AMAZON HEALING: TOWER FOR THE AMAZON

FINAL THESIS

POLITECNICO DI MILANO

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MASTER OF SCIENCE IN ARCHITECTURE - BUILDING ARCHITECTURE

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ABSTRACT - EN

The tower represents a challenge to the conventional idea of tall buildings immersed in contexts with a strong presence of nature and low-rise constructions. In the Amazon region of Ecuador, where oil exploitation, deforestation, water pollution and lack of education are palpable problems, the city of Tena stands out as one of the largest and most populated, enriched by its biodiversity and culture. This unique environment offers the opportunity to transform the concept of high-rise building towards sustainability, working with environmentally friendly materials and techniques.

The scale of the tower stands as a balance between the natural and the urban, connecting the low-rise buildings with the majestic mountains. With the insertion of a tall building in such a fragile context, it becomes essential to understand the natural conditions of the site and its distinctive cultural fabric. "Amazon Healing" is a manifesto of this richness, seeking to rethink tall buildings, their expressiveness and materiality, guided by a moral duty to explore local materials and recycle industrial by-products, promoting a cyclical and sustainable approach.

The tower's location at the eastern end of an extensive park, which replaced the former Tena airport, establishes significant connections. The site links an urban North-South axis, connecting the urban growth area and the observation tower, the current landmark, with a natural East-West axis, encompassing the Amazon region and the Andes mountain range. Serving as a backdrop to the long green path, the tower establishes various relationships with the city, highlighting the north-south axis and the views towards the urban centre and the observation tower. While the different heights of the bridges connecting the two volumes respond to the visual connection with various public spaces. The east and west facades vary to manage visuals, filter light and reduce noise from the city. The interior of the building features special volumes that create spatial connections both horizontally and vertically. In addition, the choice to internally expose wood as the main material reinforces the sustainability of the project.

At the urban level, the design of the Tena City Auditorium is proposed, surrounded by native trees, followed by a plaza sloping towards the building that encourages free and spontaneous citizen encounters, stimulating social interaction. At the back of the tower, an extensive green area symbolises the forest that protects the inhabitants and the building from urban noise.

With an integral and sustainable vision, this building not only becomes a landmark for the inhabitants of Tena, but also a tower of light for the entire Amazonian community.

ABSTRACT - ITA

La torre rappresenta una sfida all'idea convenzionale di edifici alti immersi in contesti con una forte presenza di natura e costruzioni basse. Nella regione amazzonica dell'Ecuador, dove lo sfruttamento del petrolio, la deforestazione, l'inquinamento delle acque e la mancanza di istruzione sono problemi palpabili, la città di Tena si distingue come una delle più grandi e popolate, arricchita dalla sua biodiversità e cultura. Questo ambiente unico offre l'opportunità di trasformare il concetto di grattacielo verso la sostenibilità, lavorando con materiali e tecniche ecologiche.

La scala della torre si pone come equilibrio tra il naturale e l'urbano, collegando gli edifici bassi con le maestose montagne. Con l'inserimento di un edificio alto in un contesto così fragile, diventa essenziale comprendere le condizioni naturali del sito e il suo tessuto culturale distintivo. "Amazon Healing" è un manifesto di questa ricchezza, che cerca di ripensare gli edifici alti, la loro espressività e materialità, guidato dal dovere morale di esplorare i materiali locali e riciclare i sottoprodotti industriali, promuovendo un approccio ciclico e sostenibile.

La posizione della torre all'estremità orientale di un ampio parco, che ha sostituito l'ex aeroporto di Tena, stabilisce connessioni significative. Il sito collega un asse urbano Nord-Sud, che collega l'area di crescita urbana e la torre di osservazione, l'attuale punto di riferimento, con un asse naturale Est-Ovest, che comprende la regione amazzonica e la catena montuosa delle Ande. Facendo da sfondo al lungo percorso verde, la torre stabilisce diverse relazioni con la città, evidenziando l'asse nord-sud e le viste verso il centro urbano e la torre di osservazione. Mentre le diverse altezze dei ponti che collegano i due volumi rispondono alla connessione visiva con vari spazi pubblici. Le facciate est e ovest variano per gestire le visuali, filtrare la luce e ridurre il rumore della città. L'interno dell'edificio è caratterizzato da volumi speciali che creano connessioni spaziali sia orizzontali che verticali. Inoltre, la scelta di esporre internamente il legno come materiale principale rafforza la sostenibilità del progetto.

A livello urbano, viene proposto il design dell'Auditorium cittadino di Tena, circondato da alberi autoctoni, seguito da una piazza che degrada verso l'edificio e che favorisce l'incontro libero e spontaneo dei cittadini, stimolando l'interazione sociale. Sul retro della torre, un'ampia area verde simboleggia la foresta che protegge gli abitanti e l'edificio dal rumore urbano.

Con una visione integrale e sostenibile, questo edificio non solo diventa un punto di riferimento per gli abitanti di Tena, ma anche una torre di luce per l'intera comunità Amazzonica.

CONTENT

01 INTRODUCTION

INTRODUCTION

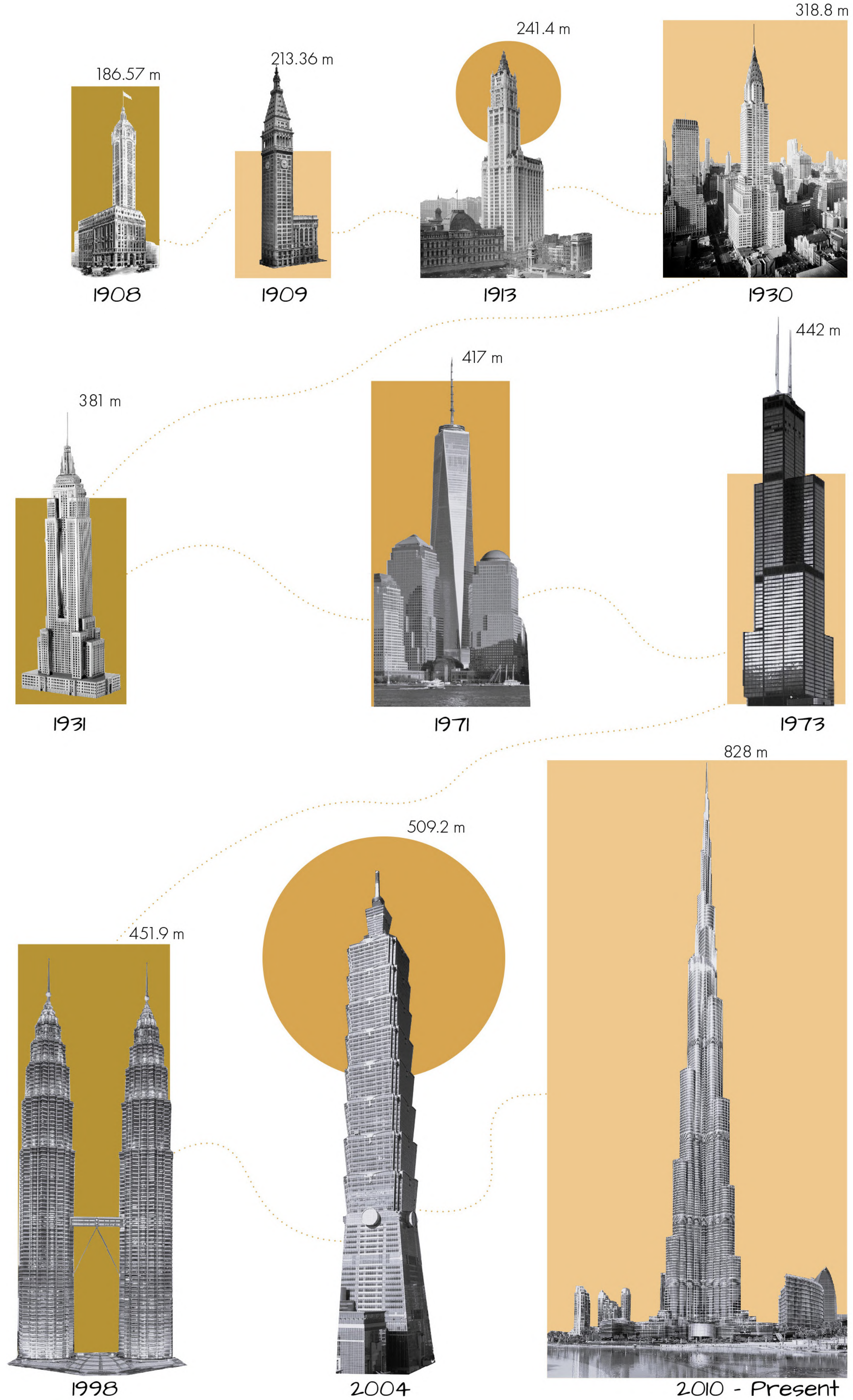
Throughout history, humanity has created towering structures for multiple purposes which, influenced by numerous factors, evolved over time. These tall structures have served as symbols, monuments, fortifications, places of spirituality, solutions to urban density, embodiments of space efficiency, and responses to environmental concerns. The specific purpose behind their construction has been contingent upon factors such as era, location, culture, and technological capabilities. Beyond mere functionality, these tall structures have played a pivotal role in shaping not only the physical landscapes but also the essence of spaces and cities.

The construction of tall buildings presents not only advantages but also challenges, encompassing safety considerations, engineering, urban planning, and environmental repercussions. In the contemporary context, balancing these factors is imperative for the sustainable development of tall buildings in modern and growing cities.

This project unfolds in the city of Tena, located in the Ecuadorian amazon region. This area is home to a rich tapestry of indigenous ethnic groups and boasts one of the world's most diverse collections of plant and animal life, with more than 100 000 square kilometers of tropical forest. Regrettably, the Amazon region has been affected by oil drilling, deforestation and water pollution, issues that generate a negative impact on both the environment and the communities that inhabit the area. Oil is the linchpin of Ecuador's economy, contributing approximately 30-34% of its revenue. While some may reap temporary material benefits, the enduring legacy of pollution manifests itself in impoverished local communities, lacking in education, healthcare, and decent working conditions.

In contemplating the insertion of a tall building into such a fragile context, it becomes essential to comprehend the natural conditions of the place and its unique cultural fabric. Moreover, there arises a moral duty to explore local materials and the possibilities of recycling industrial byproducts, thereby fostering a sustainable, cyclical approach.

Facing this reality, our pursuit centers on the creation of a timber building. This endeavor involves a meticulous study of prefabrication techniques, connection details, and requisite coverings. The configuration of the Amazon Healing Tower encompasses multifaceted analyses, aimed at enhancing architectural, structural, sustainability, technological and systems design.



The applied methodology consists of 4 phases:

Theoretical foundation: based on a documentary analysis and case studies, the objectives of the research were set out and the concepts related to the topic of study were studied.

Diagnosis: through an analysis of the theme, the study cases were selected, the site and context were studied, and the strategies were established.

Design: included five stages. The first consisted of the architectural choice in terms of form, function, and program. The second stage is about technological solutions, physical characteristics, and selected materials. The third one is for structural concept and analysis. The fourth stage consists of building information modelling. The fifth stage for the building services.

Evaluation: formulation of conclusions regarding the insertion of tall buildings in small contexts characterized by an important presence of nature.

The project aims to facilitate the understanding of the criteria and considerations of tall buildings in particular contexts, contributing to nature preservation, cultural empowerment and environmental sustainability.

