form and space are to be arranged in accordance with the host environment. Thus, the process in determining an architectural form should be based on the principles of Human and Natural Ecology (Gu and Evans, 2010), as opposed to fixated ideas of the designer. The research will now seek to uncover eco – efficient techniques that had influenced the Green Hub's architectural form.

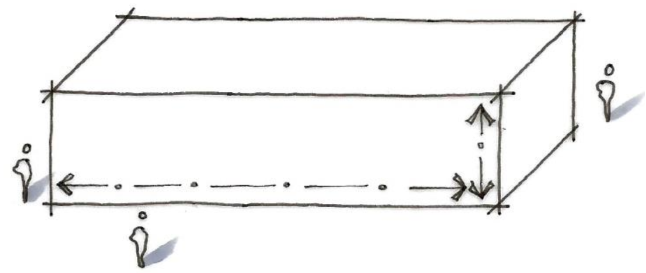


Figure 95: sketch illustrating the horizontality of the Green Hub's form and appearance, highlighting its relation to the biosphere and human scale. 2018, By Author.

The building's design employs a form that is more horizontal than vertical, as illustrated in figure (*95*). This defines the architecture's relation to the earth, whilst acknowledging human scale, as the design does not intend to engulf these two attributes. However, at this stage, the form creates a strong edge – like boundary.

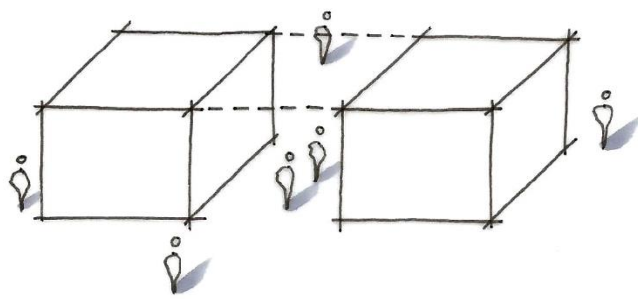


Figure 96: sketch illustrating the form being pierced by an open courtyard that intends to highlight permeability, visual links, as well as a sheltered gathering space. 2018, By Author.

Thus, figure (*96*) depicts the horizontal form being pierced by a central open space. The courtyard then allows for pedestrian permeability, visual contact, as well as a cavity that further induces wind movement.

The central courtyard had then been introduced as a covered gathering space, allowing for other human activities to manifest, thereby highlighting a key principle with an eco – efficient architecture, where it is to consider choice, convenience and connectivity of the end – user.

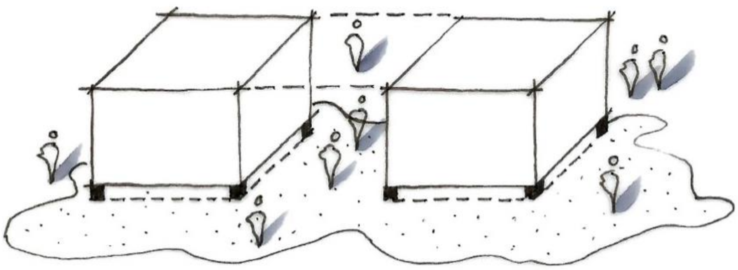


Figure 97: sketch illustrating the floor plane extrusion of the form, that highlights the sensitive approach upon the Earth, as well as the architectural response towards building upon a floodplain. 2018, By Author.

With the above in mind, figure (*97*) then illustrates the extrusion of the built form, where the floor planes are elevated. In conjunction with the underfloor ventilation explored earlier, this design ideology responds to the building being constructed upon a floodplain. Therefore, in the case of a flood, water could easily pass under the structure. Moreover, this extrusion portrays a sensitive junction between the built form and the biosphere, where it deems to be "respectful" towards its host environment.

It can be assumed that form defines the possibilities of space, to which architecture then begins to redefine that space into place (Norberg-Schulz, 1985). Thus, the research shall now explore the quality of place within the Green Hub.

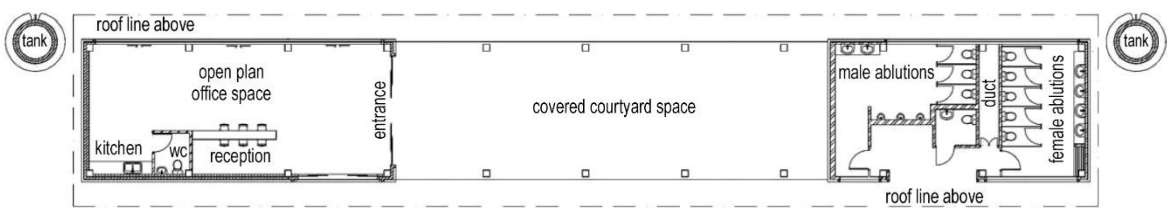


Figure 98: illustrating the floor plan of the Green Hub – with emphasis on the indoor and outdoor interfaces. (Hunt, 2011: 12). KZ-NIA Journal: Environmentally Responsible Design (Adapted by Author, 2018)

The central courtyard space is easily defined by two small rigid forms (Hunt, 2011:12), as illustrated in figure (*98*). However, the functional requirements of the Green Hub's programme is minimal, accommodating for open – plan offices, public ablutions and the covered courtyard which is intended to be a children's demonstration area. Through site visits, the ablutions have a relatively privatized interface within the public domain, whilst the central courtyard offers great opportunity for events and gatherings to spill out into the green spaces. Thus, the office spaces merge with the courtyard providing a pleasant interface between the two entities.

Aligned with "*economy; market viability"* mentioned in the Next Industrial Revolution, the Green Hub considers access and permeability as a key driver towards awareness, whilst using the central courtyard as a platform to generate an economic fabric that ensures a self-sustaining return.

5.2.4.2 investigating [eco – effectiveness]

This section is an analysis of the Green Hub's architecture towards an eco – effective design. Moreover, it is to critically unpack the built form as a nutrient that may flow in nature or one that can create a thriving material metabolism (McDonough and Braungart, 2003). This study will then investigate the following attributes: *upcycled timber (fig 99), reusable enclosures (fig 100)* and *waste equals food (fig 101)*.

Figure 99: illustrating the Green Hub's exposed timber rafters. By Author.

Figure 101: illustrating the Green Hub's enclosure, materials and textures. By Author.

Figure 100: illustrating the Green Hub's recycling corner. By Author.

In support of the building's efficiency, the architecture had considered other effective solutions, more specifically aligned with material metabolism explored within the Next Industrial Revolution. Thus, suggesting that designers had implemented materials with low – embodied energy flows (Durban.gov, 2018). This thinking then provided an enhanced platform for the Green Hub's awareness component, where the tangible elements of the building itself, forms part of the "sustainable" notion introduced to the public.

The Green Hub utilizes exposed timber rafters as a primary structural support for the roof covering. These elements are said to be upcycled hardwood timber components that are joined together through various fixtures. As illustrated in figure (*102*), timber from hardwood trees that are redefined into its first utility, thereafter, the material had been upcycled for purpose of the Green Hub's shelter. It can then be assumed that the Green Hub's architecture supports the material metabolism of the hardwood timber as a technical nutrient that can continuously flow as timber throughout its life cycle. In support of this, depending on the chemicals used to treat and protect the timber, it may even be considered a biological nutrient - where after its third or fourth utility, it can return to the soil safely. Aligned with The Next Industrial Revolution uncovered earlier, this suggests

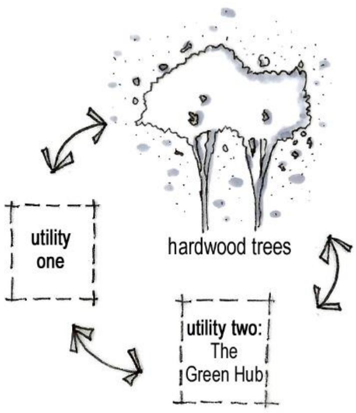


Figure 102: sketch illustrating the material metabolism of timber utilized within the Green Hub's roof structure. 2018, By Author.

that the Green Hub's architecture considers a closed loop cycle of birth, growth and decay of the timber components.

The Green Hub then utilizes brick as the primary form of enclosure. Unlike the hardwood timber discussed above, the brick is not upcycled or reused. However, as depicted in figure (*103*), due to its modularity, scale and robust aesthetical appeal, the material can be conceived as a technical nutrient that can continuously flow in the construction field. Thus, highlighting another key attribute within an eco – effective architecture, as it considers "future generations", where the bricks could be easily dismantled and utilized in another system.

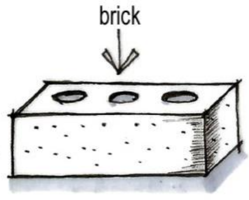


Figure 103: sketch illustrating the single module of a brick, collectively can effectively provide enclosure and privacy, etc. 2018, By Author.

In support of this, the building utilizes air – bricks, that provide a sense of enclosure within a semi - private setting. This material effectively presents the built form with a façade that illustrates permeability and a change of spatial hierarchy. As figure (*104*) illustrates, an air – brick is significantly rigid and robust and falls within a technical nutrient metabolism that can be used continuously or even upcycled to a greater utility.

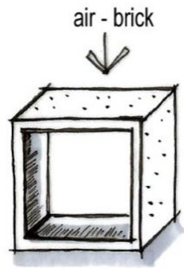


Figure 104: sketch illustrating the single module of an air – brick that provides semi private enclosure. 2018, By Author.

The above analysis gave insight to the Green Hub's material construct that may flow as either a technical or biological nutrient within the biosphere. However, this does not expose the building's treatment of waste.

As uncovered in Chapter Three, the pivotal principle within an eco – effective architecture is aligned with the ideology of waste equals food. Thus, this exploration is to critique the Green Hub's aspirations towards this notion. Figure (*101*) illustrates the start of the process where containers are implemented to efficiently collect various forms of waste exuded by the building. However, as illustrated in figure (*105*) - this poses an issue, as the Green Hub does not ensure that the waste is effectively upcycled, or even downcycled. In most cases, the waste is sent to landfills, where neither biological or technical nutrient may be attained.

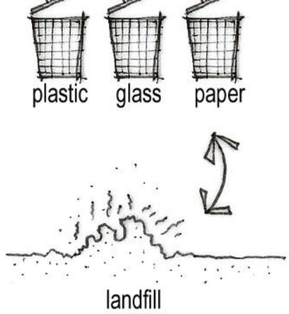


Figure 105: sketch illustrating the Green Hub's waste that is exuded to landfills. 2018, By Author.

Similarly, figure (*106*) then depicts the Green Hub's water closets that discharges human waste through the ordinary method. Discussed earlier by Lyle (1996: 227), this suggests that human waste is not treated as a nutrient, rather, it is piped through a series of mechanical processes and later discharged into a water body as a form of toxin. This begins to highlight a shortfall within this ecological architecture that aims to create environmental awareness, as the building begins to add to the environmental issues that it intends solving.

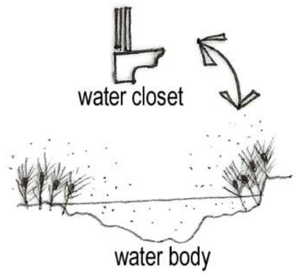


Figure 106: sketch illustrating the Green Hub's waste that is exuded water bodies. 2018, By Author.

5.3 CONCLUSION

The Green Hub provides the research with an understanding of an ecological architecture that is in an industrial symbiosis within its host environment. Moreover, it gives insight to the fostering of Human Ecological systems, as well as the host environment and its Natural Ecologies as a generator for flexible ecological architecture. Thus, these attributes begin to inform the building's awareness and conservation component.

The Green Hub's architecture showed significant efficiency and effectiveness. However, it fell short in the way it dealt with waste. As the study discussed, waste is the prominent form of ecosystem decay within the immediate context. Due to the architecture's lack of infrastructure and facilities, it cannot deal with waste effectively, mainly creating a "cradle to the grave" metabolism. Moreover, the building's interface with the uMngeni River then makes surface water "clean ups" a problematic task.

Therefore, the architectural response within this research shall detract principles from this investigation. These include an architecture's ability to consider both the environment and the end – user, the relevant eco – efficient techniques as well as the materiality of the architecture's eco – effectiveness. Thus, the research shall consider the building's shortfalls as a platform for improvement within its own paradigm, which will include greater infrastructure and facilities for the conservation of natural ecosystems within the uMngeni precinct. Moreover, it is to improve on local communities that are displaced from urban fabrics.

CHAPTER SIX: EMPIRICAL FINDINGS AND ANALYSIS

6.1 INTRODUCTION

This chapter investigates primary data gathered from first hand experiences, interviews and observations. The interviews and observations have been carried out in close proximity to the uMngeni River and the uMngeni Green Hub (Case Study) explored earlier, with a few interviews aimed at professionals from the greater Durban area, as the research utilizes a purposive sampling method. The interviews have been arranged in a similar manner to the literature review within this study. As figure (*107*) illustrates below, the interviews and observations have been influenced by the Theoretical Framework established in Chapter Two, which have been conceived through the Primary and Secondary Research Questions instated in Chapter One. Thus, ensuring a clear and concise link towards the Problem Statement and the overall Aim within this dissertation.

The aim for this chapter is to analyze and discuss the primary data gathered and unpack the overlapping principles of Human, Natural and Architectural Ecology that shall begin to inform an ecological architecture within the uMngeni Precinct.

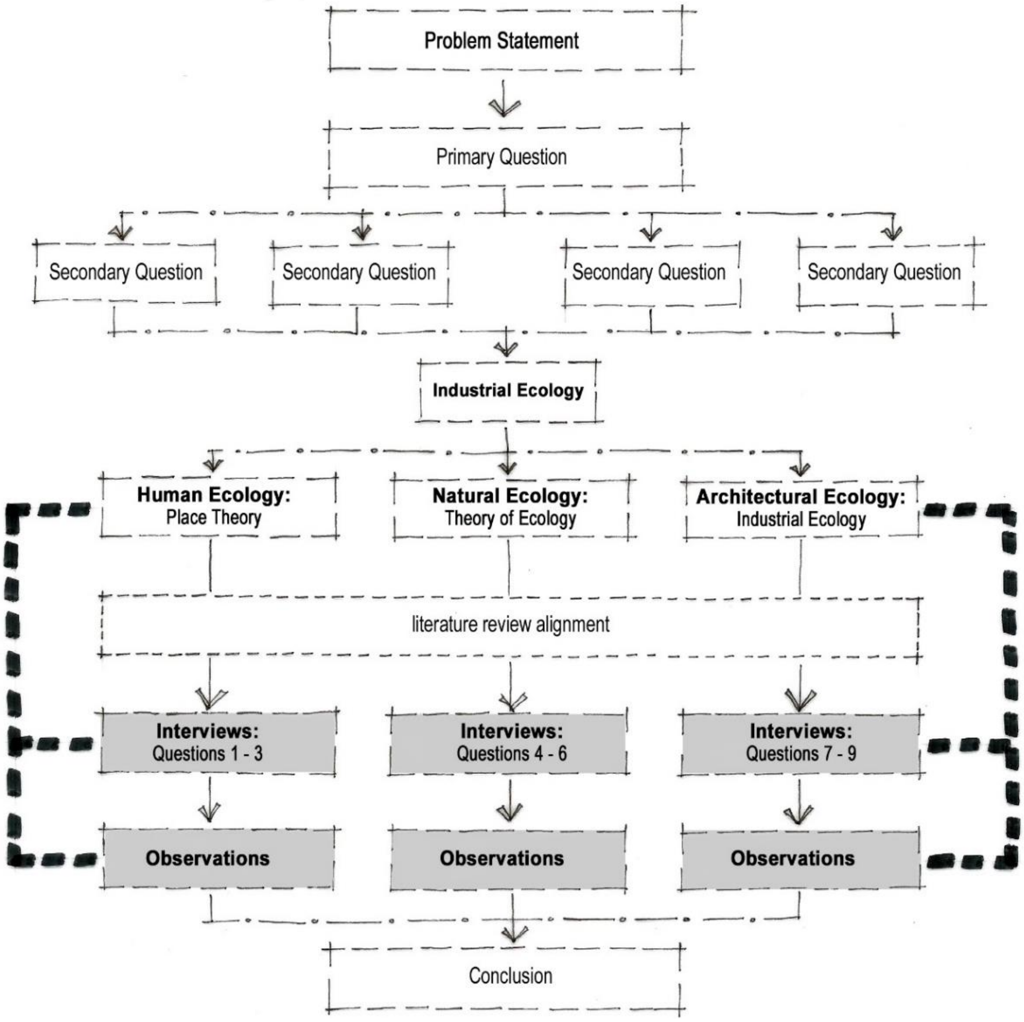


Figure 107: diagram illustrating the process in which the research shall critically unpack primary data obtained from interviews and observations. 2018, By Author.