OBJECTIVES

General Objective

Propose the design of a tall timber building through the analysis of the context, the materials, structure and sustainability.

Specific Objectives

1. Design a tall building located in a site characterized by a strong presence of nature and low-rise buildings.

2. Use timber as the main construction material and define the rainforest wood recycling.

3. Evaluate the building structure and sustainability.

BACKGROUND AND JUSTIFICATION

Tall buildings are a response to the complex interplay of economic, social and environmental factors, each building has its own motivations and purposes.

These structures have become integral parts of modern urban landscapes and continue to evolve in response to social needs, architectural design, technological and material advancements.

Tall buildings history overview:

Early Skyscrapers (Late 19th to early 20th century)

Materials: steel frames and masonry such as brick and stone.

Construction techniques: the use of steel frames and elevators was a breakthrough, enabling buildings to rise higher. Masonry was used for cladding, and decorative purposes.

Architectural style: ornate architectural styles, Beaux-Arts and Art Deco, with intricate detailing on the exteriors.

Mid-20th Century

Materials: concrete became popular material, offering strength and versatility. Glass curtains started to gain popularity for their aesthetic and functional qualities.

Construction techniques: Advances in concrete technology, prestressed and posttensioned concrete improved the strength and durability of structures. Modern curtain wall systems emerged during this period.

Architectural style: International Style, clean lines, minimalist aesthetics, and an emphasis on functionality.

Late 20th Century

Materials: composite materials, reinforced concrete and steel. High-strength steel and advanced glass technologies allowed larger transparent facades.

Construction techniques: pre-fabrication and modular construction became more common, reducing construction time and costs. Sustainable practices started gaining importance.

Architectural style: architectural diversity, various styles and forms from modernism to futuristic designs. Green building principles and sustainable design became leading considerations.

21st Century

Materials: advanced materials like carbon-fiber composites and high strength concrete, both offering structural efficiency and sustainability.
Construction techniques: Building Information Modeling (BIM), 3D printing, and robotic construction methods are being explored to enhance efficiency and precision in construction.

Architectural style: Contemporary tall buildings design present innovation with an emphasis on sustainability, energy efficiency, and iconic forms. Green roofs, wind turbines and other eco-friendly features are part of the design.

Through this constant evolution, the pursuit of taller and more sustainable buildings has been a key diving force. Advances in architectural and engineering design, materials and technology continue to shape the future of tall buildings construction. In addition, concerns about environmental impact and energy efficiency are influencing the choice of materials and construction techniques in contemporary designs.

Consequently, this project seeks to research the possibility of timber tall buildings design, considering the need of belonging to the site and context and the use of local materials in particular the cycle of reuse the rainforest deforested wood.

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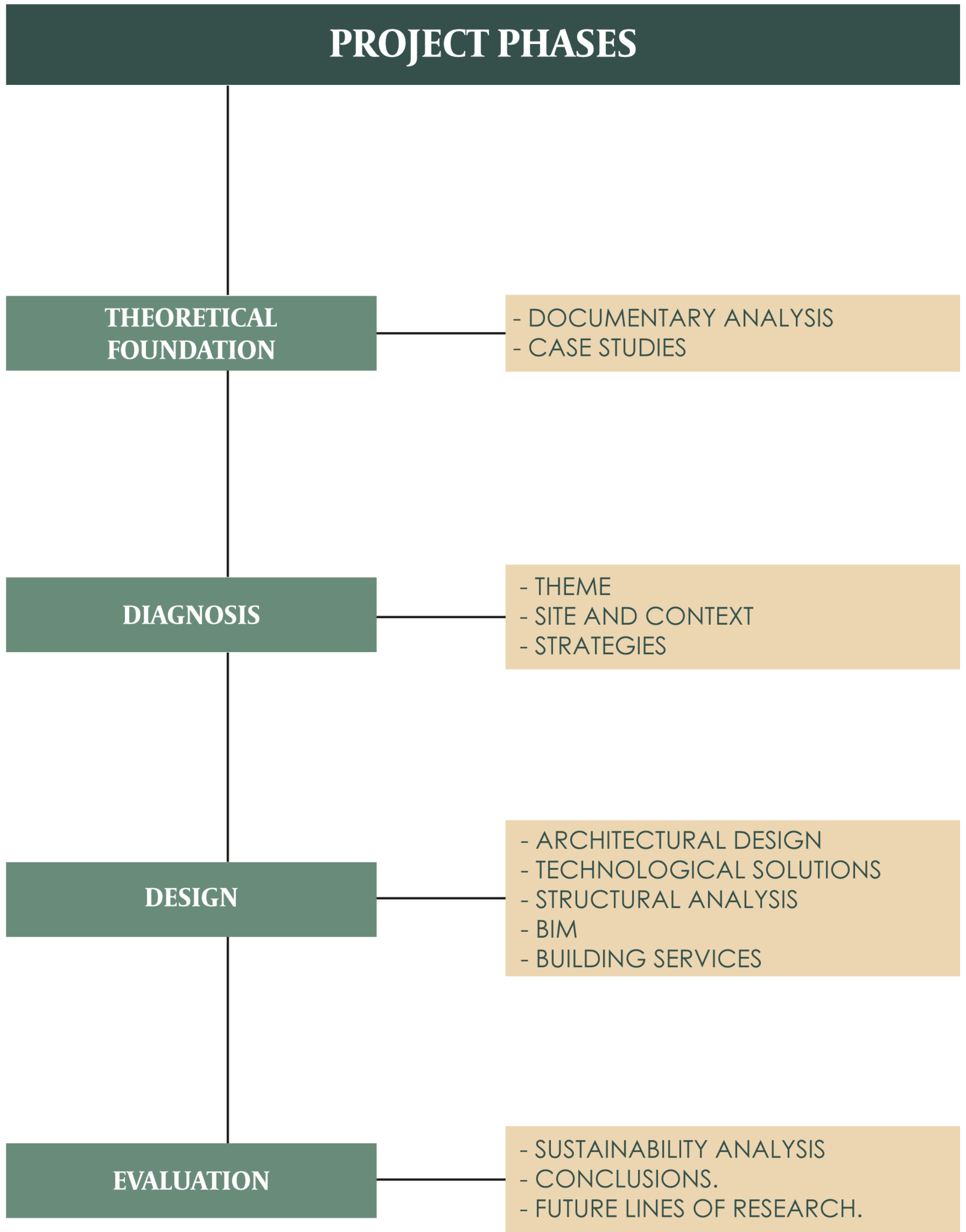


CONCLUSION

It was fundamental to understand the role of the tall buildings along time, their different characteristics and purposes, with the idea of designing a structure that belongs to the site and context by its concept, form, language, materials and technology.

The need that arises at the time to intervene in contexts with a strong presence of nature and cultural manifestations, prompted to propose a research methodology that studies the geometric and material characteristics of the surrounding buildings and the duty to explore local materials generating a tall building that responds to the social, economic and environmental issues.

As Stefan Al mentions:

"When done well, cities can use high-rise development as an opportunity to improve the quality of life for residents...We need to recalibrate the race for the tallest building. We should aim for buildings to be the greenest, with the most landscaping, and the fewest carbon emissions. We need skyscrapers to generate the most renewable energy, produce the most food, and promote the healthiest environments for residents with the most biophilic benefits. We need tall buildings created with their entire life cycle in mind and to be disassembled in the end. We need the most resilient buildings able to withstand the ravages of climate change with not only practical design but also nods to aesthetics and beauty." (Barr, 2022)

02 THEORETICAL FRAMEWORK

THEME

Historical Background of Tallness

What are tall buildings?

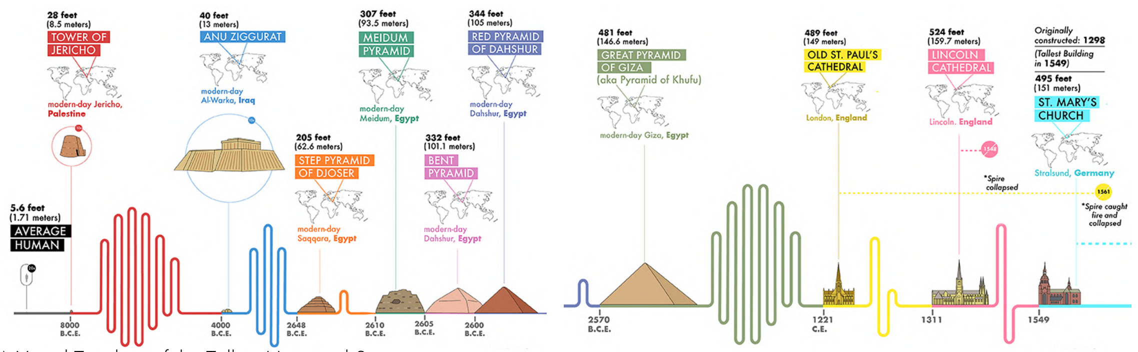
´There is no absolute definition of what constitutes a tall building. It is a building that exhibits some element of tallness (..) It is not just about height, but about the context in which it exists. » CTBUH Criteria for Defining and Measuring Tall Buildings, 2012.v

In the ever-evolving realm of architecture, tall buildings have captivated the imagination of architects, engineers, and urban planners for centuries. From the iconic pyramids of ancient Egypt to the towering skyscrapers of today, verticality in architecture has played a pivotal role in shaping our built environment and urban landscapes. This chapter sets the stage for our exploration of tall buildings, delving into their historical background, the evolution of their importance in contemporary architectural reality, and the profound ways in which they serve society as a basis and justification for the need of a tall building in Tena, Ecuador.

Why tall buildings?

"The interesting question is why does man want to build to the sky. What is there about the desire for domination, or to reach God, or for private pride — the Pyramids are an example of that, but the tall building is certainly another." In J.Duprè,Skyscrapers, Introductory Interview with Philip Johnson, 1996

In the realm of architecture, tall buildings have transcended their physical form to symbolize human ambition, innovation, and progress. We begin by investigating the symbolism of height in architectural history, drawing from the scholarly and academic perspective of architect and theorists. Subsequently, we delve into the significance of tall buildings in the context of contemporary architecture and then explore their particular importance in the cultural landscape of Ecuador.



A Visual Timeline of the Tallest Historical Structures Available at: https://www.visualcapitalist.com/a-visual-timeline-of-the-tallest-historical-structures/

Throughout history, societies have marvelled at the verticality of monumental structures. Verticality is, first of all, connection between ground and sky, It is hope of spiritual ascent. It is human effort, beyond the realm of the rationality. The concept of building tall has deep roots in human civilization, reflecting cultural, religious, and utilitarian motivations. From the ancient structure of Egypt or Mesopotamia to the Gothic cathedrals of Europe, the desire to reach for the sky has left an indelible mark on architectural history. The tall buildings were both a myth and a symbol of the human desire for technological and spiritual advancement that manifests itself in the physical form of our settlements and buildings.

Tower of Babel as a symbol of human desire to reach the divine / cult to the divine

In the cradle of civilization, Mesopotamia, particularly in Sumeria and Babylonia. the construction of ziggurats represented a symbol of cultural and spiritual aspirations. These stepped, temple-like structures reached heights that allowed them to touch the heavens. They served as a physical connection between earth and the divine, a theme that would reemerge in various forms throughout history. The Tower of Babel story reflects the cultural and religious context of the ancient times, where tall structures and temples were integral to the societal and religious landscape.