6.2 ANALYSIS OF EMPIRICAL FINDINGS

The analysis of empirical findings is based on primary data obtained from 20 interviewees from various backgrounds. The less structured interview schedule (*Appendices 03*) has been organized in a way that both professionals and members of the general public could be evaluated and understood on a common platform. Moreover, this allows the research to build up a sample that is rich in diversity and satisfies specific needs. The unstructured – naturalistic observations have then been undertaken whilst investigating the case study within this research.

6.2.1 Macro analysis: [general view]

This section discusses Questions One and Two found in Part B of the Interview Schedule. Where Part A is an optional Personal Analysis, Part B is then a general investigation of people's understanding of ecosystems and natural landscapes.

6.2.1.1 Interviews

Question One: Have you ever considered the impacts of industry on our natural environments?

When asked if interviewees have ever considered the impacts of industry on our natural environments, eighteen out of the twenty responded positively and two out of the twenty participants responded to this question negatively. The eighteen positive respondents shared some unique answers which are based on the idea of conservation, as well as personal experiences growing up in the greater Durban area that exposed them to industrial – ecological destruction. These responses suggest that the destructive path paved by industrial processes and activities have not gone unnoticed by society. The unique responses to this question provide insight into the importance of experience and memory, where the interviewees have personally experienced or felt the impacts of industry on natural ecological systems.

Question Two: Do you think that the derelict state of our natural ecosystems impact on the way society would use or perceive these natural environments?

Eighteen out of twenty interviewees responded yes, whilst two out of twenty participants were left unsure. A common theme amongst the eighteen interviewees who responded yes to the question referred to the "shifting base line" concept, as well as cultural and religious ties to natural ecosystems – as people tend to protect what has value to their livelihoods. These responses then propose that society would shy away from derelict ecosystems, unless they share a deeper ecological connection to the system.

6.2.2 Place theory: [human ecology]

The literature review within this research investigates Place Theory through the principle of Human Ecology. The literature demonstrates man's once profound connection with the natural world, where pre – industrial societies would establish their place within the biosphere based on cultural and semiological influences. With the rise of industry, industrial societies had lost their connection with the natural world as they began to rely more on machines and artificial environments. Place Theory within this investigation then gives insight to the potential of reintroducing man to the natural world, as man and nature should coexist in equilibrium.

The interviews in this section further investigates Place Theory within the industrial setting of uMngeni, and aims to answer the research question of: What is the relationship between man, nature and industrial landscapes? Therefore, Question One, Two and Three of Part C were instated in a simpler manner to allow interviewees to respond concisely and elaborate where they felt necessary.

6.2.2.1 Interviews

Question One: Does the uMngeni precinct hold any personal connection towards you and your life?

Twelve out of the twenty interviewees responded yes, as many of them grew up or still reside within the area of the uMngeni. Six out of the twenty interviewees responded no, whilst two out of the twenty responded uniquely. The unique responses came from interviewees who had no personal connection to the precinct, instead they were academically affiliated with the area.

Question Two: Do you use the area to participate in any sports, recreational, religious or social activities?

When asked if interviewees use the area to participate in any sports, recreational, religious or social activities, seventeen out of the twenty participants responded yes and three out of the twenty responded no. The seventeen interviewees who responded yes, shared similar answers ranging from employment, social gatherings, paddling, cycling, jogging and religious ceremonies along the river banks. This begins to give insight to the overlapping activities occurring within the precinct on a daily basis despite strong industrial – ecological influences.

Question Three: Do you think the state of the river influences the public's perception of ecosystems and water bodies and are there social implications?

Nineteen out of the twenty interviewees responded yes, whilst one out of the twenty responded no. A common theme amongst the nineteen positive respondents referred to the unattractive state of the uMngeni River, where it would begin to create a negative outlook on natural landscapes to the public, as well as portrays a space that is unkept. Most of the positive respondents went further and elaborated on issues related to dead and negative spaces due to ecosystem decay, that begins to encourage illegal or unsafe activities impacting on the quality of place within the area.

6.2.2.2 Observations

Observations of Human Ecologies have been conducted whilst investigating the case study in this research to further understand Place within the uMngeni precinct. The observation considers both tangible and intangible layers of context to explicitly breakdown what has been experienced and observed.

From the researcher's observation with regards to Human Ecologies (the end – user of space) in close proximity to the banks of the uMngeni River, there are strong visual connections to various man – made and ecological nodes. The immediate space is relatively quiet with small clusters of fishermen, cyclists, paddlers, onsite management and the odd social cluster. However, there is a substantial amount of noise pollution generated by the M4 and Riverside Highways that cross over the river itself. The researcher also observed small clusters of vagrants that would cling to dead and negative spaces, regardless of this, the area is relatively safe and secure as security officers continuously patrol the area.

Time within this study then plays an important role, as social clusters grew towards midday, where people would use the area as a place of escape from their busy lifestyles to purchase lunch and refreshments. In support of this demand, informal and formalized economic trade is apparent within the area.

The researcher had then observed various interventions instated to further establish Place for Human Ecologies. This refer to platforms that acknowledge human activities on a local scale to provide a sense of connectivity, choice and convenience. As observed, these attributes consider the provisions made for hardened walkways that link various nodes, park benches, bins, signage, braai facilities, artificial lighting, ablution facilities and barriers between cars and people.

6.2.3 The theory of ecology: [natural ecology]

The literature review within this research investigates the Theory of Ecology through the principle of Natural Ecology. The literature demonstrates nature's industry and how these ecological processes can facilitate human – industrial processes and activities to ensure an outcome that is both efficient and effective. The Theory of Ecology within this investigation gives insight to the potential of utilizing these ecological processes to deal with specific issues within the uMngeni precinct whilst fostering both Human and Natural ecosystems.

The interviews in this section further investigate the Theory of Ecology and aims to answer the research questions instated in Chapter One. Therefore, Question Four, Five and Six of Part C were asked in a simpler form to allow participants to respond concisely and elaborate where they felt necessary.

6.2.3.1 Interviews

Question Four: In your opinion, what do you think are the major influences towards the state of the river of present day?

When interviewees were asked their opinion based on the influences towards the state of the uMngeni river, all twenty respondents answered positively with relatively common themes. These themes referred to public neglect and lack of environmental knowledge and awareness – aligning itself with the "out of sight, out of mind concept". Similarly, all respondents touched on illegal or informal sewage discharge, non-biodegradable pollutants and industrial pollution. Four out of the twenty interviewees provided unique responses that briefly discussed the development of the floodplain, underdeveloped communities upstream and invasive plant life that consumes riparian zones.

Question Five: Through your observation, in what state do you see the river in the next ten years?

Seventeen out of the twenty interviewees responded worse, whilst one out of the twenty responded better and two out of the twenty suggested that the river could remain the same. However, the seventeen negative respondents did suggest that their opinions may change should there be stricter rules and regulations governing the river system.

Question Six: What strategies do you think should be implemented to enhance the biodiversity and quality of water in the river?

Eighteen out of the twenty interviewees responded positively with various strategies that ranged from reinforcing existing legislation and management plans, public clean ups and engagements, river patrollers and visually appealing signage. Unique responses referred to introducing environmental awareness and studies into school curricula and the possibilities of greener buildings and man – made structures. Thus, two out of the twenty interviewees were left unsure.

6.2.3.2 Observations

Observations of Natural Ecologies have been conducted whilst investigating the case study in this research. The aim of this observation is to uncover and examine existing Natural Ecologies to further understand The Theory of Ecology, mostly within the paradigm of the study area. The observation focuses more on the tangible layers of context.

From the researcher's observation, the area has a sense of openness, where induced winds beneath the low bridges cooled down most of the area and the well-maintained grass plains disappear gracefully into the river banks. Clusters of Palm trees and Aloes can be located randomly around the space, as well as generous groupings of "big leave" deciduous trees that serve as natural shading devices and provide homes for various animal life forms. Other animals such as Egyptian Geese, Seagulls, Woolly – Neck Storks and African Fish Eagles can be seen or heard within the immediate area. Similarly, the estuary then serves as the ideal platform for fish species to thrive. The researcher had observed various forms of fish such as Mullet, Spotted Grunter, Flatheads, Mud – bream and other juvenile species exposing themselves in around the mangroves and deeper banks of the river.

During this study, the quality of the river and mangroves appeared to be relatively adequate. Similar to Human Ecology, time within the investigation plays a significant role – depending on the weather, climate and tide. On an outgoing tide, the river banks are then visible, exposing non – biodegradable pollutants, remainders of fruit and cloth from religious activities, as well as fishing line and nets, many of which are entangled within the natural structures. On an incoming tide, the researcher observed salt water entering the estuary bringing in various invasive plant species that inundate local indigenous species, that also causes stress to existing riparian zones.

6.2.4 Industrial ecology: [architectural ecology]

The literature review within this research investigates Industrial Ecology through the principle of Architectural Ecology. The literature reveals that there is a more "effective" manner in which processes and activities can be carried out to ensure overall "efficiency" and a sustainable symbiosis with the biosphere. The concept further instated the principles of: *waste equals food, respect diversity and use solar energy*. This study then gives insight to the potential of utilizing these principles and concepts to facilitate a response that must address both Human and Natural Ecological issues through an Architectural lens.

The interviews in this section further investigates Industrial Ecology through the idea of Architectural Ecology and seeks to answer the research questions established in Chapter One. Therefore, Question Seven, Eight and Nine of Part D were asked in a simpler form to allow interviewees to answer concisely and elaborate where they felt necessary.

6.2.4.1 Interviews

Question Seven: Do you think providing a platform for research and awareness within the uMngeni precinct will create ecological awareness within the public realm?

Nineteen out of the twenty interviewees responded yes to the question, whilst one out of the twenty responded no. The nineteen positive respondents shared some unique answers which suggests that the uMngeni precinct requires a facility to create awareness of vital ecosystems, as man has lost his connection to these Natural Ecologies. Two out of the nineteen positive respondents further stated that should such a platform be proposed, there must be an enhanced interest on a local level.

Question Eight: Should a building be proposed to facilitate research and awareness, what other functions do you think are necessary to bring balance between nature and society?

When asked about what other functions may be necessary within a building that facilitates research and awareness to bring balance between nature and society, nineteen out of the twenty interviewees responded positively and one out of the twenty responded negatively. The nineteen positive respondents shared similar themes which were based on an architecture's ability to address both local and global communities, as well as the building's ability to create jobs, skills development, vibrancy and social fabrics. Some unique answers referred to extending the Riverside walkway, proposing a structure that facilitates with river clean ups and an architecture's ability to seek inspiration from the nature's industry.

Question Nine: Lastly, do you think an interactive and educational building / structure will create awareness for various demographics of our society?

All twenty interviewees responded yes to this question. Three out of the twenty respondents provided unique answers which emphasized the importance of tangibility – where people tend to remember what they physically interact with. This begins to suggest that a building itself is to form part of the story in creating ecological awareness.

6.2.4.2 Observations

Observations of Architectural Ecologies have been examined whilst investigating the case study within this research. Apart from the uMngeni Green Hub: Ecotourism Centre which has been critically unpacked in the previous chapter, this investigation aims at uncovering other built forms or man – made structures in the study area that provide a sense of Place for both Human and Natural Ecologies. The observation focuses on both tangible and intangible layers of context to breakdown what has been experienced and observed.

Based on the researcher's observation, the M4 and Riverside Highway bridges that cross over the river form two strong edges that help define the study area. Moreover, these man – made concrete structures provide a sense of shade and shelter for Human Ecologies. Similarly, where the bridge's vertical members meet the uMngeni River, it begins to create structure and a platform for aquatic and bird habitation. Thus, suggesting that the man - made structure fosters both Human and Natural Ecologies.

Other structures or buildings observed within the study area refer to a small public ablution facility that is defined by a strong boundary, creating a sense of security and defendable space. This building then appears to be the place of rest for most onsite employees as the built form provides shade, change room facilities and a space to lock away valuables. Parallel to this facility resides a medium sized building that is modular in its design, allowing for flexibility and adaptation and houses various small restaurants and stores. This building supplements the study areas publicness and provides an economic layer of exchange.

Another building observed, approximately 280 meters from the public ablution, restaurant facility and the case study, is the King Fisher Canoe Club. The facility comprises of a small reception and lounge area, as well as showers and change rooms that opens into an uncovered courtyard where canoes can be stored and maintained.

Through the lens of Industrial Ecology, the researcher further observed the above Architectural Ecologies that are mostly constructed from air bricks, bricks, steel, concrete and timber that responds to the wear and tear brought by the immense public utilization and exposure to the elements.

6.3 CONCLUSION

The interviews conducted in the Macro Analysis [General View] section revealed that the public is aware of industrial – ecological destruction, which is based on firsthand experience and memory. Furthermore, it has been noted that 90% of the respondents felt that natural landscapes that have been destroyed or consumed by industry, are spaces that are isolated from the public domain. Thus, suggesting that natural systems that are inaccessible to society, have little to no value to people's livelihoods, leaving them vulnerable to the destructive nature of global – industrial processes and activities.

Such as the literature review uncovered in Place Theory earlier, the interviews conducted in the Place Theory [Human Ecology] section reveals that the uMngeni Precinct holds personal connections to various demographics. It has been noted that 80% of the interviewees have either grew up in the area, or still reside in close proximity. Furthermore, 85% of the interviewees utilize the area for sports, recreational, social and religious activities. This suggests that society still recognizes the natural value of the area for activities despite harsh boundaries created by industry. In support of this, the observation undertaken within this section then confirms that people are desperately trying to reconnect with the natural world.

Aligned with the literature review based on The Theory of Ecology, the interviews conducted in The Theory of Ecology [Natural Ecology] section proves that all twenty interviewees are aware of some sort of ecological decay within the uMngeni Precinct and gave insight to various influences that may impact to the state of the river. Thus, 85% of the respondents felt that the river may end up worse. However, it has been noted that the interviewees are aware of interrelated ecological processes in all their spatial scales and provided unique strategies to facilitate in the conservation of these systems. The observation conducted within this section then reinforces the ecological value within the uMngeni precinct that is in dire need of a platform which conserves and fosters Natural Ecologies.

Similar to the literature review explored in Industrial Ecology, the interviews conducted in the Industrial Ecology [Architectural Ecology] section reveals that 95% of interviewees felt that there should be a platform for awareness and education within the uMngeni Precinct. Many of which felt that an architectural response within this scenario must be tangible, vibrant, accessible and aspire to utilize nature's industry. This then provides the potential for an architecture to adopt ecological processes that must respond to local issues, whilst aligning itself to Natural and Human Ecological demands. The observation within this section gives insight to the materiality of various built forms and man – made structures, as they need to respond to the context on a local level. Additionally, this provides the research with the understanding of how the process of architecture and design can be changed, adapted and used differently over time. Subsequently an architecture's ability to align itself with the principles of Industrial Ecology and the Next Industrial Revolution is informed.

The aim of this chapter is to present the primary data collected through less structured interviews and unstructured – naturalistic observations. The primary data obtained forms a vital part of understanding the theories and concepts that are utilized within this document, as well as to critically analyze precedent and case studies. This chapter then provides a basis to which the research questions can be answered and addressed. Thus, the primary data gathered in this qualitative research is crucial in informing the study towards the design of a Centre for Awareness and Research in the uMngeni Precinct.

The information gathered, discussed and synthesized within this chapter will therefore inform the Conclusions and Recommendations chapter that is to follow, where an overall conclusion shall be presented.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 INTRODUCTION

This study sets out to investigate the symbiosis of the natural world in relation to the man – made world. The research uncovered earlier provides strategies, principles and information that can facilitate an Architectural Ecology to deal with Human and Natural Ecological issues within the uMngeni Precinct.

As previously stated, the research had adopted various research methodologies to achieve and address the aims and objectives instated within Chapter One. Where the overall aim of this dissertation is to:

- *To consider ways in which the processes of natural environments may facilitate architecture and the built environment to conserve natural landscapes.*

The research had then instated objectives to explicitly provide the boundaries to ensure that the overall aim can be addressed and achieved. As per Chapter One, these refer to:

- *To improve the quality of water and natural ecosystems of the uMngeni River, through industrial ecological influences on an architecture.*
- *To understand man's place on earth in relation to natural and man – made environments.*
- *To consider systems that will ensure an architecture, is to consume local energies and materials towards a state of equilibrium within its host environment.*
- *To explore ecological processes that may facilitate an architecture towards achieving industrial symbiosis.*

The primary and secondary Research Questions are then established to ensure that the above aims and objectives can be achieved. Thus, as figure (*108*) illustrates and through the lens of the Theoretical Framework, this chapter is the culmination of the Literature Review, Precedent Studies, Case Study and Findings that provides a means for which the research shall answer the Research Questions.

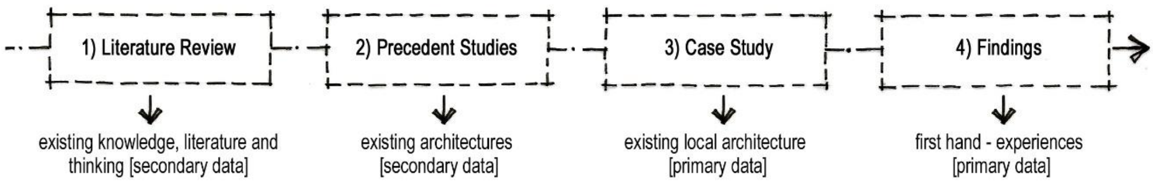


Figure 108: diagram illustrating culmination of research inquiry to achieve aims and objectives through answering relative research questions. 2018, By Author.

7.2 CONCLUSIONS

As with the previous chapter, this section will be unpacked in a similar manner – where questions will be answered relative to the principle, theories and concept that they have been paired with (*fig 109*).

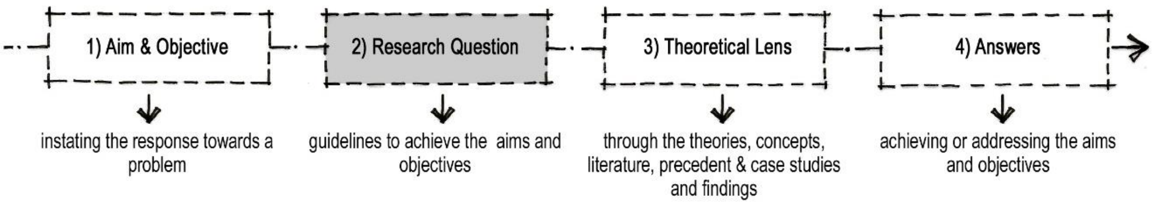


Figure 109: diagram illustrating culmination of research inquiry to achieve aims and objectives through answering relative research questions. 2018, By Author.

7.2.1 Addressing and answering the secondary research questions

Industrial Ecology has been utilized throughout this research as an overarching concept that provided the idea of a "cradle to cradle" thinking towards an architecture that must be "eco – effective". In addressing the research question; *how can industrial ecology foster architecture to conserve natural ecologies?* - the research proves that an architecture must firstly adhere to the principles of the Next Industrial Revolution which forms the basis of an industrial ecological built form. Thereafter, the material construct of an architecture may be conceived as a nutrient that can flow in nature as either a source of food for the biosphere (biological nutrient) or as a continuation of a thriving metabolism (technical nutrient). This concept then goes further and suggests that in order for an architecture to conserve natural ecologies within an industrial landscape, it must consider existing industrial loops which must extend the life of waste byproducts in order for them to return to the biosphere safely, without causing environmental decay.

Human Ecology through Place Theory had been utilized within this research to understand man's once profound connection to the natural world, and how that connection had influenced his architectures. Place Theory suggests that man had lost this connection due to industrialization and the reliance on artificial environments. Thus, posing the research question; *what is the relationship between man, nature and industrial landscapes?* - through the theoretical lens, it suggests that industrialization forced pre – industrial societies to adopt a global lifestyle, segregating them from natural landscapes. Similarly, industry and nature had been perceived as two seperate units. Thus, depicting man, nature and industry as fragmented entities that rely so heavily upon each other. The research then proves that architecture may serve as the pivotal attribute within an industrial landscape that brings equilibrium to man, nature and the "effectiveness" of industrial processes and activities.

Architectural Ecology through Industrial Ecology has been utilized within this research to provide the understanding of architecture as a system in nature. In addressing the research question; *what systems can be employed to ensure an architecture, that is in equilibrium with its host environment?* Aligned with the ideologies uncovered in the Next Industrial Revolution (Industrial Ecology), the research proves that an architecture must utilize the biosphere's renewable energy and resources towards achieving an eco – efficient design. Therefore, for an architecture to serve as a system in nature it must integrate solar energy, wind energy, water energy and rain water harvesting into the arrangement of its form, structure and space.

Natural Ecology through the Theory of Ecology has been utilized within this research to gain insight into ecological processes that can be applied as a system within an architecture. Thus, addressing the research question; *how can ecological processes influence an architecture towards an industrial symbiosis?* Aligned with the thinking of the Next Industrial Revolution, the research proves that specific ecological processes can be adopted within an architectural design to address the needs of man, more specifically within an industrial landscape. Similar to eco – efficiency addressed above, this answer considers eco – effective principles that allows an architecture to extend the life of waste byproducts through nature's technologies. The processes then provide complexity, attractiveness, tangibility and the ability to foster natural systems. These systems refer to; photosynthesis, constructed treatment wetlands, solar aquatic wastewater treatment and sludge disposal.

7.2.2 Addressing and answering the primary research question

Through critical inquiry the research within this study then forms a culmination of knowledge to which it may answer the primary research question; *how can biodiversity facilitate architecture towards an industrial symbiosis that will positively impact on the conservation of natural environments and estuarine ecosystems?*

The literature, precedent, case studies and findings within this dissertation proves that architecture can be influenced by biodiversity – where it is to utilize high – tech thinking as opposed to high – tech technologies. Furthermore, this high – tech thinking can then be paired with low – tech technologies, which poses simple architectural forms that can be successfully upcycled in their next life cycle. Similarly, for an architecture to foster both Natural and Human Ecological processes and activities, it must utilize technologies provided by the biosphere as opposed to artificial machinery, that adds to the environmental decay which it is intended to mitigate.

7.2.3 Addressing and achieving the aims and objectives

This section then proves that the overall aim and objectives for this research have been achieved through the primary and secondary research questions. Thus, the above section provides the answers for these questions, suggesting that the aim and objectives have been achieved through critical theoretical inquiry.

7.3 RECOMMENDATIONS AND DESIGN PRINCIPLES

The recommendations presented within this section influence the principles of architectural design derived from the Research Questions, Theoretical Framework, as well as the primary and secondary data unpacked within this research. The diagram below (*fig 110*) makes reference to the overriding concept of Industrial Ecology instated in Chapter Three and illustrates a culmination of various recommendations and design principles adopted from this study that ensures a research – led design.

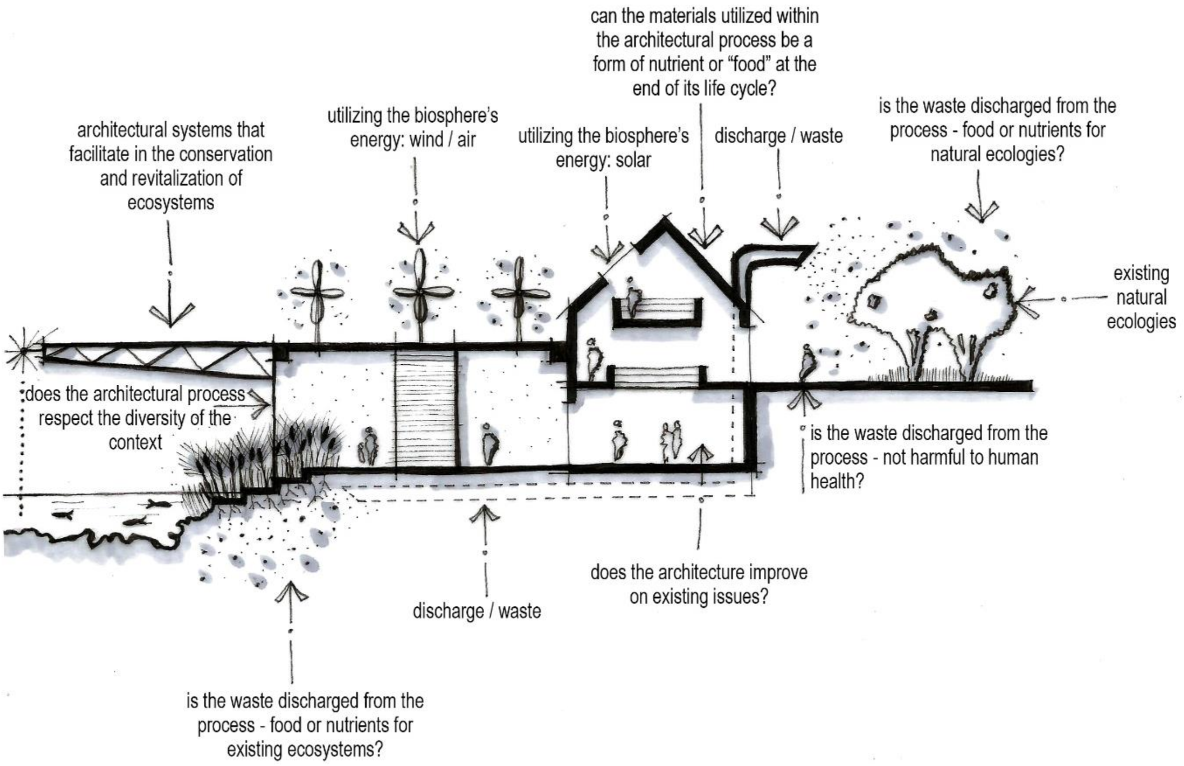


Figure 110: sketch illustrating the culmination of the research providing the basic design strategies and recommendations. 2018, By Author.

Aligned with the Next Industrial Revolution, these principles refer to:

[Architectural Ecology]: Industrial Ecology

- A "cradle to the grave" thinking: [eco] – efficiency

This principle recommends that for an "eco – efficient" architecture to be achieved, solar, water and wind energy must form the nucleus of the design. Supportive to this, an efficient design must acknowledge existing energy flows within its host environment, influencing architectural form.

[Natural Ecology]: The Theory of Ecology

- A "cradle to cradle" thinking: [eco] – effectiveness
  - Waste equals food – technical and biological nutrients within the built environment.
  - Respect diversity – an architecture's ability for foster human and natural ecologies.
  - Use solar energy – an architecture's ability to utilize the biosphere's energies and processes.

This principle recommends that for an "eco – effective" architecture to be achieved, the design must consider the materiality of the built form.

Furthermore, the design must acknowledge both human and environmental issues in determining ecological processes that can be utilized. This make reference to:

Issue:

1) Human Ecology – Sewerage Wastewater
2) Human Ecology – Stormwater Runoff
3) Human Ecology – Industrial Surface Runoff
4) Human Ecology – Human Waste Byproducts

Response:

1) Natural Ecology – Solar Aquatic Wastewater Treatment
2) Natural Ecology – Constructed Treatment Wetlands
3) Natural Ecology – Constructed Treatment Wetlands
4) Natural Ecology – Sludge Disposal

This suggests that the "eco – effective" thinking provides answers for all Human Ecological issues through Natural Ecological technology and therefore, an architecture is to merely support and facilitate these processes and activities.

[Human Ecology]: Place Theory

- Fostering pre – industrial, industrial and post – industrial man:
  - Basic needs – an architecture's ability to foster and improve on the basic needs of man.
  - Reconnection – reintroducing man to that of the natural world.

This principle recommends that an architecture must address the fragmentation caused by industry between man and nature, and that there should various platforms within its parameters to offer connectivity, choice and convenience to visitors and the end – user.

Industrial Ecology: As a key concept

- **Towards an industrial symbiosis:**
    - Enhancing, closing and improving on existing industrial loops.

This principle recommends that an architecture must acknowledge its urban context, as it falls part of a greater paradigm of processes and activities. Moreover, the concept recommends that the design must lend its infrastructure to its industrial counterparts to help achieve equilibrium between man, the natural world and the built environment.

Finally, the research recommends that this thinking should influence the architectural paradigm and serve as a catalyst to promote the Next Industrial Revolution, being the 4th Industrial Revolution: The Age of Ecology.

CHAPTER EIGHT: REFERENCES

8.0 BOOKS

Alexander, C., 2017. A city is not a tree. Sustasis Press/Off The Common Books.

Bennetts, H., Radford, A. and Williamson, T., 2003. Understanding sustainable architecture. Taylor & Francis.

Burton, T., Jenkins, N., Sharpe, D. and **Bossanyi, E.,** 2011. *Wind energy handbook*. John Wiley & Sons.

Fletcher, B. 1924. A History of Architectureon the Comparitive Method. 7th. London : Batsford

Hillier, B., 2007. Space is the machine: a configurational theory of architecture. Space Syntax.

Lyle, J.T., 1996. *Regenerative design for sustainable development*. John Wiley & Sons.

Lyle, J., 1999. Design for human ecosystems: landscape, land use, and natural resources. Island press.

Macy,C & Bonnemaison, S . 2003. Architecture and Nature: Creating the American landscape. London: Routeledge

Mc Dounough,W & Braungaut,M. 2002. Cradle to Cradle: *Remaking the way we make things*. New York: North Point Press

White, D.R., 1998. Postmodern ecology: Communication, evolution, and play. SUNY Press.