The Gothic Cathedrals: Vertical Worship and Technical Innovation / cult to the divine

During the medieval period, Gothic cathedrals like Notre-Dame and Chartres soared to unprecedented heights. These architectural masterpieces sought to inspire awe and reverence, creating sacred spaces that connected people to the divine. Achieving such soaring heights required architectural innovation, including the use of flying buttresses and ribbed vaults.

The Birth of the Skyscraper: Urbanization and Technological Advancement / cult to the individual

The 19th and early 20th centuries saw the birth of the modern skyscraper, a typology that would forever alter urban landscapes. The Industrial Revolution, urbanization, and the invention of the elevator transformed the way we thought about architecture and city life.

In 1888, Leroy S. Buffington, an American architect, conceived a twenty-eight-floor structure he named the "Cloudscraper." This marked the initiation of a competition among cities to erect the tallest building (Lepik, 2004). Similar to individuals, cities aspire to possess distinctive features, and skyscrapers represent a noteworthy architectural accomplishment (Maslovskaya et al., 2018). Initially constructed as office spaces, skyscrapers eventually found use as residential structures. This shift was prompted by the convergence of urban migration and the escalating scarcity of space, coupled with rapidly rising land prices (Lepik, 2004).

Interestingly, tall wooden structures had already made their mark, particularly in Asian architecture. Pagodas, religious temples constructed from wood, stood at an impressive height of 67.31 meters and were erected in 1056 AD (B. Orta, 2020).

The verticality as an expression of human aspiration was manifested in Rem Koolhaas, essay "Enter the Prophets of New Sobriety," which addresses the notion of verticality as a representation of human ambition. Koolhaas introduces us to the idea that tall buildings, as much as they are physical entities, are reflections of society's collective dreams and aspirations. In this context, they signify the ongoing pursuit of excellence, the indomitable human spirit, and the desire to push the boundaries of what is possible. In this line of thought we can clearly see the recent rise in the collective ambition to decrese the energy consumption and carbon footprint in the construction industry by building more and more in wood which also extends to the desire to advance the timber tall buildings construction as fast as possible.

In "Delirious New York," Rem Koolhaas presents a unique perspective on the development of skyscrapers in New York City. He introduces the concept of "Manhattanism," a term that encapsulates the city's unique urban condition. It is in this context, that tall buildings are more than just utilitarian structures; they become symbols of the city's unceasing ambition and the embodiment of its collective dream.

Hence, it is this argument that justifies the progress in tall timber construction.

Tall buildings, in his philosophy, represent the ultimate realization of Manhattan's delirious pursuit of verticality. They are not just architectural solutions; they are expressions of a collective desire to push the boundaries of the possible, to reach for the sky and stake a claim on the urban landscape. Koolhaas' philosophical lens encourages us to view tall buildings as integral to the metabolism of the city. The tall building, then, is not just an architectural form; it's a physiological response to the needs and desires of urban society. It takes in people, industries, and cultural expression and redistributes them in a vertical dance of life and innovation. In this interpretation, tall buildings become the physical embodiment of the city's ambitions, creativity, and relentless energy.

On the other hand, Lewis Mumford expressed scepticism and critique regarding the development of skyscrapers. He was critical of the rapid urbanization and vertical growth in cities, particularly in New York. He believed that skyscrapers, with their towering, monotonous forms, dehumanized the city. He thought that they isolated individuals and discouraged social interaction by diminishing the sense of community.

Therefore, this thesis project aims to reconnect the human scale to the tallness of the building in the context of Tena,Ecuador. Through a number of interconnected spaces and atriums, the desire to create a vertical plazza that mirrors the dynamic of the linear park was of main imporatance to the project. Mumford was wary of the relentless pursuit of efficiency, which he saw as leading to a mechanical, dehumanized urban environment. He believed that the focus on efficiency overshadowed the importance of aesthetics, human scale, and cultural richness in architecture. Over time, Mumford's views on tall buildings began to evolve. While he maintained his critique of the negative aspects of rapid urbanization, he also started to recognize that tall buildings had the potential for positive contributions to the urban environment. Mumford's later views emphasized the importance of context-sensitive design. He believed that tall buildings should be integrated into the urban fabric, respecting the existing scale, character, and history of the city. Considering the sensitive context of the Amazon region, the tall building stand as a beacon for the people while not being intrusive in the context of the surrounding peaks and mountains. We have taken into consideration the local traditionas and techniques of buildings with wood to design a tall building which is fit just for the context of Tena, Ecuador.

Tall Buildings in the Contemporary Architectural Reality

In today's architectural landscape, tall buildings continue to hold a prominent place, albeit with evolving purposes and challenges. Urbanization, sustainability, and cultural considerations have reshaped the role of tall buildings in our cities. As cities expand, the scarcity of available land encourages architects and developers to build vertically. Tall buildings are not only efficient in terms of land use but also crucial in addressing housing and office space demands in dense urban areas.

In the contemporary era, a new race for constructing the tallest buildings is unfolding, but this time, the focus is on timber structure skyscrapers. Notable instances include the 'Mjøstårnet' in Norway, boasting 19 stories and initially considered the largest timber building, now surpassed by the 'The Ascent MKE Building' in Wisconsin, USA, reaching 25 stories by 2022. Ongoing endeavors aim to push the boundaries of height in building design.

However, the tall building as a building typology has been a subject of intense debate since its inception. In Europe, conservative building regulators initially resisted its acceptance due to concerns about potentially undermining the aesthetic advantages of surrounding old buildings (Lepik, 2004).

Sustainability and Vertical Living

Tall buildings have gained attention as a means to reduce urban sprawl and promote sustainability. Modern tall buildingsv are designed with energy-efficient systems, green spaces, and eco-friendly materials to minimize their environmental impact. Initiatives such as LEED and green roof technologies have further emphasized the importance of sustainability in tall building design.
Tall buildings are more than symbols of architectural prowess; they serve society in various ways. They offer spaces for living, working, leisure, and cultural expression, often creating iconic landmarks that define cityscapes.

Housing and Population Density

In densely populated urban areas, tall residential buildings provide solutions to housing shortages. They accommodate large numbers of people while maximizing open space and amenities.

Workspaces and Innovation Hubs

The corporate world has embraced tall buildings as iconic headquarters. These structures represent economic powerhouses, fostering innovation, collaboration, and urban vitality.

Culture and Research in the current architectural reality in Ecuador

In Ecuador, the concept of tallness holds a unique significance and symbolism deeply rooted in the country's cultural, historical, and geographical context. From the majestic Andes Mountains to the towering trees of the Amazon rainforest, Ecuador's landscape has played a pivotal role in shaping the perception of tallness. To understand the need of a timber skyscraper in Tena, Ecuador we will delve into the significance and symbolism of tallness in Ecuador, exploring how it is intertwined with nature, heritage, and identity.

The Andes Mountains: Guardians of the Heights

Ecuador's most iconic geographical feature, the Andes Mountains, stands as a towering testament to the nation's rich tapestry of tallness. The Andes, stretching from north to south, not only define the country's topography but also symbolize its resilience and strength. Ecuadorians have long admired the towering peaks for their majestic beauty, and the mountains have been sources of inspiration and spirituality.

Religious Significance

For many indigenous communities in the Andean region, the high peaks of the Andes are considered sacred. Mounts like Cotopaxi and Chimborazo have deep-rooted spiritual connections, often associated with deities and rituals. These mountains are revered as protectors and providers, and their symbolic significance transcends their physical stature.

Metaphorical Ascent

Tallness in the Andes becomes a metaphorical ascent to greater heights. The determination of mountaineers who challenge themselves to reach mountain summits mirrors the perseverance and courage that Ecuadorians exhibit in their daily lives.

The Amazon Rainforest: Vertical Biodiversity

Ecuador's share of the Amazon rainforest, a sprawling expanse of lush greenery, epitomizes the concept of vertical diversity. The towering trees and abundant plant life symbolize the interconnectedness of the natural world and the ecological balance that sustains life.

Biodiversity and Abundance

The towering trees of the Amazon rainforest are not just sources of sustenance but also embody the diverse, interconnected ecosystems of the region. The wealth of plant and animal species, all coexisting in the vertical space, reflects the idea of abundance and unity in diversity.

Medicinal and Cultural Significance

The indigenous peoples of the Amazon have long regarded the rainforest's towering flora as sources of medicinal plants and cultural symbols. The tallness of the trees, combined with their biodiversity, emphasizes the relationship between the environment and human well-being.

Traditional Architecture: Tallness in Heritage

Ecuador's architectural heritage often incorporates tallness in its design, reflecting the influence of indigenous and colonial traditions. From the towering spires of churches to the multi-story indigenous homes, tallness in architecture embodies historical and cultural continuity.

Indigenous Housing

Traditional indigenous homes in the Andes, like the "choza," are often multi-story structures, enabling efficient use of space in vertical dimensions. These tall dwellings reflect the practicality and resourcefulness of indigenous communities in adapting to their mountainous environment.

Colonial Influence

The colonial era introduced architectural elements that emphasized tallness, particularly in the construction of churches. The imposing bell towers and spires of colonial churches are architectural symbols of spiritual and cultural influence.

Identity and National Pride

The concept of tallness is woven into the very fabric of Ecuador's national identity. It reflects the nation's diverse geography, its resilient spirit, and its cultural and natural heritage. Ecuadorians take pride in their tall mountains, lush forests, and architectural grandeur, seeing them as symbols of their nation's uniqueness.

Unity in Diversity

Ecuador's diverse landscapes, each with its own tall elements, represent unity in diversity. The nation's motto, "Ama la vida" (Love Life), reflects the Ecuadorian spirit of embracing life in all its heights and depths.

Pride in Heritage

Ecuadorians take pride in their indigenous heritage and colonial history, both of which are reflected in the tallness of their architecture and natural wonders. The nation's history is a source of pride, and tallness is a visual reminder of that heritage.

Tallness in Ecuador is not just a physical attribute; it is a symbol of the nation's natural beauty, cultural heritage, and national identity. The towering Andes Mountains, the rich biodiversity of the Amazon rainforest, traditional architecture, and historical significance all contribute to the multifaceted symbolism of tallness. Ecuadorians cherish their nation's tall elements as sources of inspiration, cultural heritage, and pride, embracing them as symbols of unity, diversity, and the resilience of their nation.

Alternative

Ancient climate evidence, or paleoclimate data, indicates that current warming is occurring approximately ten times faster than the average rate of ice-age-recovery warming. The primary driver of climate change is CO2 emissions. he Paris Climate Agreement, signed in 2016, builds on the Tokyo Agreement and marks a significant step toward concrete efforts to reduce CO2 emissions by the world's wealthiest nations.
Cities are predominantly constructed using two materials: concrete and steel, which dominated the 20th century. In the United States, steel became the preferred material, especially for high-rise buildings. While these materials have been crucial in shaping cities, their production processes entail significant energy consumption and greenhouse gas emissions. Steel accounts for 3% of global human greenhouse gas emissions, and concrete contributes over 5%. Collectively, these two materials are responsible for 8% of human gas emissions, with almost half of CO2 emissions linked to the building industry—surpassing the emissions from the transportation sector, which accounts for 33%. Considering that three billion people will need new homes in the next 30 years and recognizing the environmental impact of conventional city-building materials, such as concrete and steel, it becomes imperative to explore alternative materials. Wood emerges as a promising alternative.

EVOLUTION OF WOOD CONSTRUCTION

Wood construction is one of the oldest building techniques employed by humans throughout history. From humble beginnings to innovative modern applications, wood has played a significant role in shaping the built environment. The history of wood construction can be traced back to the earliest civilizations when humans first discovered the utility of timber. The use of wood for shelter and construction can be divided into three key phases:

Prehistoric Origins: Wood was one of the first building materials used by early humans. Primitive shelters were constructed using wooden branches, leaves, and animal hides. The discovery of fire allowed early humans to make wooden structures more durable by using controlled burning to strengthen wooden supports.

Early Wooden Dwellings: As human societies advanced, wood became a more sophisticated building material. In regions with abundant timber, such as Europe and Asia, wood was used to create more permanent dwellings. Log cabins, for instance, are an early example of wood's adaptability as a construction material. They provided efficient insulation and protection from the elements.

Timber Buildings in South America

South America has a rich history of timber construction, with several ancient wooden structures that hold cultural and historical significance. Here are a few examples of some of the oldest timber structures in South America and their respective significance and history:

Torres del Paine Ranch, Chile (c. 1890):

The Torres del Paine Ranch, located in the Chilean Patagonia, features some of the oldest timber structures in South America. These well-preserved buildings, made primarily of local timber, showcase the region's history of livestock farming and ranching.
Significance: The ranch's buildings serve as a historical testament to the early European settlers in Patagonia and their agricultural practices. They offer insights into the architectural techniques and materials used during that period.
Capilla de San Antonio, Argentina (c. 1760):

The Capilla de San Antonio, situated in the province of Santiago del Estero, Argentina, is an adobe and timber chapel constructed in the colonial era.
Significance: This chapel, with its wooden roof structure, exemplifies the architectural styles of colonial Argentina. It serves as a historical and religious site of importance, reflecting the influence of Spanish colonial architecture in the region.

The Alerce Costero National Park, Chile (c. 1500-2000 years old):

The Alerce Costero National Park in Chile is home to some of the oldest living trees on the planet, the Alerce trees (Fitzroya cupressoides). These ancient trees are a form of timber structure in their own right, with massive trunks and towering canopies.
Significance: The Alerce trees hold immense ecological and cultural significance. They are not only valuable for scientific research but also revered by indigenous Mapuche communities for their cultural and spiritual importance.

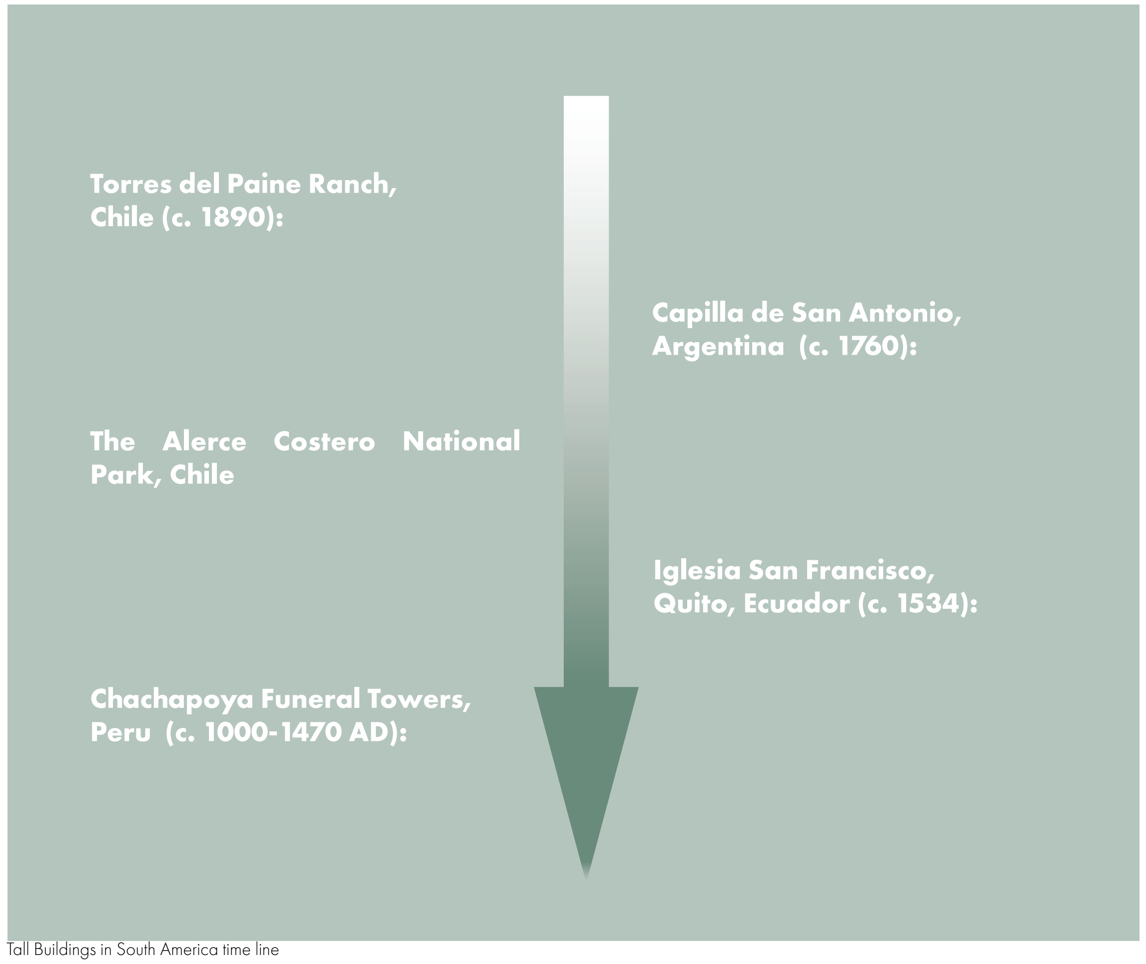
Chachapoya Funeral Towers, Peru (c. 1000-1470 AD):

The Chachapoya Funeral Towers, also known as the "Llactapata," are ancient stone and timber structures located in the Amazonas Region of Peru. These structures were built by the Chachapoya civilization as burial sites.
Significance: The Chachapoya Funeral Towers represent the architectural and cultural heritage of the Chachapoya people. They are important for their unique construction, combining timber and stone in structures that are both practical and sacred.

Iglesia San Francisco, Quito, Ecuador (c. 1534):

The Iglesia San Francisco in Quito is a historic church featuring timber elements in its architectural design. It was constructed in the early colonial period.

Significance: The church is a UNESCO World Heritage Site and is significant for its architectural and historical value. It represents the blend of Spanish and indigenous architectural styles and materials, including timber, in the early colonial period of South America.
These examples of timber structures in South America hold cultural, historical, and architectural significance. They provide insights into the building traditions and materials used by various civilizations and communities throughout the region's history. They serve as a testament to the cultural diversity and architectural ingenuity of South America's past and continue to be valuable for preservation and cultural understanding.

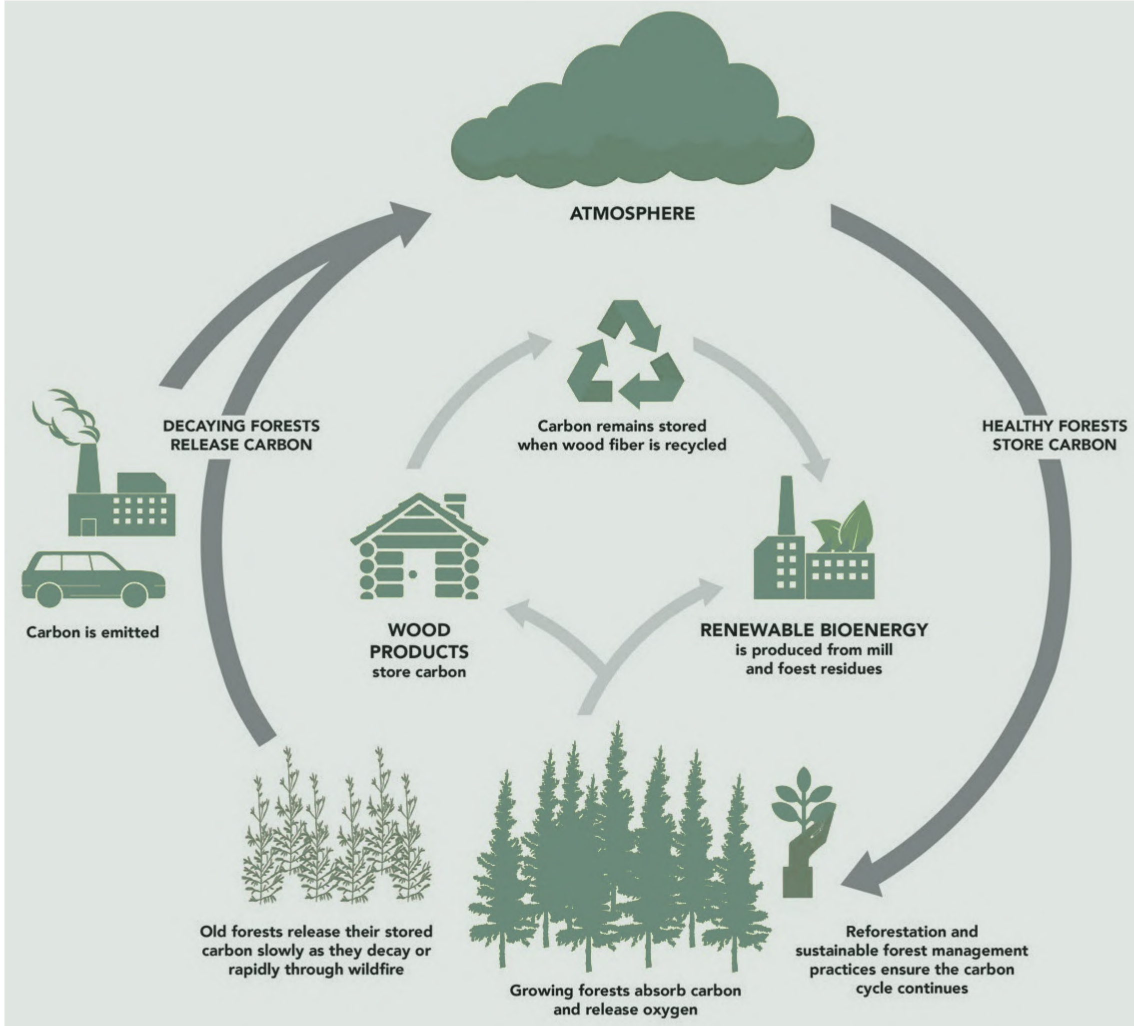


Tall Buildings in South America time line

Sustainable Cycle Of Wood

The Amazon rainforest, renowned as the "lungs of the Earth," holds unparalleled biodiversity and a pivotal role in global climate regulation. Designing a tall building in Tena, Ecuador means exploring sustainable design solutions and investigating the intricate relationship between sustainable forestry in Ecuador's Amazon and the construction of a timber tall building. By scrutinizing the wood production life cycle, sustainability principles, and forest management strategies, we underscore the symbiotic link between responsible forestry and the realization of environmentally conscious architectural marvels.