8.1 DISSERTATIONS

Docrat, Z., 2013. The Reconnection of the Built Form to the Natural Environment: Towards an Ecological Awareness Centre for Durban (Masters dissertation, University of KwaZulu-Natal, Durban).

Govender, I., 2000. A study of vegetation change along the north coast of KwaZulu-Natal from the Umgeni river to the Tugela river (Doctoral dissertation, University of Natal, Durban).

Littman, J.A., 2009. *Regenerative architecture: a pathway beyond sustainability* (Doctoral dissertation, University of Massachusetts Amherst).

Serfontein, Z., 2012. Reconfiguring Built Form Within the Landscape: Towards Interpretive Facilities, ISimangaliso Wetland Park (Masters dissertation, University of KwaZulu-Natal, Durban).

8.2 JOURNALS

Athavale R.N. 2003, Water Harvesting and Sustainable Supply in India, Centre for Environment Education, Ahmedabad.

Baxter, R.M., 1977. Environmental effects of dams and impoundments. *Annual Review of Ecology and Systematics*, *8*(1), pp.255-283.

Bell, D., 1976. Welcome to the post-industrial society. *Physics today*, *29*(2), pp.46-49.

Beller, C., 2011. Urban wind energy (Doctoral dissertation, Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi).

Bjørn, A. and Strandesen, M., 2011. The Cradle to Cradle concept-is it always sustainable?. In The Life Cycle Management (LCM) conference: Towards Life Cycle Sustainability Management.

Blinder, A.S., 2006. Offshoring: the next industrial revolution?. Foreign affairs, pp.113-128.

Boers, T.M. and Ben-Asher, J., 1982. A review of rainwater harvesting. *Agricultural water management*, *5*(2), pp.145-158.

Braungart, M., McDonough, W. and Bollinger, A., 2007**.** Cradle-to-cradle design: creating healthy emissions–a strategy for eco-effective product and system design. Journal of cleaner production, 15(13-14), pp.1337-1348.

Bubolz, M.M. and Sontag, M.S., 2009. Human ecology theory. In Sourcebook of family theories and methods (pp. 419-450). Springer, Boston, MA.

Commoner, B., 2014. The closing circle: nature, man, and technology. Knopf.

Crowe, N. 1995. Nature and the Idea of a man-made world. London: The MIT Press

Edelstein, W.A. and **GE R&D, S.,** 2003. A Report Prepared for the Panel on Public Affairs (POPA), American Physical Society William A. Edelstein, Rensselaer Polytechnic Institute, Troy, NY, and GE R&D, Schenectady, NY (retired), POPA Member. mailto: wedelst1@ nycap. rr. com Christopher J. Walcek, State University of New York, Albany, NY. *WIND ENERGY*.

Ehrenfeld, J. and Gertler, N., 1997. Industrial ecology in practice: the evolution of interdependence at Kalundborg. Journal of industrial Ecology, 1(1), pp.67-79.

Erkman, S., 1997. Industrial ecology: an historical view. Journal of cleaner production, 5(1-2), pp.1-10.

Feng, H. and Hewage, K., 2014. Lifecycle assessment of living walls: air purification and energy performance. Journal of Cleaner Production, 69, pp.91-99.

Georgantzas, N.C., Katsamakas, E., Solowiej, D., Ford, A., Ford, D.N. and Anderson, G.E., 2009. Giddens' globalization: Exploring dynamic implications. In Proceedings of the 27th System Dynamics Society International Conference (pp. 26-30).

Gómez-Baggethun, E. and Barton, D.N., 2013. Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86, pp.235-245.

Gueymard, C.A., 2004. The sun's total and spectral irradiance for solar energy applications and solar radiation models. *Solar energy*, *76*(4), pp.423-453.

Gust, D., 2006. What is photosynthesis?. Center for Bloenergy and Photosynthesis, Arizona State University.

Helmreich, B. and Horn, H., 2009. Opportunities in rainwater harvesting. *Desalination*, *248*(1-3), pp.118-124.

Jelinski, L.W., Graedel, T.E., Laudise, R.A., McCall, D.W. and Patel, C.K., 1992. Industrial ecology: concepts and approaches. Proceedings of the National Academy of Sciences, 89(3), pp.793-797.

Kaldellis, J.K. and **Zafirakis, D.,** 2011. The wind energy (r) evolution: A short review of a long history. Renewable Energy, 36(7), pp.1887-1901.

Khan, M.J., Bhuyan, G., Iqbal, M.T. and Quaicoe, J.E., 2009. Hydrokinetic energy conversion systems and assessment of horizontal and vertical axis turbines for river and tidal applications: A technology status review. *Applied energy*, *86*(10), pp.1823-1835.

Maslow, A. and Lewis, K.J., 1987. Maslow's hierarchy of needs. *Salenger Incorporated*, *14*, p.987.

McDonough, W. and Braungart, M., 1998. The next industrial revolution. *The atlantic monthly*, *282*(4), pp.82-92.

McDonough, W. and Braungart, M., 2003. Towards a sustaining architecture for the 21st century: the promise of cradle-to-cradle design. *Industry and environment*, *26*(2), pp.13-16.

Meldan, R. 1959. Besondere Luftechnische Aufgaben der Industrie. Staedtebygiene. 3(8).

Morey, A., Dhurve, B., Haste, V. and Wasnik, B., 2016. Rainwater harvesting system. *International Research Journal of Engineering and Technology*, *3*(4), pp.2158-2162.

Najafi, M. and Shariff, M.K.B.M., 2011. The concept of place and sense of place in architectural studies. International Journal of Human and Social Sciences, 6(3), pp.187-193.

Odum, E.P., Odum, H.T. and Andrews, J., 1971. Fundamentals of ecology (Vol. 3). Philadelphia: Saunders.

Rapoport, A., 2006. Local environments in a global context. Ekistics, pp.122-131.

Rahman, M.M. and Jahra, F., 2007. Challenges for Implementation of Rain Water Harvesting Project in Arsenic Affected Areas of Bangladesh.

Ruhela, M., Bhutiani, R. and Anand, A., 2004. Rain water harvesting. *Environment Conservation Journal*, *5*(1-3), pp.21-34.

Story, M.F., 2001. Principles of universal design. Universal design handbook.

Stephens, J.C., 1998. Factors limiting the acceptance and use of innovative environmental technologies: a case study of the Solar Aquatics System (SAS) technology for wastewater treatment. *J. Environ. Syst*, *26*(2), p.163.

Vestergaard, I., 2014. Preindustrial versus postindustrial architecture and building techniques. *Vernacular Architecture*, pp.747-752.

Vogler, A. and Vittori, A., 2006, December. Genius loci in the space-age. In 1st Infra-Free Life Symposium (pp. 11-15).

Von Bertalanffy, L., 1972. The history and status of general systems theory. Academy of Management Journal, 15(4), pp.407-426.

Wang, Yi. "Globalization enhances cultural identity." Intercultural Communication Studies 16.1 (2007): 83.

Weinstock, M. 2010. The Architecture of Emergence: the evolution of form in nature and civilization. United Kingdom : Wiley & Sons

White, L., 1967. The historical roots of our ecologic crisis. *Science*, *155*(3767), pp.1203-1207.

Worm, B. and Duffy, J.E., 2003. Biodiversity, productivity and stability in real food webs. Trends in Ecology & Evolution, 18(12), pp.628-632.

Zimmerman, M.E., 1993. Rethinking the Heidegger-deep ecology relationship. Environmental Ethics, 15(3), pp.195-224.

8.2 WEBSITES:

Amy Frearson, 2013. *National Ecology Center botanic greenhouses by Grimshaw and Samoo*. [online]. Available: https://www.dezeen.com/2013/11/07/national-ecology-center-botanic-greenhouses-by-grimshaw-and-samoo/ [Accessed: 5th May 2018]

Arch20, 2012. Ecorium of the National Ecological Institute | S.A.M.O.O. [online]. Available: https://www.arch2o.com/ecorium-of-the-national-ecological-institute-s-a-m-o-o/ [Accessed: 8th May 2018]

Archdaily, 2013. *Ecorium of the National Ecological Institute / Samoo Architects & Engineers + Grimshaw Architects.* [online]. Available: https://www.archdaily.com/423255/ecorium-of-the-national-ecological-institute-nbbj-in-collaboration-with-samoo-architects-and-engineers-grimshaw-architects [Accessed: 8th May 2018]

Ask an Astronomer, 2015. *Thermodynamics.* [online]. Available: http://curious.astro.cornell.edu/about-us/136-physics/general-physics/thermodynamics/816-does-evolution-contradict-the-second-law-of-thermodynamics-intermediate [Accessed: 6thMarch 2018]

Durban: State Of Biodiversity, Ethekwini Municipality Environmental Planning & Climate Protection Department. 2014. Available: http://www.durban.gov.za/City_Services/development_planning_management/environmental_planning_climate_protection/Publications/Documents/BiodiversityReport1415_Content. pdf [Accessed: 13th September 2017]

Greenhub Tourism Info Centre. 2016. Available: http://www.durbangreencorridor.co.za/explore/venues/greenhub [Accessed: 15th June 2018]

Umgeni Green Hub. [online]. 2013. Available: https://www.opengreenmap.org/greenmap/durban-ethekwini-municipality-south-africa/umngeni-green-hub-25064 [Accessed: 15th June 2018]

Umngeni River and Neighbouring Rivers and Streams. [online]. 2017. Available: http://www.dwa.gov.za/iwqs/rhp/state_of_rivers/state_of_umngeni_02/umngeni_02.pdf [Accessed: 12th August 2017]

Umngeni River Estuary Green Hub. [online]. 2010. Available: http://www.durban.gov.za/City_Services/engineering%20unit/City%20Architects/Documents/UMNGENI%20RIVER%20ESTUARY%20GREEN%20HUB.pdf [Accessed: 15th June 2018]

African Center for Biosafety. [online]. 2017. Available: https://acbio.org.za/about/acb/ [Accessed: 11th August 2017]

Biodiversity as a Tool for Sustainable Landscape Design. [online]. 2017. Available: http://urbionetwork.org/data/documents/2014-10-11_11-OR3-5-03_Ignatieva.pdf [Accessed: 11th August 2017]

Our Biodiverse City, Ethekwini Municipality Environmental Management Department. 2009. Available: http://www.durban.gov.za/City_Services/development_planning_management/environmental_planning_climate_protection/Publications/Documents/Our%20Biodiverse%20City.pdf [Accessed: 13th September 2017]

Center for Biological Diversity. [online]. 2017. Available: http://www.biologicaldiversity.org/ [Accessed: 11th August 2017]

Green Facts. [online]. 2017. Available: https://www.greenfacts.org/en/biodiversity/l-3/1-define-biodiversity.htm [Accessed: 11th August 2017]

The African Centre for Biosafety (ACB). [online]. 2017. Available: http://www.greenafricadirectory.org/listing/the-african-centre-for-biosafety-acb/ [Accessed: 12th August 2017]

The KwaZulu-Natal Sharks Board Maritime Centre of Excellence. [online]. 2017. Available: http://www.shark.co.za/Pages/Default [Accessed: 12th August 2017]

Umgeni River 'one of dirtiest' in SA. [online]. 2017. Available: http://www.iol.co.za/news/umgeni-river-one-of-dirtiest-in-sa-1529000 [Accessed: 24th May 2017]

8.3 NEWS BROADCASTS

Bear River Solar Aquatics. [broadcast]. 1995. CBC News. Available: http://www.ecotek.ca/ECO-TEK_Ecological_Technologies/Video.html [Accessed: 12th June 2018].

APPENDICES

APPENDICES 01: CONSENT FORM

(To be signed by the participant before each interview)
One copy to participant and one signed copy to the researcher

I have read the information presented in the consent letter about the project being conducted by Meloshan Pillay of The Department of Humanities and Built Environment Studies at Howard College, UKZN. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions and additional details I required.

I am aware that I have the option of allowing my interview to be recorded to ensure an accurate account of my responses.

I am aware that my quotations will be anonymous if I wish them to be.

I was informed that I may withdraw from the interview process at any time, without penalty, by advising the researcher.

I was informed that if I have any comments or concerns resulting from my participation in this project, that I may contact the researcher.

With full knowledge of all preceding, I agree, of my own free will, to participate in this study:

☐ Yes ☐ No

I would prefer that my identity be kept anonymous:

☐ Yes ☐ No

I agree to the use of anonymous quotations in the final research report of this project:

☐ Yes ☐ No

I agree to allow audio-recording during the interview.

☐ Yes ☐ No

Participant name :………………………………………….(please print)

Participant signature……………………………………….

Witness name :...……………………………………………(please print)

Witness signature………………………………………….

Date………………………………………………………….

APPENDICES 02: GATEKEEPERS FORM

Information Sheet and Consent to Participate in Research

My name is Meloshan Pillay (Student No. 217 075 600).

I am currently gathering research information towards a master's degree on: " **A Symbiosis of Bio - Diversity And Architecture:** Towards A Centre For Awareness And Research In The uMngeni Precinct.".

Student Details
Meloshan Pillay
Architecture discipline within the:
School of the Built Environment and Development Studies
University of KwaZulu-Natal, Howard Campus, Durban
Email: meloshanpillay@yahoo.com
Cell: 073 326 3668

Supervisor/s Details
Juan Solis-Arias
School of the Built Environment and Development Studies
University of KwaZulu-Natal, Howard Campus, Durban
Email: solis@ukzn.ac.za
Cell: 060 492 8804

HSSREC Research Office Details
Dr Shenuka Singh. Humanities & Social Sciences Research Ethics Committee
University of KwaZulu-Natal, Westville Campus, Durban
Email: ximbap@ukzn.ac.za
Cell: 031 260 3587

To whom it may concern:

This consent letter, a copy of which has been submitted to you, outlines the details of my research topic and what your participation may entail. This project is part of the requirement for the completion of course, Arch808: Dissertation: Architectural Design.

The research will focus on the creation of ecological architecture which will foster natural environment towards the conservation of ecosystems, as well as socio – cultural communities. This research attempts to create awareness of the derelict state of uMngeni River, through educational and research platforms.

We are required to find a case study (an example of a facility, institution or organization that embodies the features and qualities that we believe should be incorporated into the type building that we are proposing) and visit the chosen facility, whilst observing the architecture, spatial planning, and if possible, to photograph possible aspects of the space.

I would greatly appreciate the opportunity to visit your facility, as it is one of a kind in Durban, South Africa and seems to inherent a similar programme that I would like to instil within my design. It must be said that if you do allow me to explore your facility, your organization will have total access to my research and design once it is complete.

Participation in this project is entirely voluntary and there are no known or anticipated risks to your facility within this study. The exploration of the facility will be no longer than 60 minutes. You may also terminate the exploration of your facility at any time you wish.

All data collected for this project will be retained for five years in my supervisor's locked office at Howard College. Access to this information will be limited to myself and my supervisor.

If you have any questions, please feel free to contact me. Please indicate below your willingness to participate in this study. Thank you in advance for your co-operation in this research.

Participant name :……………………………………………………………………..(please print)

Participant signature………………………………………………………………..

Witness name :....……………………………………………………………………...(please print)

Witness signature………………………………………………………………………

Date……………………………………………………………………………………...

……………………………………………………..