Ecuador's Amazon harbors unique flora and fauna, necessitating a shift toward sustainable forestry. This entails selectively harvesting trees, allowing natural regeneration, and maintaining biodiversity. As awareness grows, Ecuador seeks to balance economic interests with the long-term health of the Amazon, emphasizing responsible forest management.

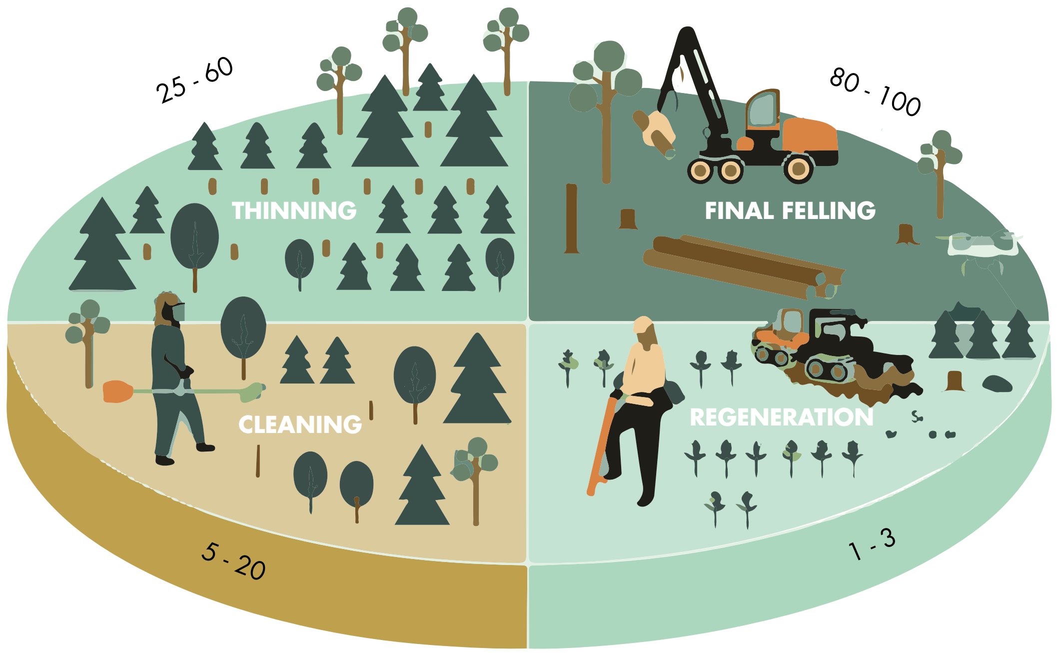


Managed forests and climate change Available: https://www.ontario.ca/page/managed-forests-and-climate-change

Wood Production Life Cycle

The critical wood production life cycle involves identifying, harvesting, and processing trees. In Ecuador's Amazon, responsible forest management includes selective harvesting, environmentally friendly transportation, and meticulous processing to minimize ecological disruption and carbon emissions. Sustainable timber production extends beyond the forest, aligning with ecological balance, social responsibility, and economic viability. Responsible forestry contributes to biodiversity conservation, supports local communities, and provides a renewable resource, aligning with global efforts to reduce the environmental impact of construction. Strategic forest management ensures a continuous supply of quality timber for construction. Harvested trees, selected to meet project needs, are processed into engineered wood products like cross-laminated timber (CLT) and laminated veneer lumber (LVL). These products offer sustainable alternatives, enhancing the safety and longevity of timber tall buildings while sequestering carbon and supporting climate change mitigation. .

Forest management in Tena ,Ecuador entails the meticulous protection and upkeep of forested regions. It frequently involves assessing the soil, trees, and vegetation in a forest ecosystem, undertaking a range of intricate tasks to enhance land management practices.
Strategies in Forest Management include the harvesting of timber. This is the process of felling trees for timber, often conducted by those in the timber industry to generate income.

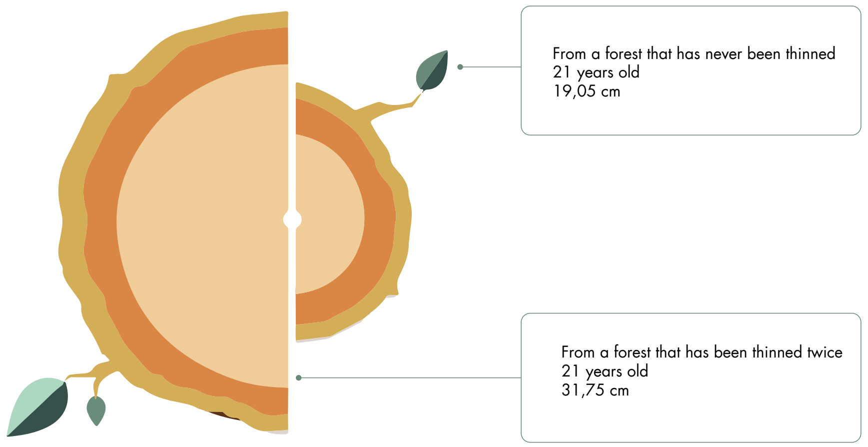


The cycle of forestry Available at: https://www.forestindustries.se/forest-industry/forest-management/the-cycle-of-forestry/

Forestry managers may responsibly harvest wood, ensuring minimal impact on the surrounding environment, such as targeting mature trees nearing the end of their life cycle.Thinning of trees involves removing trees or other vegetation to facilitate the growth of naturally occurring species, eliminate invasive species, and enhance the value of timber. Forestry managers might opt to thin out trees that do not positively contribute to wildlife habitats or wood production. Planting Trees with the aim to replace previously removed trees.

Lastly, managing wildlife encompasses practices to oversee wildlife within a forested ecosystem, ensuring that actions taken do not harm existing wildlife while promoting the health of endangered species. This may involve monitoring species, reintroducing them into specific areas, and developing strategies for dealing with predators.

Thining is the process of periodically removing smaller, unhealthy, or malformed trees to reduce the density of working forests.Less competition for sunlight and nutrients means healthy trees grow bigger more quickly.Younger trees in foresrs that have been thinned are larger than older trees in forests that haven't.



Tree thinning Available at: https://www.drax.com/sustainable-bioenergy/healthy-forests-need-markets-for-sustainable-management/

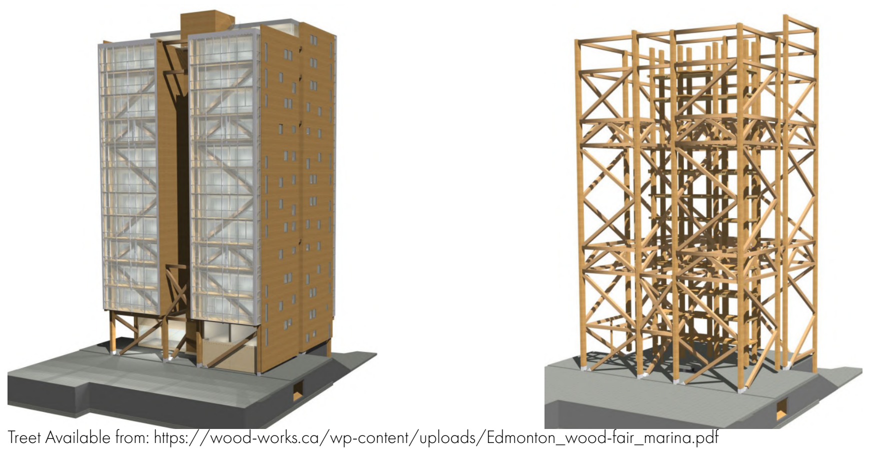
Building high with timber has many challanges which needs to be taken into consideration during the design phase. Timber construction provides many advantages to boost local Ecudorian economy for timber production , especially for small scale timber proudecrs which are often overtaken by larger corporations. With the aid of the forest management, the trees can be used for the construction of the skyscraper which will serve the local communities in Tena and provide more alternatives for occupation and incomes in comparison to the oil drilling and the illegal deforestation practices.

TALL WOOD SYSTEMS

Structural systems	Lateral Force Systems	Connections Design	Fire Strategies	Longevity	Building Process
Mass timber Panel System	Vertical Lateral Seismic force Resisting	Beam to beam	Sprinklers systems		
Post and beam	Horizontal Lateral Seismic force Resisting	Beam to column	Design for burnout		
Hybrid	Diaphragm	Column to column	Encapsulation		
	Wind	Column to foundation	Facade		

Tree thinning Available at: https://www.drax.com/sustainable-bioenergy/healthy-forests-need-markets-for-sustainable-management/

Case Studies



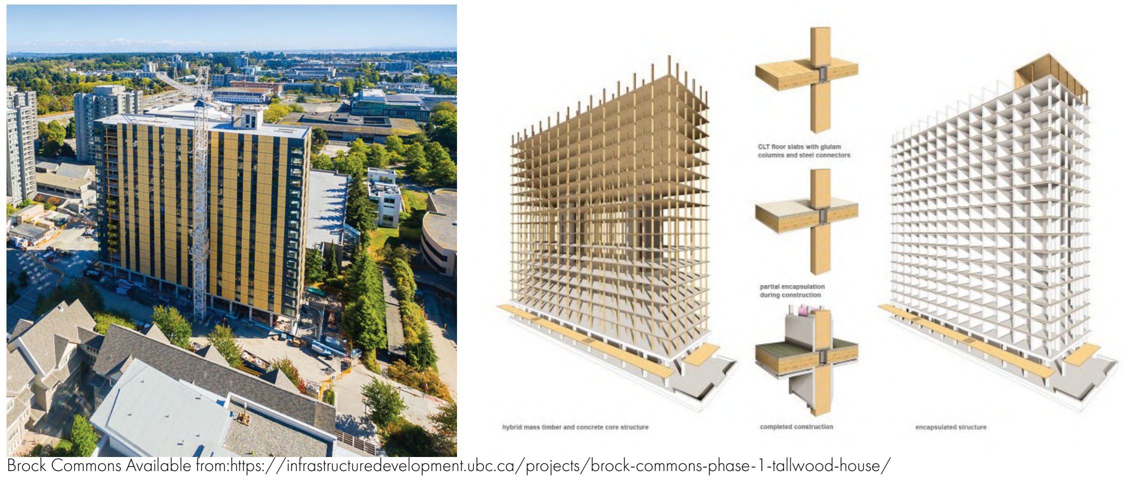
Treet Available from: https://wood-works.ca/wp-content/uploads/Edmonton_wood-fair_marina.pdf

Treet

The structure of the building consists of a framework of diagonal, vertical, and horizontal beams and columns, situated above a concrete podium with a Mass Timber core. The residential units are fully prefabricated and have been assembled on-site in a finished state. The gravity loads system includes CLT floors that support the residential modules, with two levels featuring concrete floors essential for the construction phase and contributing to the overall stiffness of the building. Large diagonal beams bear the lateral forces and also enhance the building's visual appeal. The Mass Timber Core incorporates the main stairs, elevator shaft, and corridor walls made of CLT.

The primary fire strategy involves encapsulating the structural elements while leaving the vertical and diagonal columns exposed within the building. Despite this, all construction components possess a fire resistance of R90. The modules composing the flats are designed to endure fire for 74 minutes. All visible timber elements are treated for fire resistance, and no cavities with combustible materials are left uninsulated. The building is fully equipped with sprinklers, including the balconies.