Yours sincerely

APPENDICES 03: INTERVIEW SCHEDULE

Researcher: Meloshan Pillay (email: meloshanpillay@yahoo.com)

Dissertation Topic: A Symbiosis of Bio - Diversity And Architecture: Towards A Centre For Awareness And Research In The uMngeni Precinct.

To the participant:
I would like to thank you for your time that you have set aside to participate in this interview. This interview is structured to be treated like a conversation, rather than a questionnaire or survey. The purpose of this participation is to gather information based on your experiences, perceptions and ideas towards my Master Research Project. The aim of the project is to conserve the natural ecosystems and habitats of the uMngeni River towards awareness and socio – cultural cohesion. You have the authority to skip questions that you do not wish to answer, and you can end the interview at any time during your participation.

RESEARCH INTERVIEW

Part A: Personal Analysis (optional)

1. **Name:** ____________________
2. **Age:** 18-25 □ 25-35 □ 35-45 □ 45-65 □ 65+ □
3. **Nationality:** ____________________
4. **Ethnicity:** Black □ White □ Coloured □ Indian □ Other(specify) □ _____
5. **Occupation:** ____________________

Part B: Macro Analysis

1. Have you ever considered the impacts of industry on our natural environments?

____

____

2. Do you think that the derelict state of our natural ecosystems impact on the way society would use or perceive these natural environments?

____

____

Part C: [Human – Natural] Ecological Analysis

1. Does the uMngeni precinct hold any personal connection towards you and your life?

2. Do you use the area to participate in any sports, recreational, religious or social activities?

3. Do you think the state of the river influences the public's perception of ecosystems and water bodies and are there social implications?

4. In your opinion, what do you think are the major influences towards the state of the river of present day?

5. Through your observation, in what state do you see the river in the next ten years?

6. What strategies do you think should be implemented to enhance the biodiversity and quality of water in the river?

Part D: [Architectural] Ecological Analysis

7. Do you think providing a platform for research and awareness within the uMngeni precinct will create ecological awareness within the public realm?

8. Should a building be proposed to facilitate research and awareness, what other functions do you think are necessary to bring balance between nature and society?

9. Lastly, do you think an interactive and educational building / structure will create awareness for various demographics of our society?

THANK YOU

APPENDICES 04: ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

10 September 2018

Mr Meloshan Pillay 217075600
School of Built Environment & Development Studies
Howard College Campus

Dear Mr Pillay

Protocol reference number: HSS/1066/018M
Project title: Bio-diversity and Architecture, A Symbiosis: Towards a centre for Awareness and Research in the uMngeni Precinct

Full Approval – Expedited Application

In response to your application received 9 July 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application 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.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Professor Shenuka Singh (Chair)
Humanities & Social Sciences Research Ethics Committe

/pm

cc Supervisor: Juan Soilis-Arias
cc. Academic Leader Research: Prof Oliver Mtapuri
cc. School Administrator: Ms A Msomi

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

PART TWO: DESIGN REPORT

CHAPTER NINE: PROJECT DESCRIPTION

9.1 INTRODUCTION

This chapter presents the project description for the proposal of a Centre for Awareness and Research in the uMngeni Precinct. The architectural response then serves as an extension of research uncovered within this dissertation and is set out to emphasize a research – led design development, as opposed to design as a product.

9.2 PROJECT DESCRIPTION

9.2.1 Who?

The architectural response targets pupils and students from surrounding schools, universities and colleges. Furthermore, the design aims at housing researchers and professionals in the fields of environmental science, biology and marine biology. Also, the design provides insurgency within the industrial landscape, targeting the public and local communities.

Figure 111: illustrating the target group (end users) intended to experience or utilize the proposed architectural response. 2018, By Author.

9.2.2 Why?

This section aims to justify the building typology, as various communities and the public find themselves fragmented from the uMngeni River system due to the overwhelming belt of industry. Thus, suggesting their lack of knowledge, access and engagement towards the estuary. Therefore, the architectural response aims at creating ecological awareness through memory and responsibility, whilst addressing the lack of biologist and scientist establishing a research platform. The design further supports the conservation of the river and aims at creating public / social interfaces with the natural world.

Figure 112: illustrating the various activities and process expected to be an outcome within the architectural response. 2018, By Author.

9.2.3 How?

As mentioned earlier, the design utilizes high tech thinking with low tech technologies in creating an industrial ecological architecture. The response utilizes the biosphere's energy and processes in dealing with various forms of Human – Industrial issues within the precinct.

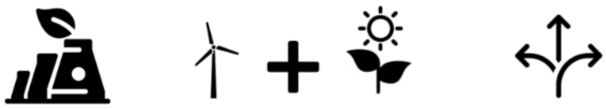


Figure 113: illustrating the processes utilized within the architectural response that supplements the building's typology and programme. 2018, By Author.

9.3 PROPOSED CLIENT

Within the parameters of Durban, South Africa, such a typology and design would be governed and managed by the eThekwini Municipality: Parks, Leisure and Cemeteries Department. Similar to the case study within this research, the local municipality then adopts small clusters of professionals and organization to utilize the building. Therefore, this design aims at treating the eThekwini Municipality: Parks, Leisure and Cemeteries Department as the primary client, with the smaller clusters of professionals and organizations as secondary clients.

It must be noted that the secondary clients must have direct association with the uMngeni Estuarine system, as well as affiliations with marine biology, environmental science and oceanic research.

9.4 PROJECT BRIEF

The eThekwini Municipality requires the architect to design and conceive a Centre for Awareness and Research within the uMngeni Precinct. Furthermore, the selected site for the architectural response must be located within close proximity to the study area and must have direct interactions with the uMngeni River and industry.

According to the clients, the project must consider all ecological and industrial impacts, and the architecture must then act like a “living filter” to facilitate and rehabilitate processes and activities. Aligned with the theoretical and conceptual framework explored earlier, the built form must allow for the following to occur within its domain:

- An Orientation Centre with supportive drop – off facilities, parking and administrative offices.
- A Solar Aquatic – Green House facility that could effectively deal with sewage wastewater for approximately 14 080, 65 m^2 of industrial processes located within immediate context of the selected site.
- Supportive Sludge Disposal facilities for the Solar Aquatic – Green House: ensuring that byproducts can obtained.
- The Sludge Disposal facility must then house a platform for the public and small commercial clusters to access these byproducts, as well as consider vehicle and heavy vehicle logistics.
- An amphitheater to host socio – educational gatherings for approximately 300 people.
- Green Tenants – that refer to a green open space that utilizes deciduous vegetation to create a sense of "relief" within the confinements of the built form. This space must also address human scale and provide a platform that can be hired out for events and private - social gatherings.
- A Constructed Treatment Wetland facility that could effectively deal with stormwater and surface runoff wastewater for approximately 14 080, 65 m^2 of industrial processes located within immediate context of the selected site.
- The Constructed Treatment Wetland facility must be arranged systematically to ensure that the byproduct (water) of the process can be safely discharged back into the river system.
- In support of the Constructed Treatment Wetland facility, provision must be made for attenuation tanks to store stormwater and surface runoff.
- A Media Centre and Library – that is to address the influx of students and pupils visiting the scheme.
- In support of the plant and animal byproducts that can be obtained through the various ecological processes, a Waste Harvest Market must then form the platform from which the public, visitors and restaurants may purchase them.
- A café – that utilizes the above plant and animal byproducts to support local socio – recreation clusters. The eatery must be arranged around a pleasant industrial process and is to provide ablution facilities, a kitchen, social spaces for rest and a bird watching platform.
- A Conservation Building that provides relevant spaces for biologist, scientist, researchers and organizations. Furthermore, this building is to provide social spaces for the end – users, necessary storage, ablution facilities, circulation as well as a Plant Lab, a Dry Lab and a Wet Lab.
- The Conservation Building must also assist with river clean ups through various local low-tech technologies.
- Lastly, provisions are to be made to support the scheme's publicness, therefore, there should be spaces that accommodate for fisherman, paddlers, birdwatchers and local water cultures.

9.5 ACCOMMODATION SCHEDULE

Primary Spaces:	**Area Required:**
Orientation Centre & Main Entrance	
Drop – Off Zone	200m^2
Briefing Area	250m^2
Amphitheatre	550m^2
Entrance / Foyer	65m^2
Reception + Small Staff Room	65m^2
Circulation	20m^2
Ablutions	100m^2
Maintenance Room	15m^2
Board Room	40m^2
Admin Offices (x5)	20m^2
Storage	15m^2
Staff Ablutions	40m^2
Staff Kitchenette	15m^2
Solar Aquatic Wastewater Treatment Plant	
Green House + Ecological Processes	750m^2
Circulation	20m^2
Staff Ablutions	20m^2
Admin Offices (x4)	15m^2
On Site Testing Lab	20m^2
Sludge Disposal & Byproducts	
Anaerobic Digestors	200m^2
Aeration Tanks	200m^2
Evapotranspiration Beds	550m^2
Circulation	20m^2
Extensive Planting & Vegetation	150m^2
Courtyard Space	
Green Tenant + Reflective Pond	350m^2
Constructed Treatment Wetlands	
Treatment Chambers	650m^2
Ecologically Engineered Riparian System	250m^2
Supportive Attenuation Tank (provisions to be made)	
Socio – Economic Space	
Media Centre & Library	120m^2
Café Kitchen	80m^2
Café Seating	200m^2
Ablutions	40m^2
Services	10m^2
Conservation Building	
Circulation	120m^2
Ablutions + Service Duct	200m^2
Research Offices (x6)	35m^2
Board Room	50m^2
NGO Offices (x2)	20m^2
Student Offices	100m^2
Staff Room	35m^2
Supportive Laboratories	450m^2

CHAPTER TEN: SITE SELECTION

10.1 SITE SELECTION CRITERIA: THROUGH RESEARCH LED INQUIRY

Research Questions, Theoretical and Conceptual Framework	Description	Criteria
The Theory of Ecology: [Natural Ecology] 	• Natural – ecological challenges.	• Interface with the uMngeni River and the main water body. • In close proximity to the estuary and Beachwood Mangroves. • Does not take away from any protected or special natural systems. • Possibly a South facing bank along the river's edge.
Place Theory: [Human Ecology] 	• Displaced local and global communities. • Human ecological challenges.	• Centralized location for various local and global communities. • An abundance of river or water "cultures". • Historical and meaningful affiliations. • Various forms of access. • Visual contact and connections.
Industrial Ecology: [Architectural Ecology] 	• Challenges caused within the paradigm of the built environment.	• Within close proximity to industry. • Within the parameters of the Springfield Industrial Park. • Potential for river conservation. • Potential for waste water treatment. • Potential for platform awareness and research.

Table 1: illustrating the site selection criteria utilized within this research to establish the "host environment" for the architectural design response, which has been viewed through the lenses of the Theoretical Framework. 2018, By Author.

10.2 SELECTED SITE AND DISCUSSION

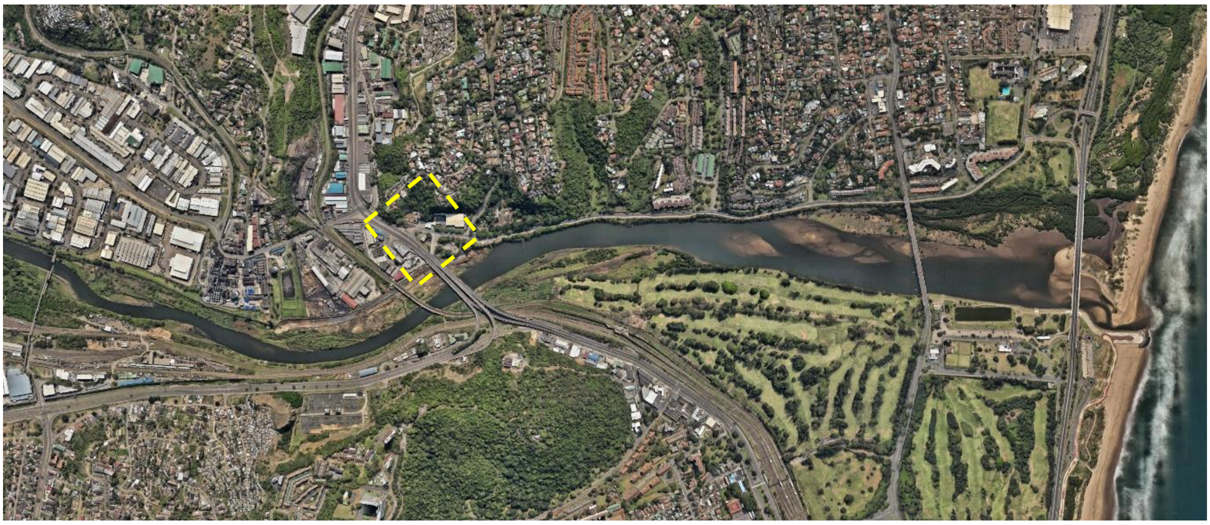


Figure 114: illustrating macro locality map of the selected site for the architectural design response in relation to Human, Natural and Architectural Ecologies, (online). 2018.

The selected site within this research is located along the banks of the uMngeni River, Durban, South Africa. Rezoned for industrial utilization - the site complies with all relevant selection criteria instated earlier. Defined by the uMngeni Road and Railroad interchange, the site may be accessed through Roadhouse Crescent or the river itself.

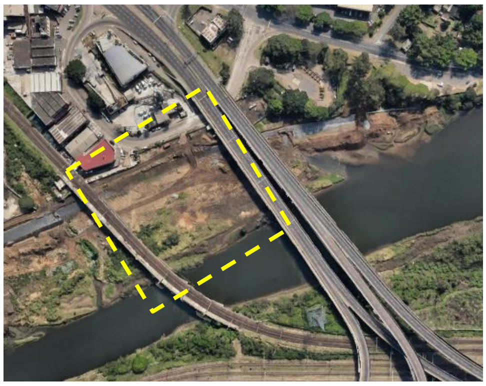


Figure 115: illustrating selected site along the banks of the uMngeni River, (online). 2018.

Site Location: the site is located at 9 Roadhouse Crescent, Briardene, Durban North, 4051. With natural interfaces, the site is mostly surrounded by medium to large scale industry sprawling into commercial, residential and clusters of informal settlement.

Infrastructure: the site finds itself central to various schools, colleges and universities that supplements the awareness component within the building's programme. Similarly, on site infrastructure provides the architectural design with access to municipal water and sewerage discharge. Furthermore, the site experiences a sewer servitude that runs through it, posing various issues to which, the architectural intervention may respond to.

Topography: the site experiences a gentle slope from the road level towards the river's edge whilst hosting clusters of vegetation within a mostly sandy terrain.

Accessibility: the site is accessible by various forms of transport, as it is situated within a prime location, which includes: rail, bus, taxi, private vehicles and canoes. However, it must be noted there is poor pedestrian movement within the immediate parameters of the site.

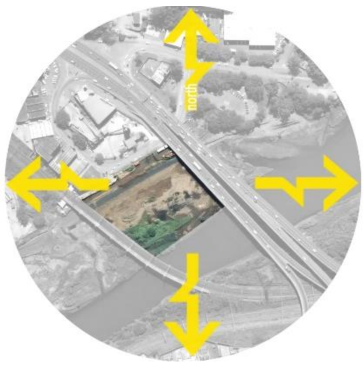
Orientation: the site has direct interactions with the uMngeni River, suggesting that there is immense potential for the built environment to assist with river conservation. In support of this, the bank on which the site is located, faces South, allowing the design to take advantage of South – solar radiation.

Town planning, land use and zoning controls: the site is currently zoned – "General Industrial", of ERF 234, portions 8 – 12, with only a front building line of 6 meters and no limits with regards to Coverage and FAR. Furthermore, parking and height restrictions are dependent on the building typology or land utilization (to be explored further in this chapter).

10.3 SITE ANALYSIS AND PHYSICAL FEATURES

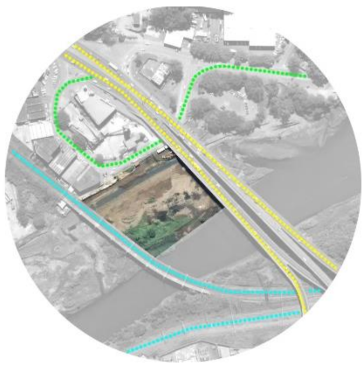
Figure Ground: Existing Built Forms

Site Boundary: Defining edges and interfaces



North Axis: Acknowledging solar radiation

Existing Industrial Zones: Acknowledging existing industrial loops



Linkages and Movement: Acknowledging vehicle, train and pedestrian routes

Existing Natural Features: Acknowledging existing natural ecologies

Figure 116: diagrams illustrating forms of analysis upon the selected site for the architectural design response. 2018, By Author.

10.4 S. G DIAGRAM

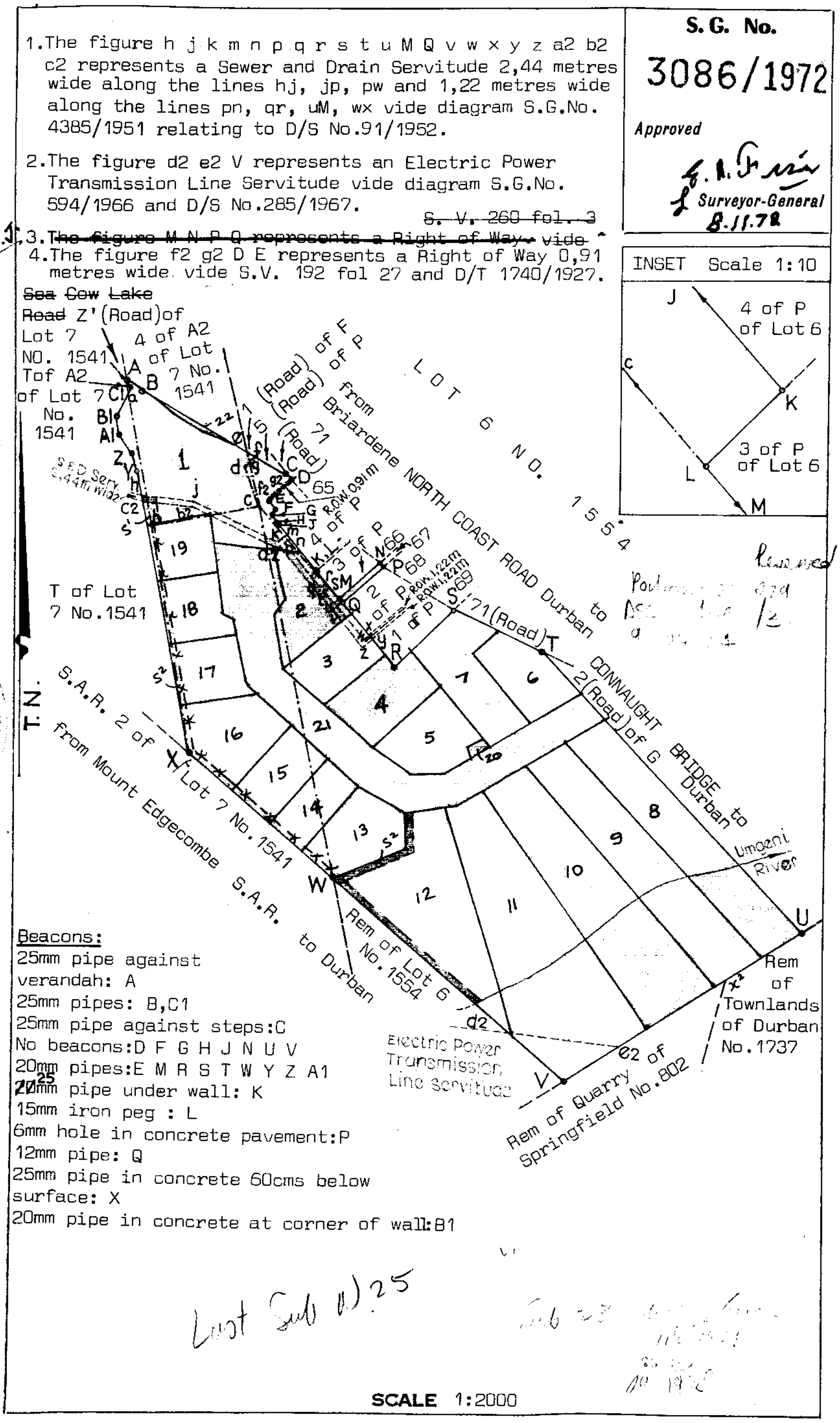
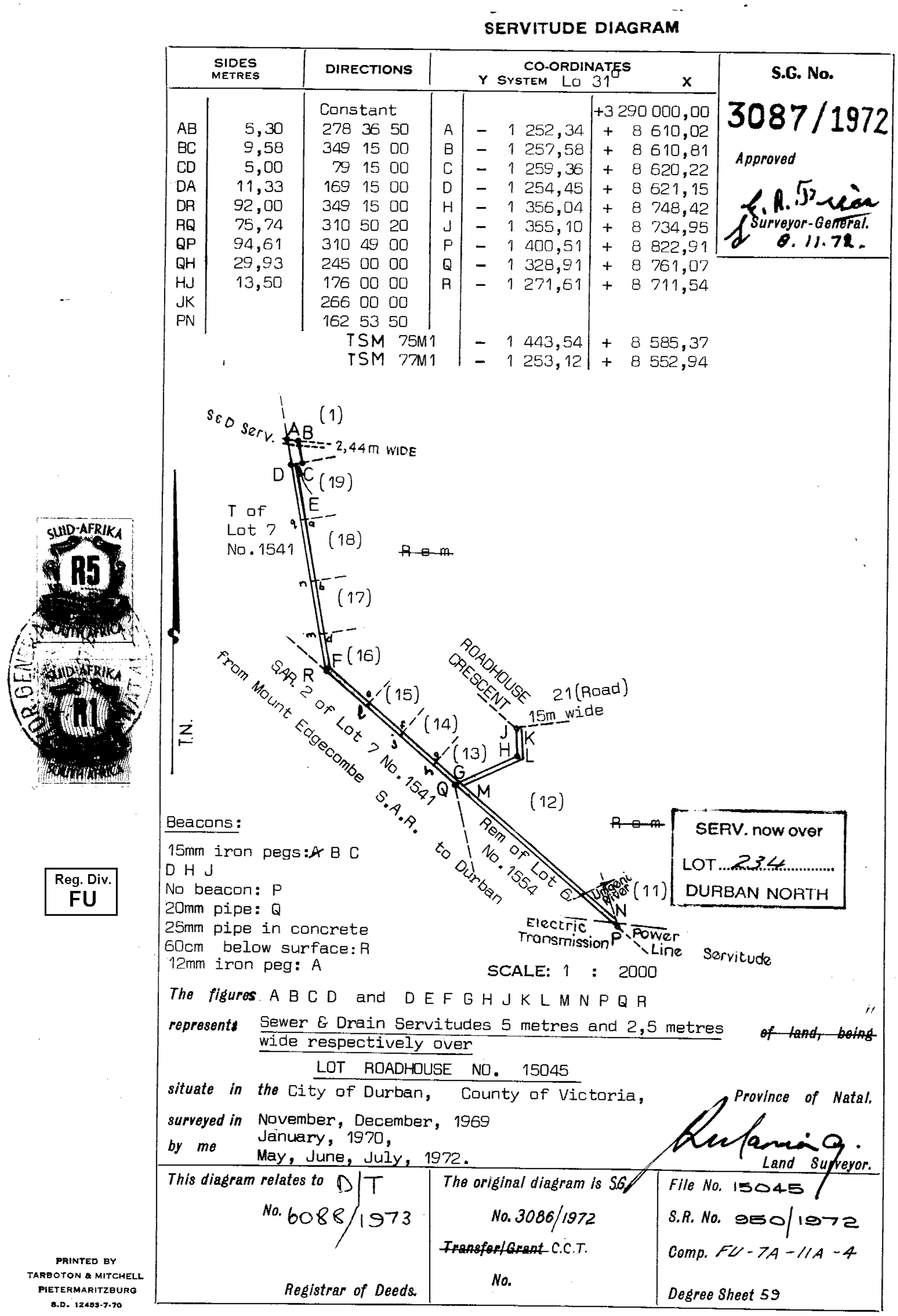


Figure 117: illustrating the surveyor – general diagram of the selected site, (online). 2018.

10.5 SERVITUDE DIAGRAM



SERVITUDE DIAGRAM

SIDES	METRES	DIRECTIONS	CO-ORDINATES Y SYSTEM Lo 31°		X
		Constant			+3 290 000,00
AB	5,30	278 36 50	A	− 1 252,34	+ 8 610,02
BC	9,58	349 15 00	B	− 1 257,58	+ 8 610,81
CD	5,00	79 15 00	C	− 1 259,36	+ 8 620,22
DA	11,33	169 15 00	D	− 1 254,45	+ 8 621,15
DR	92,00	349 15 00	H	− 1 356,04	+ 8 748,42
RQ	75,74	310 50 20	J	− 1 355,10	+ 8 734,95
QP	94,61	310 49 00	P	− 1 400,51	+ 8 822,91
QH	29,93	245 00 00	Q	− 1 328,91	+ 8 761,07
HJ	13,50	176 00 00	R	− 1 271,61	+ 8 711,54
JK		266 00 00			
PN		162 53 50			
		TSM 75M1		− 1 443,54	+ 8 585,37
		TSM 77M1		− 1 253,12	+ 8 552,94

S.G. No.
3087/1972
Approved
Surveyor-General.
8. 11.72.

SERV. now over
LOT 234
DURBAN NORTH

Reg. Div.
FU

Beacons:
15mm iron pegs: A B C D H J
No beacon: P
20mm pipe: Q
25mm pipe in concrete 60cm below surface: R
12mm iron peg: A

SCALE: 1 : 2000

The figures A B C D and D E F G H J K L M N P Q R *represent* Sewer & Drain Servitudes 5 metres and 2,5 metres wide respectively over ~~of land, being~~ LOT ROADHOUSE NO. 15045 *situate in the* City of Durban, County of Victoria, *Province of Natal,* *surveyed in* November, December, 1969 January, 1970, May, June, July, 1972. *by me*

Land Surveyor.

This diagram relates to DT *No.* 6088/1973 *Registrar of Deeds.*

The original diagram is SG *No.* 3086/1972 ~~*Transfer/Grant*~~ C.C.T. *No.*

File No. 15045
S.R. No. 950/1972
Comp. FU-7A-11A-4
Degree Sheet 59

PRINTED BY TARBOTON & MITCHELL PIETERMARITZBURG S.D. 12453-7-70

Figure 118: illustrating the servitude diagram for the selected site, (online). 2018.

10.6 TOWN PLANNING, LAND USE AND ZONING CONTROLS

PARCELS

OBJECTID	250537
PROPKEY	1125523
FARMALLOTC	A
REGIONCODE	FU
FARMTOWNNA	DURBAN NORTH
FARMALLOTN	0086
ERF	234
PORTION	8, 9, 10, 11, 12
REM	
PAR	
DOCREF	SG 3095/1972
AREASG	0.206
STRNUM	3
STRNAME	ROADHOUSE
STRTYPE	CRESCENT
SUBURB	UMGENI PARK
DISTRICT	DURBAN NORTH
SPLITPAR	00
PROPERTYID	N0FU00860000023400008
GP	
STATUS	Registered
LBLTXT	8/234
Shape	Polygon
Shape.STArea()	2059.285601
Shape.STLength()	263.545585

CENTRAL ZONING

OBJECTID	106435
COMMENTS	General Industrial
CODE	40
REGION	C
ZONE_SCH	NSC
FAR	N/A
COVERAGE	N/A
MIN_BLDG_L	Street improvement: 6.0m from c.l of road in certain instances; 4.5m's from C.L of road cl.5(3). Generally: N/A, in certain areas applicable, see cl.18(5) - where opposite public open space or reside*

MIN_SIDE_S	N/A
MIN_REAR_S	N/A
MAX_HEIGHT	Dependant on location: either 15.0m or 25.0m see cl.22(4). Springfield Park: as per original conditions of sale
PARKING_RE	Dependant on land use - see clause 12

CHAPTER ELEVEN: DESIGN DEVELOPMENT

11.1 UNPACKING THE HOST ENVIRONMENT THROUGH THE DESIGN PRINCIPLES

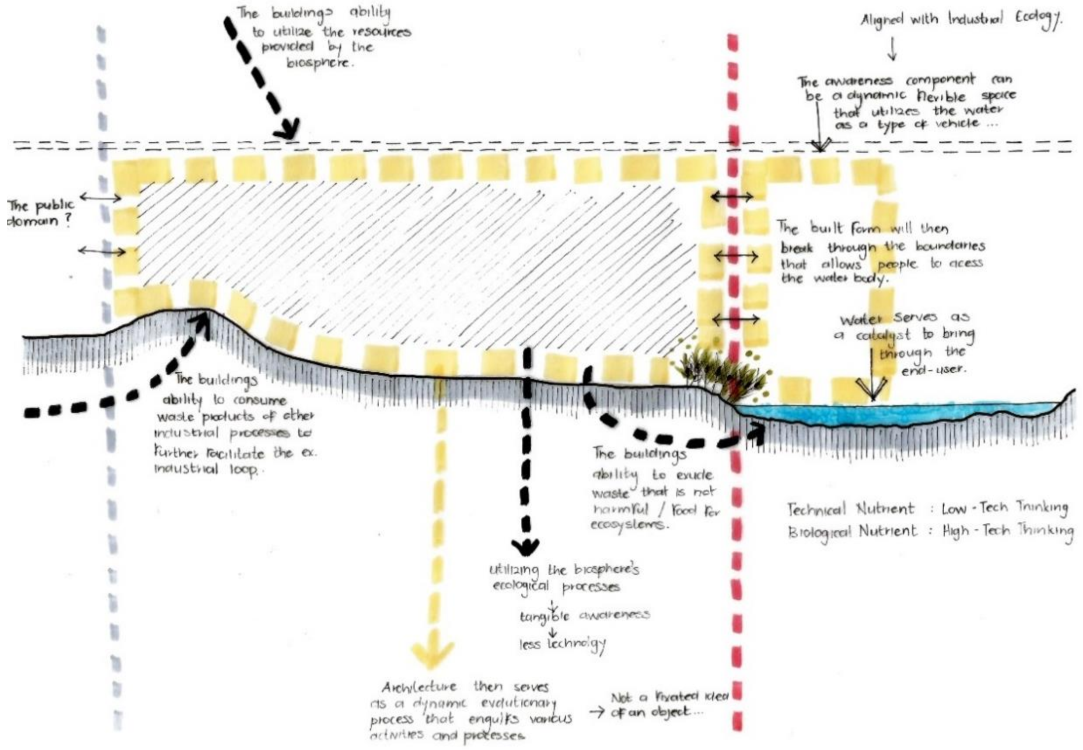


Figure 119: sketch illustrating the conceptual and theoretical breakdown of the host environment to establish parameters and guidelines that may facilitate an architecture response. 2018, By Author.