In terms of structural data, the building was constructed in 2014 and stands at a height of 52.8 meters with 14 storeys. The floor surface of the 11th floor is 480 square meters, and the floor-to-floor height is 2.9 meters. The core is positioned laterally/centrally, and the floor plans measure approximately 25 x 25 meters. The columns are spaced at a distance of 8x8 meters, and the floor-span is 8x4 meters. The structural system employs a Post & Beams configuration, with Glulam beams measuring 40x40 cm and Glulam columns measuring 40x60 cm or 50x50 cm. The floors are made of Mass Timber, with only three storeys featuring concrete. The lateral force systems involve the concrete podium and diagonal beams.



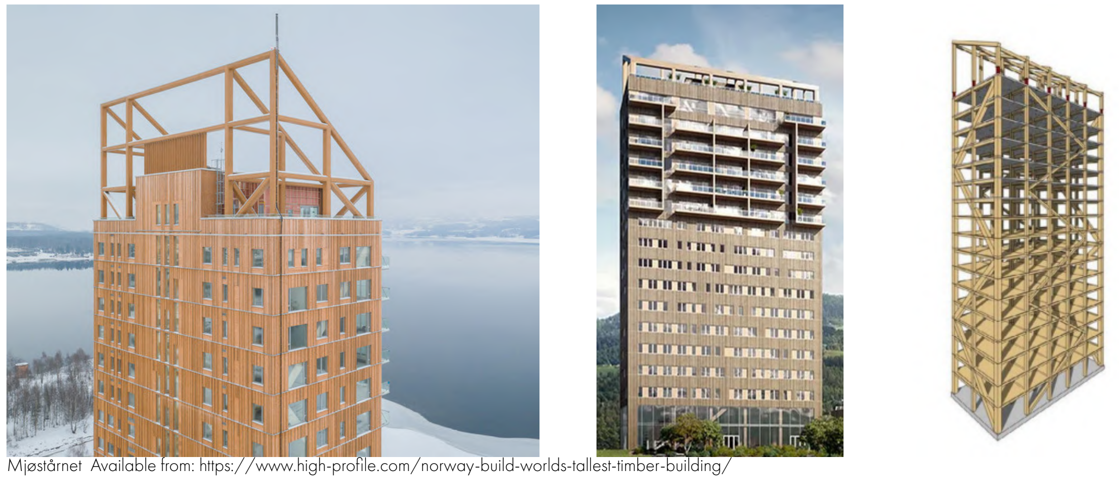
Brock Commons Available from:https://infrastructuredevelopment.ubc.ca/projects/brock-commons-phase-1-tallwood-house/

Brock Commons

This tower features a hybrid structure with 17 mass timber constructed storeys situated on a concrete podium. The timber structure bears the vertical loads, while the lateral stability is provided by two concrete cores. From levels 2 to 18, the gravity load system incorporates glulam columns with steel connectors supported by 5-ply CLT panels arranged in a regular grid. These panels act as a two-way slab diaphragm, with a staggered configuration and orientation along the long axis of the building.

All structural elements are covered with multiple layers of gypsum board for fire-rating purposes, encapsulating the mass wood structure. However, in the top-floor amenity space, the wood is intentionally left exposed. The building is equipped with an automatic sprinkler system with a backup water supply. The units are compartmentalized with a 2-hour fire rating between suites, exceeding the typical 1-hour rating. The building's facade is highly prefabricated, with panels measuring 8 meters in length and the height of one floor (2.8 meters). These panels are composed of high-pressure laminate containing 70% wood-based fibers and pre-installed windows.

In terms of structural data, the tower was constructed in 2017 and stands at a height of 53 meters with 18 storeys. The floor surface of the 5th floor is 840 square meters, and the floor-to-floor height is 2.8 meters. The core is positioned laterally/double, and the floor plans measure 15 x 55 meters. The columns are spaced at a distance of 2.85 x 4 meters, and the floor-span is 2.6x9.6 meters. The structural system employs a Post & Beams configuration, with glulam columns measuring 26x26 cm or 26x21 cm. The floors act like beams, and the core is made of concrete. The lateral force systems involve the concrete podium and concrete cores.



Mjøstårnet Available from: https://www.high-profile.com/norway-build-worlds-tallest-timber-building/

Mjøstårnet

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PLACE

Amazon region and its issues

The amazon region in Ecuador covers 120 000 km2 (48% of the national territory) and includes the provinces of Sucumbios, Orellana, Napo, Pastaza, Morona Santiago and Zamora Chinchipe. With approximately 740 000 inhabitants, it is important to underline the existence of community that voluntarily remain without contact with society. A place rich in flora, fauna, rivers, landscapes, gastronomy, and variety of activities to do. Due to its proximity to the Ecuadorian capital city Quito and its easy accessibility, it is possible to enter its unique territories in just 30 minutes by road.

The Ecuadorian Amazon has been called the "Lungs of the Planet" and many of its forests, parks and reserves have been recognised as sanctuaries of life and places that every nature and conservation lover should visit. However, its main economic activity is the extraction of oil, gold and copper, which is the cause of constant social conflicts and environmental damage. Since 1960s, the inhabitants have been fighting against the harmful consequences for their health and dignity caused by the extractive activity.

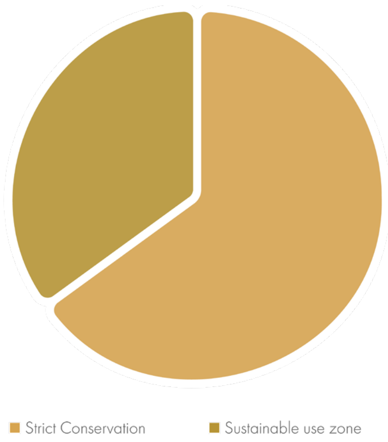
The six big threats in the Amazon

1. Minning concessions
2. Increase in hydroelectric dams
3. Road construction
4. Expansion of intensive agriculture
5. Deforestation
6. Changes in the legislation related to protected areas

Forest management in the Amazon

The Environment Ministry of Ecuador is the authority responsible for the management of the forestry resources in the country. The Sustainable Forest Development Strategy, created in 1999, points out the role of forests as providers of environmental goods and services and establishes the goal of using them in a sustainable manner. Therefore, it creates two technical standards with criteria and indicators for Sustainable Forest Management, differentiated according to the degree of mechanisation of harvesting. One the one hand, when the producer uses heavy machinery to extract timber from the forest in logs, the authorities require the elaboration of a Sustainable Forest Harvesting Program. On the other hand, when forest management is carried out on a small scale, so that logs are sawn in the forest and the pieces are then transported in a non-mechanised way to marketing points, a Simplified Forest Harvesting Program is required. (Matamoros, A. et al, 2012)

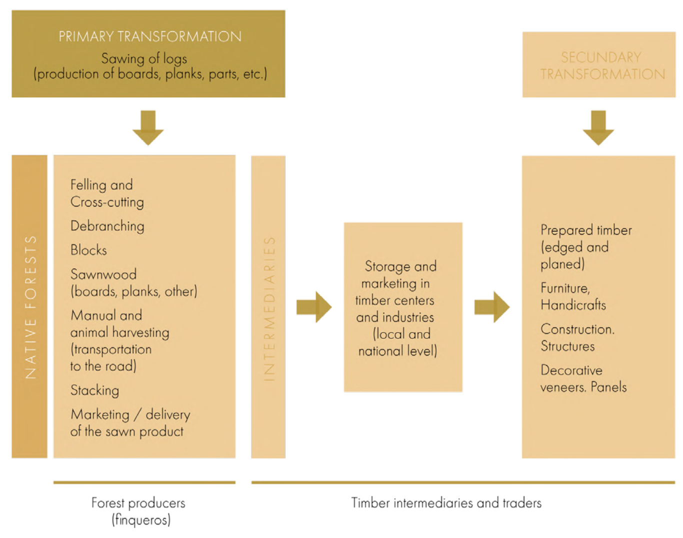
In 2004, the Shuar Arutam Government Council (CGPSHA) prepared a "Life Plan" that outlines its education and health model. This model is based on a culture that bases its economic organization on sustainable use of natural resources, using appropriate agricultural systems like traditional orchards, agroforestry techniques and silvopastures. Following the model, the more than one thousand Shuar families zoned their properties in collective territories and prepared a land use planning mechanism. Through this activity, they determined that between 65 and 70% of the land would be set aside for conservation, specifying two zones: (i) strict conservation area promoted by the Socio Bosque Program covering approximately 58,000 ha (Socio Bosque, MAE, 2010); and (ii) sustainable use zone, reserved for management of timber and non-timber forest products. The rest of the territory (30 to 35%) is used for cropland, livestock production and family living areas.



Technical and commercial aspects

Forest management and utilization practices in the Center-South of the Ecuadorian Amazon are developed by small-scale forest producers, including indigenous communities and settlers, who possess production units called "fincas" that vary from 20 to 70 ha.
The forest, mainly timber, is an important source of economic income for households in the Amazon region, supplying the markets of different provinces especially with timber destinated to exportation, furniture, and construction industry. As part of a sustainable economic development, timber harvesting takes place mainly in primary forests and agroforestry systems. This indicates that families own land with native forests and trees within logged-over areas. Both are of similar importance for the economy as they are adapted to the different biophysical and political situations in the Amazon. Nevertheless, as forest tend to degrade over time, it is crucial to adapt better incentive policies, improve the benefits for smallholders by making better use of their forest resources or to adopt strategies for more sustainable forest management.

MAIN SCHEME OF THE TIMBER TRANSFORMATION AND MARKETING PROCESS IN THE CENTER-SOUTH OF THE ECUADORIAN AMAZON.



Main Scheme of the Timber transformation and marketing process in the center-south of the ecuadorian amazon. From: SFA. 2008. El aprovechamiento forestal y la comercialización de madera en la zona de la Cordillera del Cóndor – Ecuador. Macas, Ecuador. 23 p.

Tena City as a strategic place

Tena is the capital city of the Napo province, being its largest and most populated city. It is located at the north-central part of the amazon region of Ecuador. It is situated on the outher slopes of the eastern Andean mountain range. The city is traversed by the Tena and Panorivers and rest at an elevation of 510 meters abosea sea level. With an avarage tropical rainy climate, Tena maintains a temperature of around 22.7 °C.

Its geography, defined by its central location in the Ecuadorian Amazon region and the Andes mountain range to the west, favours the strong presence of nature and biodiversity. Furthermore, Tena is conviniently positioned three and a half hours from Quito, the capital city of Ecuador. Over the years, Tena, once a small town, has significantly expanded its tourist offerings, placing and particular emphasis on ecological and adventure activites, allowing local and international people to discover more about its rich culture and nature.

With a population of 1959,39 people per square kilometer, Tena thrives as a bustling hub of extensive commercial activity, serving as the largest economic and commercial center in the province of Napo and a prominent player in the broader Amazon region. The city houses major financial and commercial organizations, making it a key contributor to the country's economic landscape. Its economic foundation rests on a blend of trade, tourism, and agriculture.

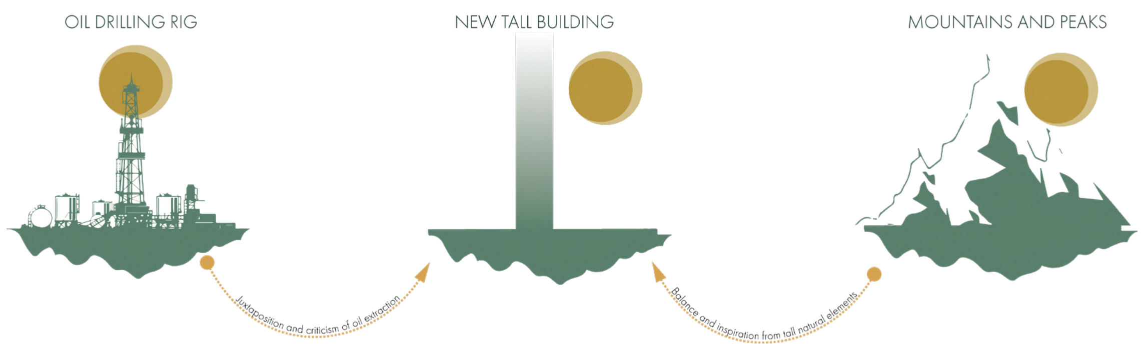
Timber and agriculture, including activities like fish farming and poultry farming, constitute the primary industries fueling Tena's economy. The city's residents derive their income from both formal and informal sectors, with a significant portion engaged in small and micro-enterprises. The informal economy plays a crucial role, providing employment opportunities for thousands.

Regarding the educational aspect, Tena boasts a well-established educational infrastructure, encompassing both public and private institutions. There are several universities and one higher institute, notably the recently established Ikiam Regional Amazonian University. The name "Ikiam," derived from the Shuar language, translates to "jungle." This university is dedicated to research and the training of professionals specializing in Life Sciences, Earth Sciences, and Science of Human Settlements. In addition to Ikiam, other universities in the city primarily offer distance education programs, exemplified by the Universidad Técnica Particular de Loja.

Having an evident natural-urban landscape with low buildings surrounded by high mountains, this project site aims to be a manifesto of the cultural and natural wealth. The place is strategically positioned in relation to a natural axis from east to west and a urban axis from north to south. Setting a strong relation between the amazon rainforest, the high Andes mountains, the new urban development and the city center and its landkmar, the Observatory Tower (50m high).

CONCEPT

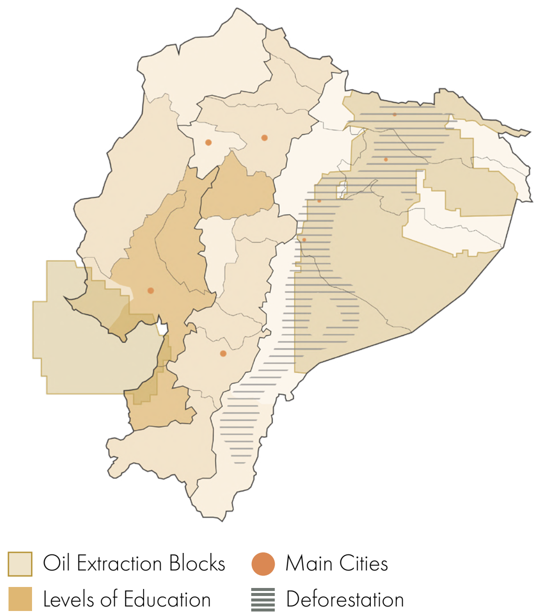
In addition to be a part of Amazon rainforest, the location for designing the tall tower is proposed to address specific issues as oil extraction, deforestation, water polution and lack of education which are crucial for indigenous people. The Amazon Healing tower aims to point out and heal these issues by its existence.



Oil Extraction

There is a great deal of oil under the Ecuadorian Amazon. The Ecuadorian government recently approved a controversial plan to drill for the oil which lies under the pristine Yasuní National Park. Some locals think that a poor nation cannot afford to ignore such vast oil wealth, while others feel that protecting the wildlife in the park (and respecting the right of the uncontacted cultures to be left alone) is much more important than drilling for oil although oil is one of the main sources of income for the country.

Ecuador extracts an average of 497.16 thousand barrels of oil per day. Most of them are destined for export, which is why they are considered one of the most important items in the financing of the state budget. Ecuador counts with 60 blocks of oil extraction, 52 of them located in the amazon. These blocks overlap the ancestral or titled lands of ten indigenous groups. Many blocks also cover protected areas such as national parks that were originally established for biodiversity protection. Also, oil extraction causes major environmental and social impacts.




Deforestation


Oil Extraction


Water Pollution


Lack of Education

Deforestation

For decades, the primary catalyst for deforestation in the Ecuadorian Amazon has been the oil industry. The initial impact is typically felt through the establishment of roads and pipelines to reach oil installations, causing significant harm to the integrity of the rainforest. This process is often followed by colonization. The direct consequences of oil extraction encompass deforestation for access roads, drilling platforms, and pipelines, as well as environmental contamination resulting from oil spills and wastewater discharges.

The exploration for oil involves the extensive construction of jungle roads covering thousands of kilometers and the use of hundreds of seismic detonations, contributing to land erosion and the dispersal of wildlife. Additionally, indirect effects emerge due to the newfound accessibility of previously remote primary forests through newly established oil roads and pipeline routes. This accessibility leads to heightened logging, hunting, and deforestation resulting from human settlement.

Between 2002 and 2020 in Ecuador, the following environmental impacts were observed:

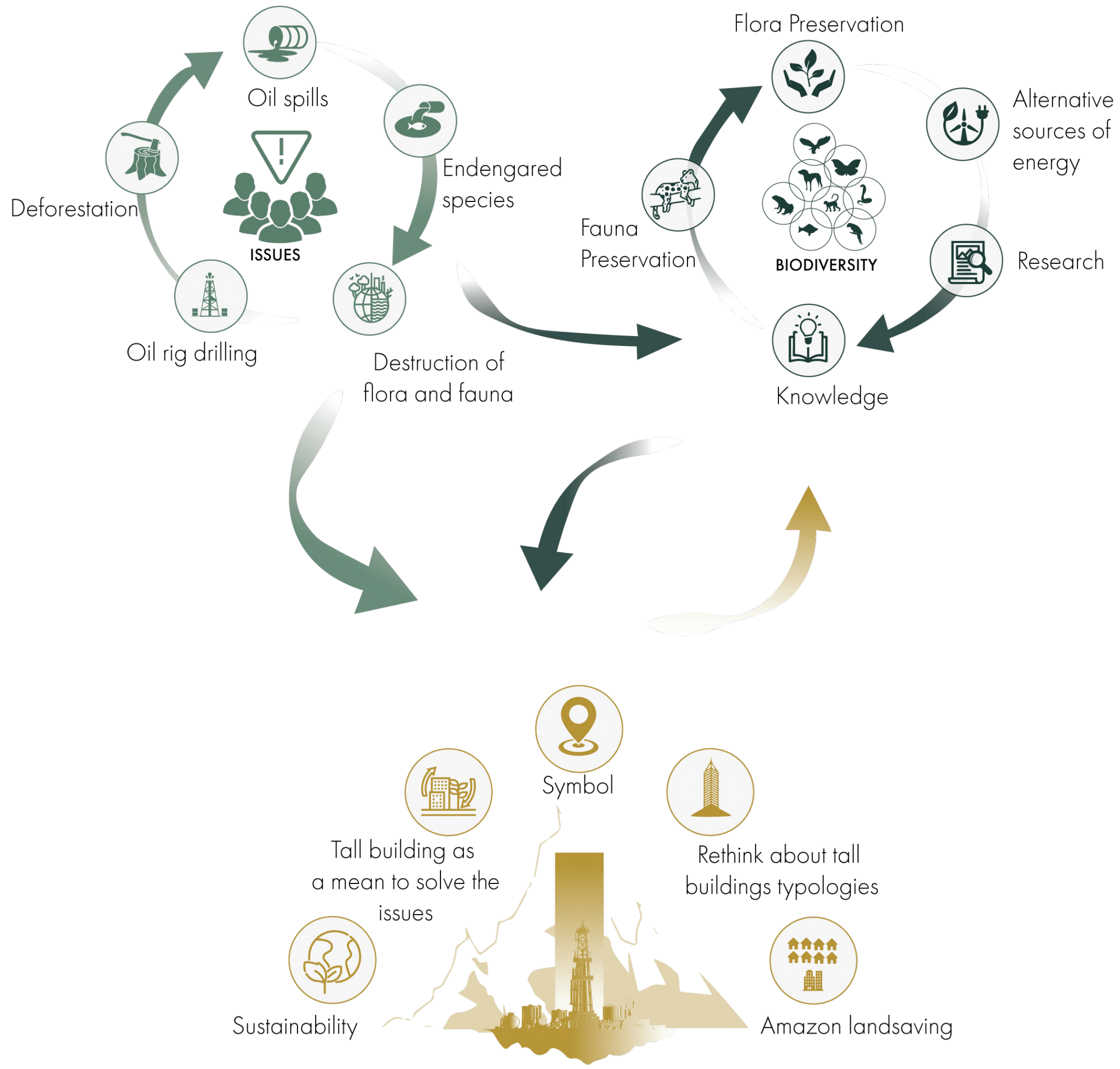
Approximately 193,000 hectares of humid primary forest were lost, constituting 23% of the total tree cover loss.
The overall area of humid primary forest in Ecuador experienced a 1.8% decrease during this period.
A total loss of 871,000 hectares of tree cover occurred, equivalent to a 4.6% reduction in tree cover since 2000, accompanied by 547 million metric tons of CO_2 equivalent emissions. (Mainville, N. 2018, October 5)

Water Polution

Each well that is drilled produces an average of 4,000 cubic meters of waste from the interior of the earth. These highly toxic wastes are frequently deposited in earthen pools, from where they are either disposed of directly into the environment, or they are dumped into it due to breakage of the pools or overflow due to rain. Moreover, major spills due to rupture of the main oil pipeline generates a loss of millions of gallons of oil in the environment, and in rivers' water that are usually the unique "Residents of the Oriente are exposed to levels of oil-related contaminants significantly exceeding internationally recognized safety limits" (Brooke, J. 1994, March 22)

Social Impact Of Oil Extraction

The national representative organizations of indigenous peoples in Ecuador (CONAIE) have opposed new oil and gas projects, citing the widespread contamination from previous and current oil projects. In fact, all these practices have polluted countless rivers, streams and estuaries, often the only sources of water for the inhabitants of this region. (Finer, M. et al, 2008)
Both peasants and indigenous people have reported how many local estuaries and rivers, once rich in fish, today lack aquatic life; reports of livestock deaths from drinking these waters are frequent. The waters of these rivers are also the same waters that the population habitually uses for drinking, cooking or bathing. The indigenous and peasant communities of the Ecuadorian Amazon have repeatedly denounced this situation to the different governments and oil companies, demanding a better quality of life, the presence of basic needs, adequate technical assistance and, above all, the cleaning of contamination without any response or new strategy to protect the environment.