11.2 RESEARCH - LED GENERATIVE SKETCHES INFORMING DESIGN INTENT

On establishing the host environment, the design response explores analytical diagrams that emanate from the research. As figure (*120*) illustrates, within the "macro concept", an Architectural Ecology must fall within an existing industrial loop, within which it must foster Human and Natural Ecologies. Similarly, the "meso concept" gives insight to man as the end - user of space – that relies on five basic processes to sustain life. Thus, the five basic processes can be integrated within the design response, providing richness and diversity to the building typology. The "micro concept" then merges the macro and meso into a form of insurgency for the uMngeni Precinct, in relation to its local context.

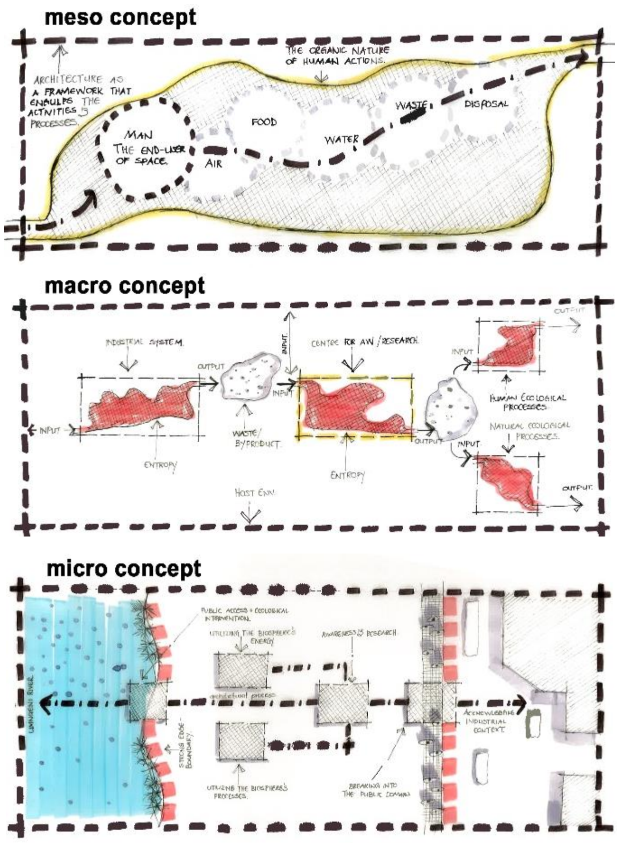


Figure 120: illustrating conceptual diagrams. 2018, By Author.

11.3 URBAN RESPONSE

Aligned with the overriding concept of Industrial Ecology and the generative sketches explored earlier – it suggests that the built form must latch onto the urban fabric to supplement the building typology, as well as extends the awareness component within the research, illustrated below in figure (*121*).

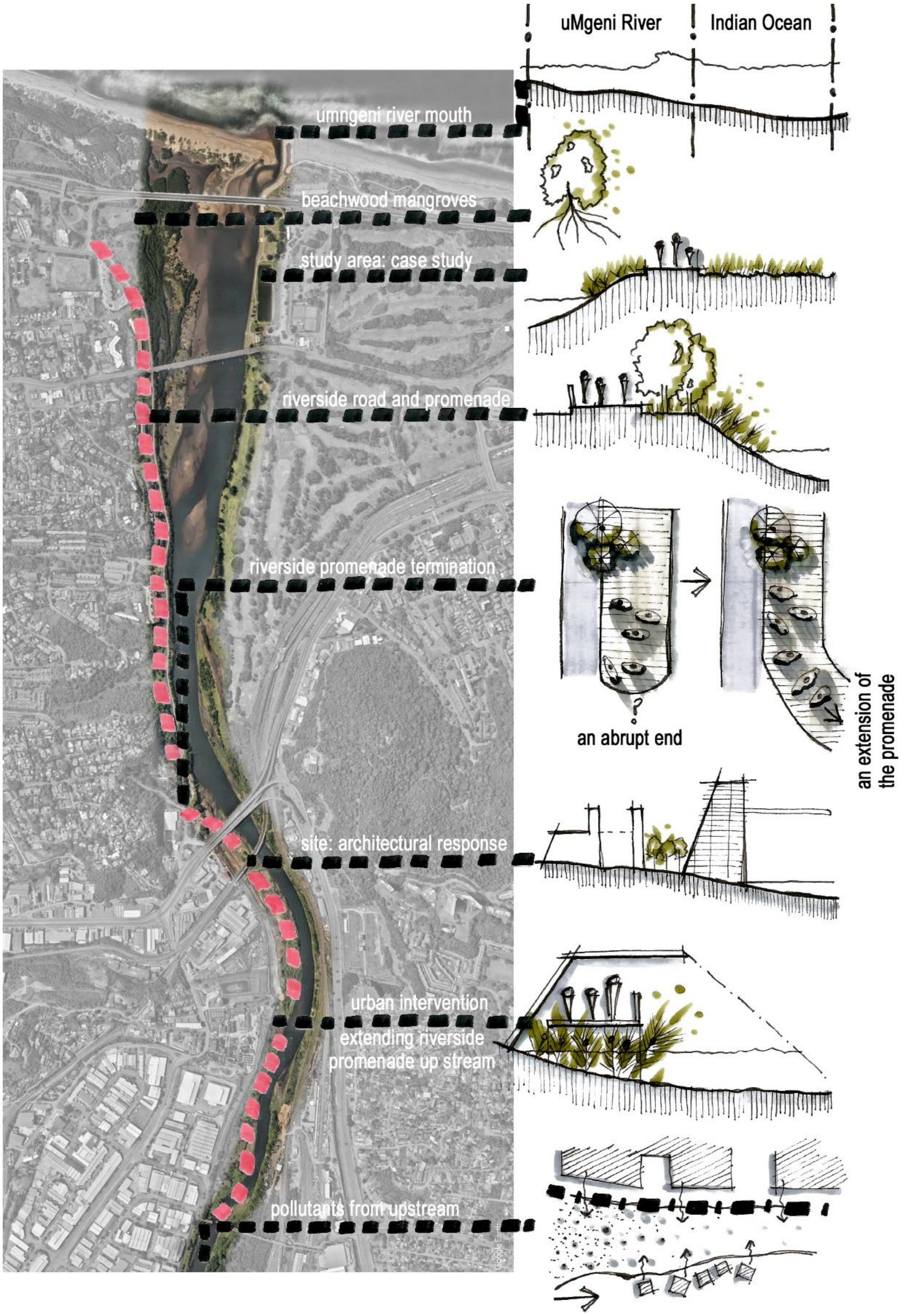


Figure 121: illustrating the urban interventions and nodes along the river's edge. 2018, By Author.

11.4 DERIVING URBAN AND CONTEXTUAL STATISTICS

This section presents the basic statistics gathered from contextual analysis that is to inform and guide the architectural response.

Determining the size and area of the largest social gathering space:

Four main users:

- **Schools (approximately 32 in a 5km radius)**
- **Colleges (approximately 14 in a 5km radius)**
- **Universities (approximately 2 in a 5km radius)**
- **Communities (approximately 5 in a 1km radius)**

On average there are between **20 – 30 people, pupils** and/or **students** per class:

30 (people)

And at each grade, level or academic year there are between **1 – 3 classes** or **groups**:

3 (groups)

∴ Therefore 30 (people) x 3 (groups) = 90 people

Which suggests that on average there will be at least 90 people utilizing the space:

∴ Therefore 90 (people) x 2m (personal space) = 180m^2

However, at any given time, there might be two groups of attendees:

∴ Therefore 180m^2 (space) x 2 = 360m^2

Thus, the basic size for the auditorium will be approximately 360m^2 with an additional 40m^2 for a stage, speaker or screening facility.

∴ Thus, the amphitheater will be approximately 400m^2

Determining the size and area of the largest water holding space:

Two main contextual plots:

- **Plot 1: 7 506, 664m^2**
- **Plot 2: 6 573, 986m^2**
- **∴ Therefore, the total: 14 080, 65m^2**

For every 40m^2 the site must provide 1m^3 of attenuation.

∴ Therefore 14 080, 65m^2 ÷ 40 = 352, 099m^3

∴ Thus, provisions on site must provide for at least 352, 099m^3 of attenuation

11.5 ARCHITECTURE AS A PROCESS: A SELF CRITIQUE

As the research suggests – "*an architecture should not be treated as a mere object, but rather an evolutionary process of change within time and space*". Thus, a self-critique of the design response is employed to explore more effective and efficient ideas.

As figure (*122*) illustrates the fundamental deviations come from the rearrangement of spaces with the introduction of an orientation centre and the merging of exhibition spaces with ecological processes that create "live" exhibits.

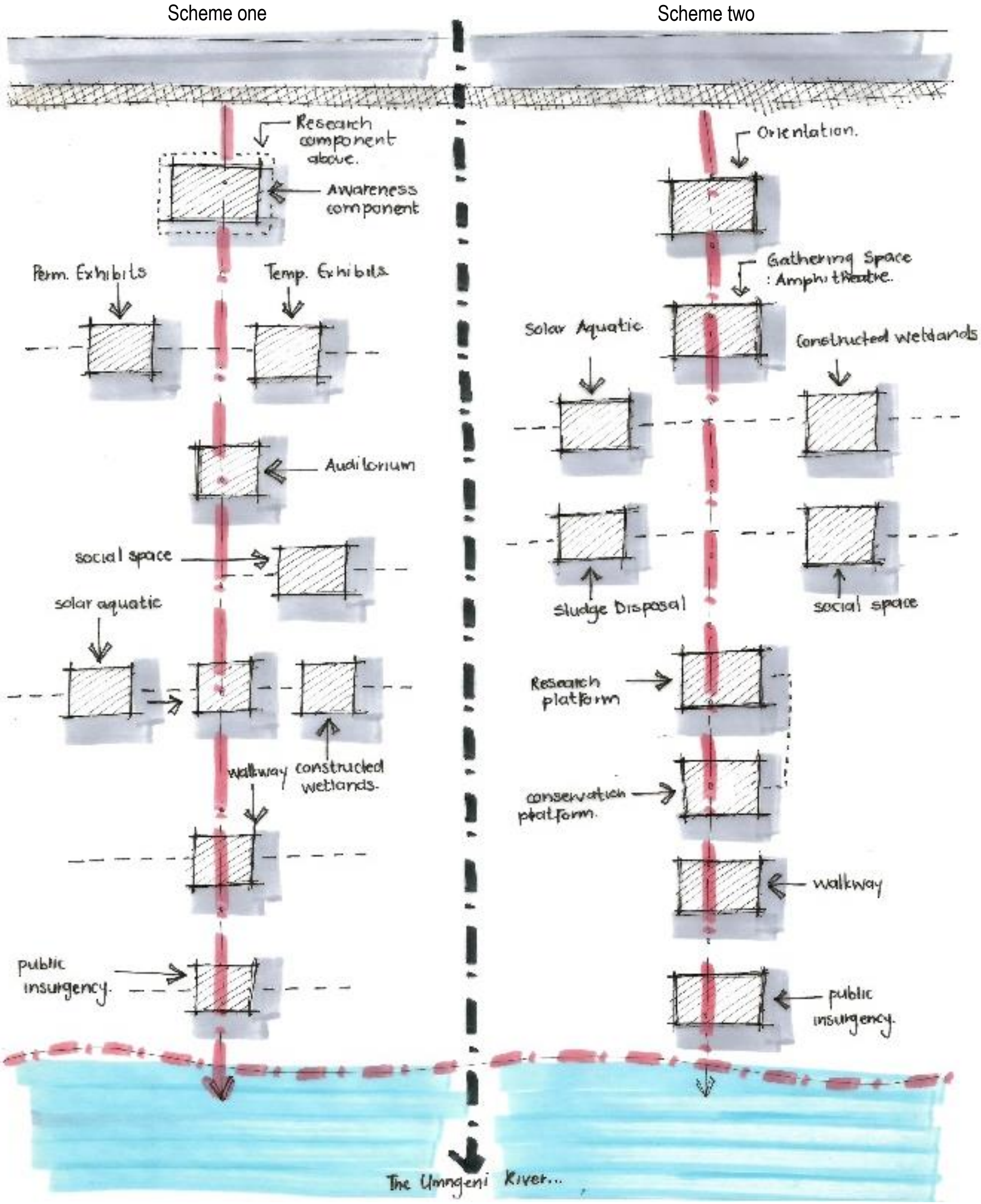


Figure 122: illustrating the rethinking of scheme one. 2018, By Author.

11.6 THE PROCESS OF SPACE AND FORM EVOLUTION

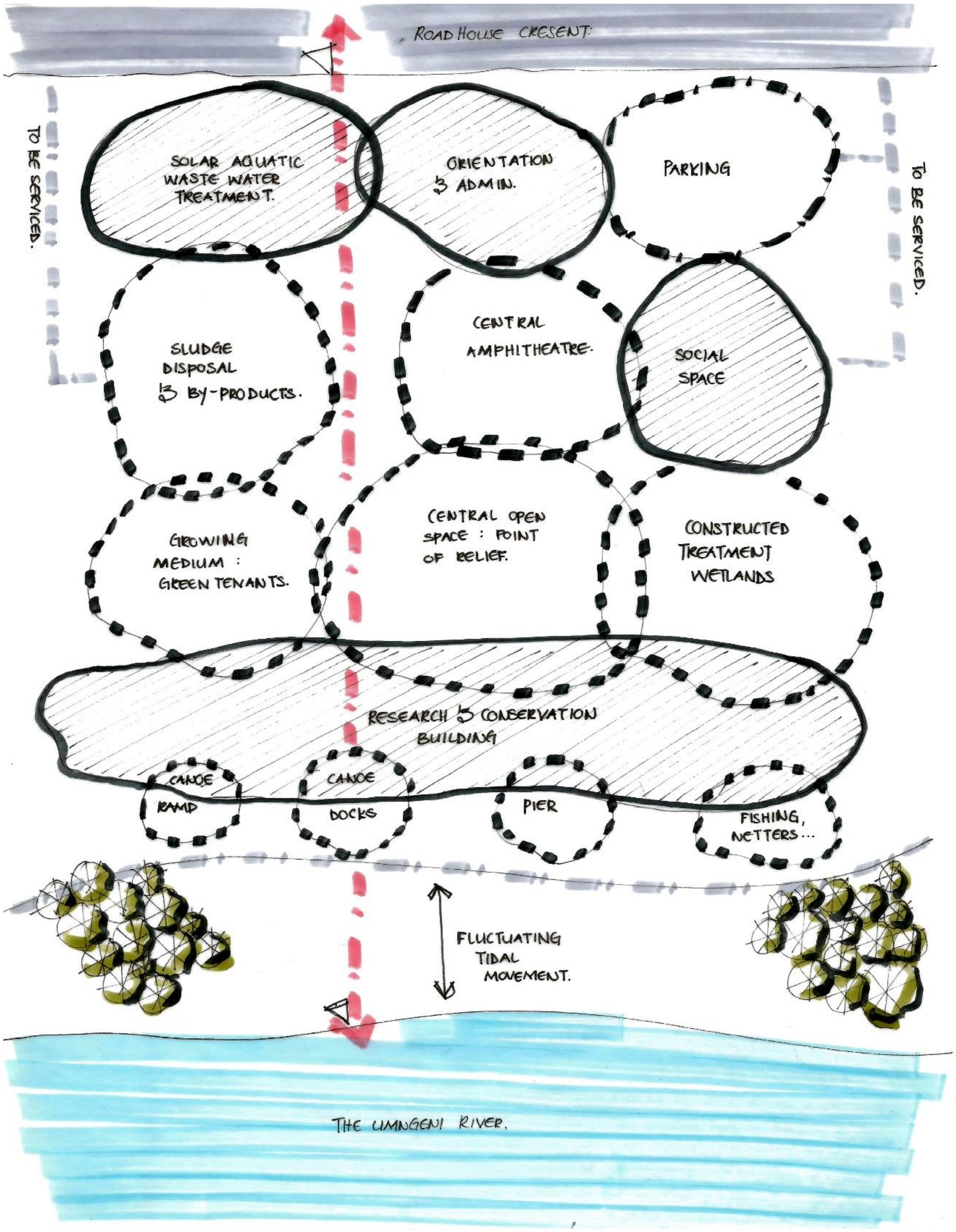


Figure 123: illustrating spatial diagram in relation to the site and context. 2018, By Author.

Figure (*123*) illustrates the arrangement of spaces that have been established and informed by the conceptual brief and accommodation schedule. Moreover, the spaces are arranged relative to their publicness that supplements the building's typology. Thus, the spaces are first determined in plan view, then arrange in section to address spatial hierarchies. Thereafter, floor plates are introduced to express volume and interconnectedness (*fig 124*). The floor plates are then shaped and alter by the building's formation which is defined by solar radiations, views and contextual influences.

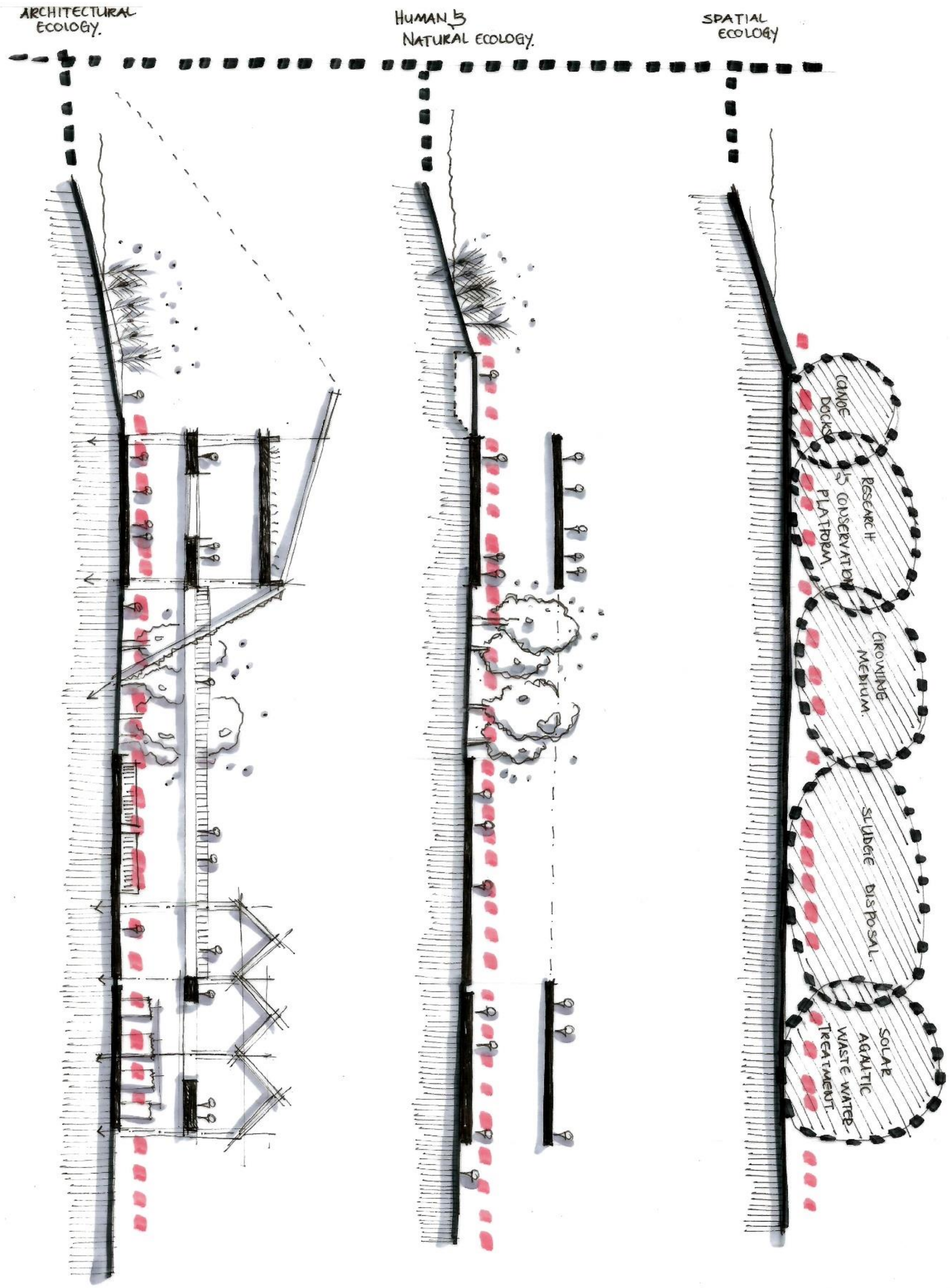


Figure 124: illustrating spatial diagram being transformed from space into place. 2018, By Author.

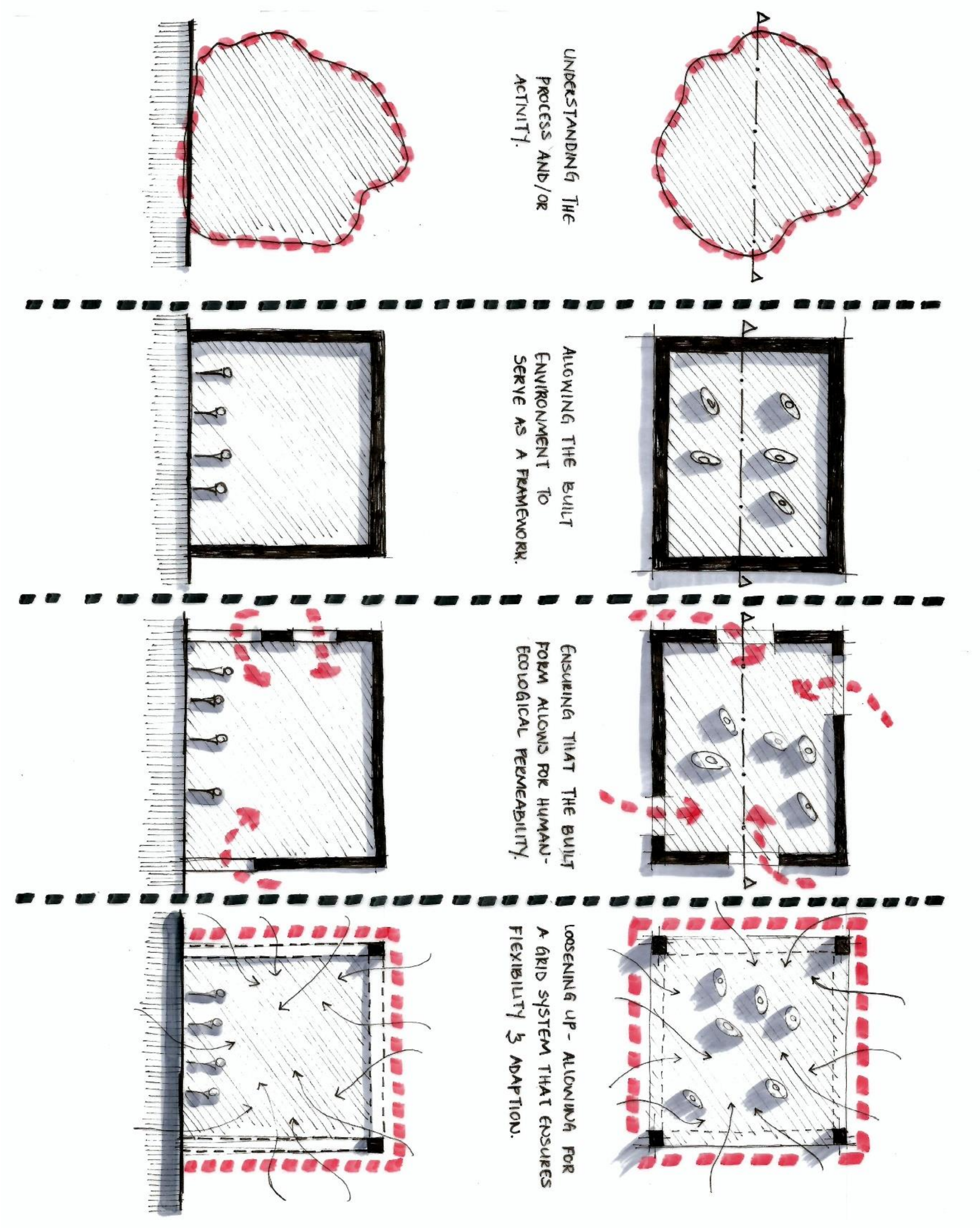


Figure 125: illustrating the start process of understanding a space, process and/or activity and allowing architectural form to manifest thereafter. 2018, By Author.

As figure (*125*) illustrates, the conceptual process of unpacking an architectural form investigates the process or activity to which an architecture must respond to. Thereafter, an architecture begins to manifest according to enclosure, permeability, flexibility and structure.

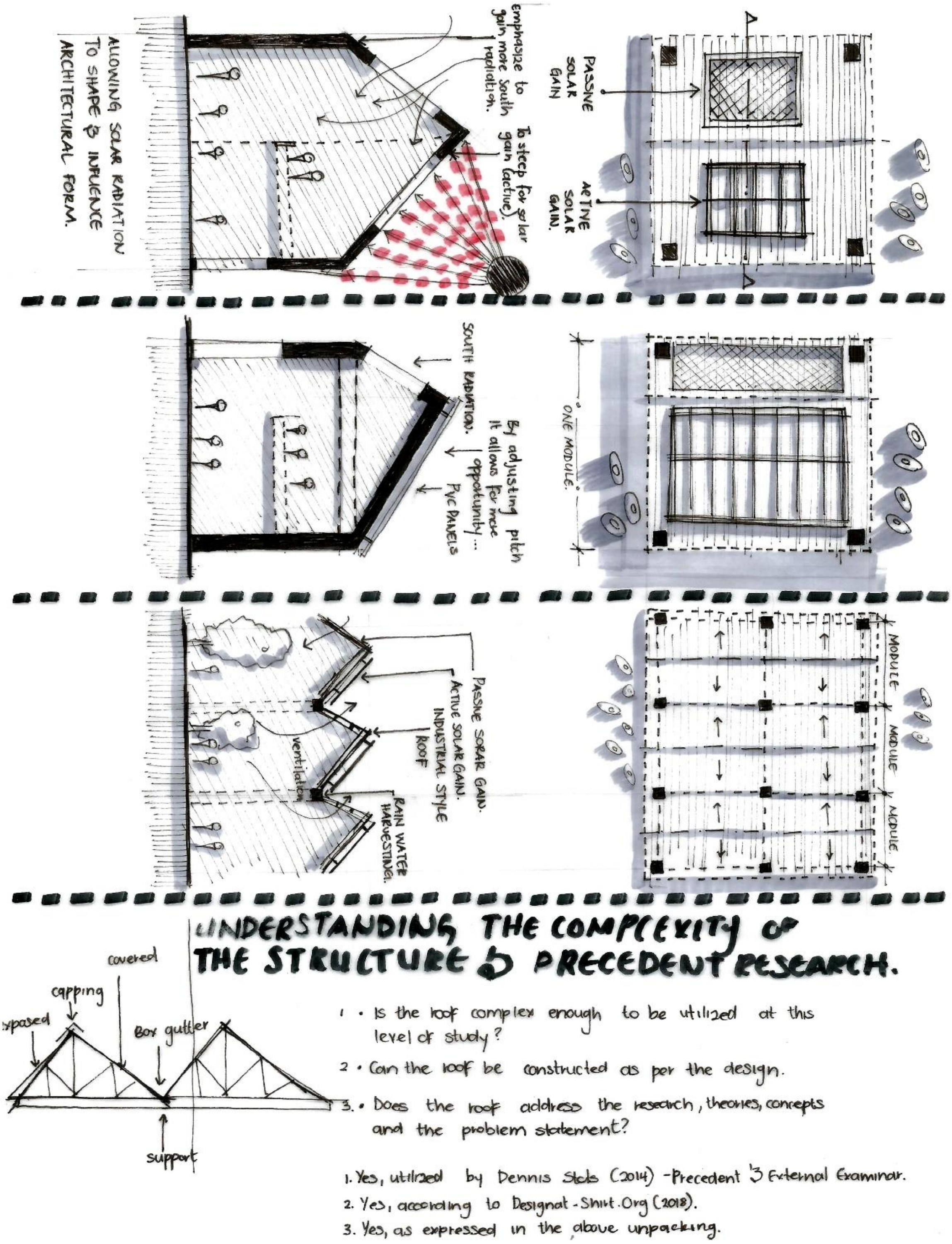


Figure 126: illustrating the start process of understanding a space, process and/or activity and allowing architectural form to manifest thereafter. 2018, By Author.

Figure (*126*) then depicts the loosely arranged industrial form, that is further shaped and molded by the principles of the Next Industrial Revolution. Thereafter, the established form is researched and unpacked in relation to precedent study and existing architectures that may have utilized the form.

11.7 RESEARCH LED – MATERIAL SELECTION

Material selection forms a vital part of this response, as the theoretical and conceptual ideology of Industrial Ecology proclaims that the constructs of an ecological architecture must be able to flow in nature as either a technical or biological nutrient.

This suggests that the embodied energy and life cycle of a material is essential to responsive architectural design. And therefore, materials have been carefully considered.

Brick: potentially can be treated as a technical nutrient that can continuously flow as a brick, a form of enclosure, screening, foundation and various other utilities within the construction field. Aligned with the theoretical framework with emphasis on Place Theory [Human Ecology], brick addresses human scale and forms a robust mediator between Human and Architectural Ecologies.

Glass: potentially can be considered as a technical nutrient – similar to that of brick, it can be upcycled for a greater utility at the end of its life cycle. Moreover, it serves as an ideal transparent enclosure that allows for enhance passive solar radiation.

Timber: potentially can be considered as a technical nutrient, depending on its treatment and exterior coating. However, less – treated timber may be allowed to age and deteriorate, serving as a form of nutrient for the soil to which it can be decomposed and replaced.

Concrete: potentially can be treated as a technical nutrient, provided it is prefabricated into modules that is relevant to the field of construction and the built environment. Its modularity will ensure a longer life cycle of the material.

Structural Steel: potentially can be considered as a technical nutrient that can continuously flow in the construction industry. Similar to concrete, the structural must be design so it can be easily dismantled and used later or even upcycled for a greater utility.

CHAPTER TWELVE: FINAL DESIGN