Health Impacts Of Oil Extraction

Residents of communities near oil wells and stations are exposed to high concentrations of petroleum chemicals in the river waters they routinely use. In some of them, the concentration exceeded the limit allowed by European Union regulations by more than a hundred times. Women from contaminated communities were at higher risk of symptoms such as eye irritation, nose irritation, sore throat, headache, skin irritation, gastritis, diarrhea, and tiredness compared to women living where there was oil exploitation. Moreover, women who lived in communities near oil wells and stations also had a 2.5 times higher risk of miscarriage. Studies carried out by the IESCMA team showed significantly elevated results in cancers of the stomach, rectum, melanoma, connective tissue and kidney in men and those of the cervix and lymph nodes in women belonging to municipalities in the Ecuadorian Amazon where there is oil exploitation The risk of suffering from leukemia in children under 10 years of age was also higher in municipalities with oil exploitation

"This is a conflict between two different ways of seeing the forest. The government and the industry see the forest as a place of extraction, to exploit essentially whereas indigenous see the forest as their home, a place to be cared of, a place that you live in, they never poison their fishing holes for instance." Testimony of a local indigenous of Ecuador

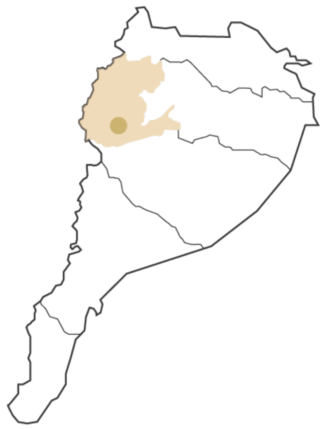
SITE AND CONTEXT

ECUADOR

Data

Population : 17.640000 Extension : 283560 km²
Density : 42 /km² Height : 0 - 6267m

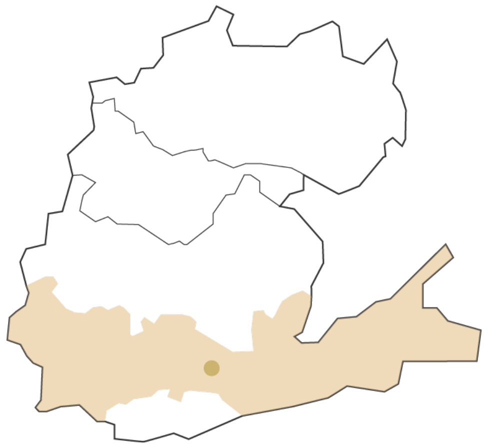
AMAZON REGION



Data

Population : 740000 Extension : 120000 km²
Density : 2 /km² Height : 300 - 500 m

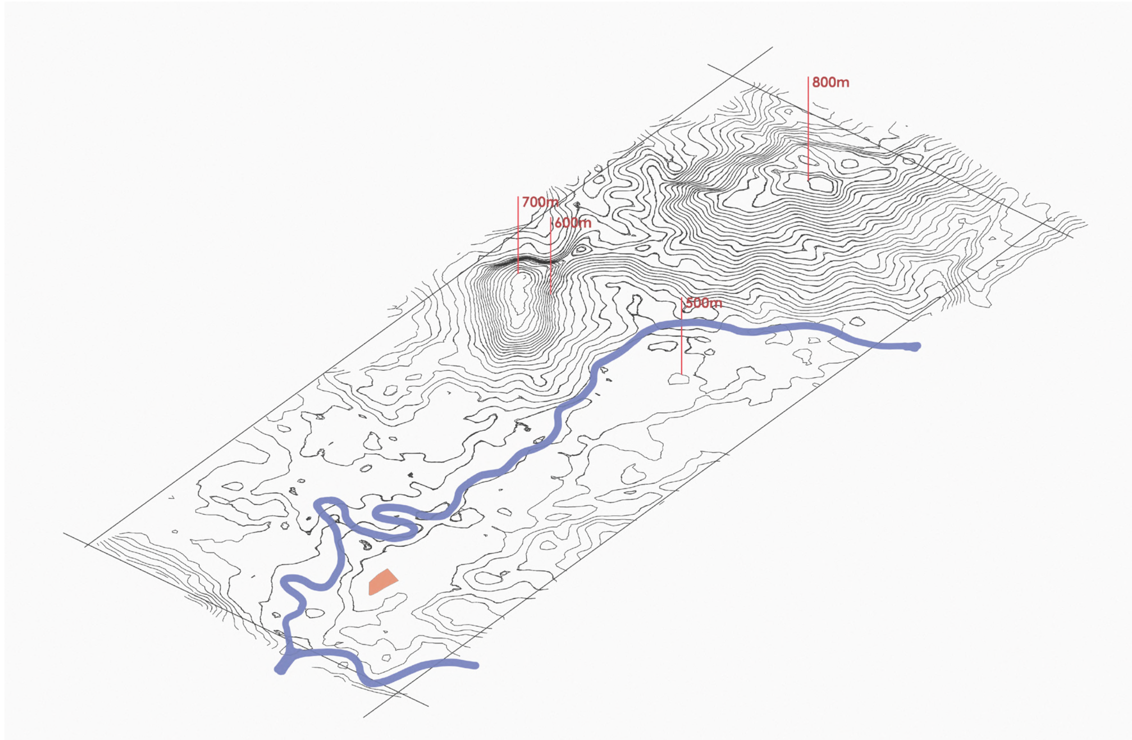
NAPO REGION



Data

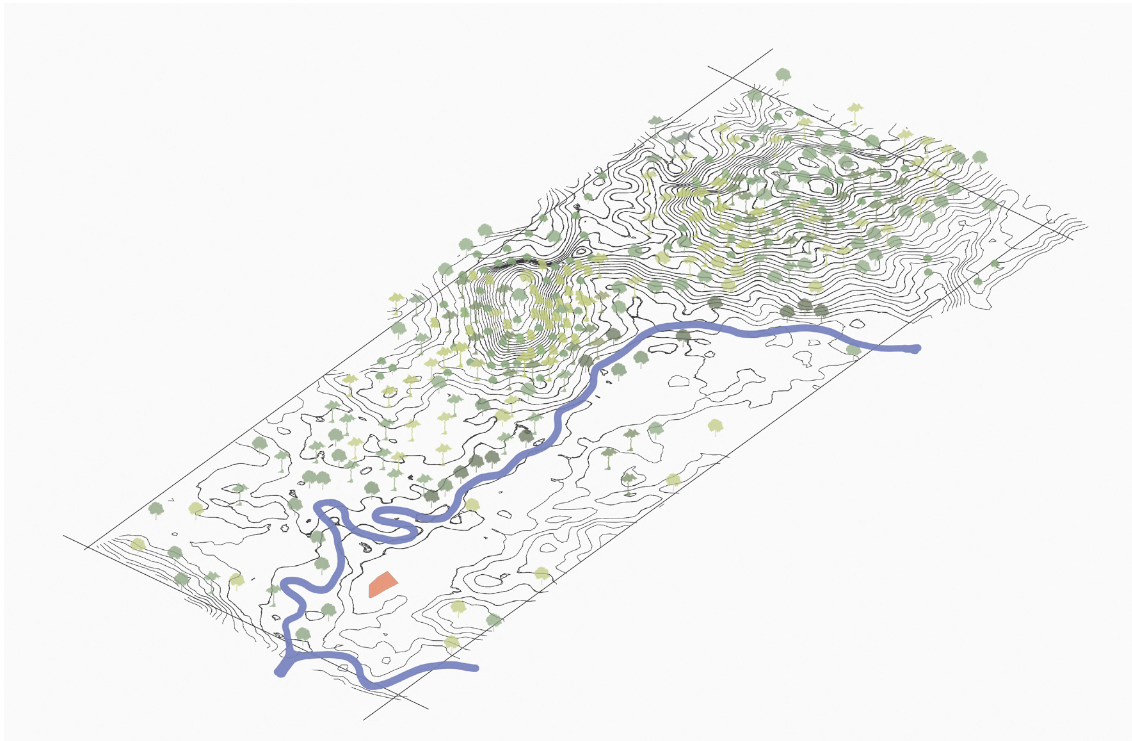
Population : 133705 Extension : 12542 km²
Density : 8.3 /km² Height : 450 - 1372 m

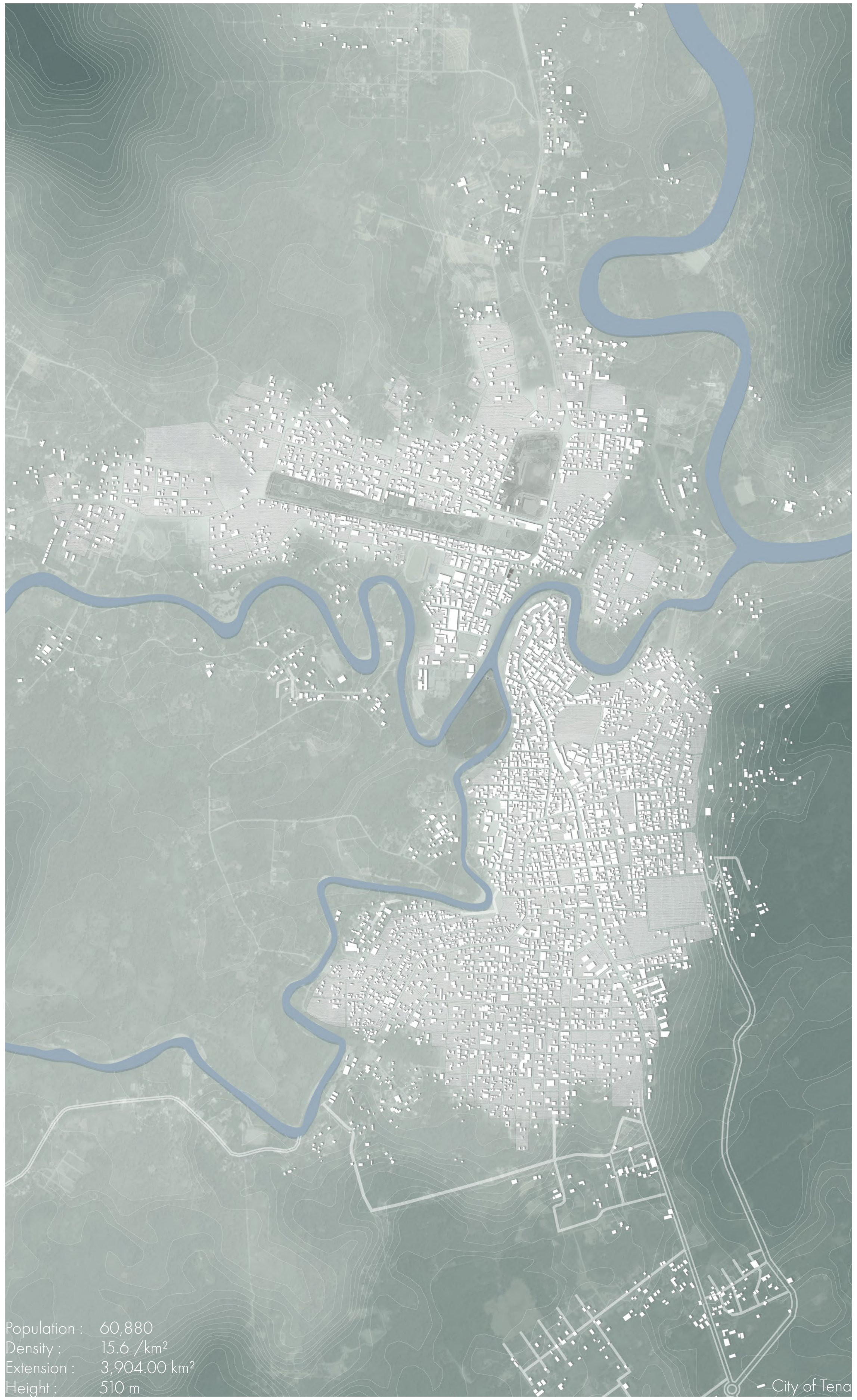
The topography of the selected site is characterized by an elevation of approximately 200m difference within the part of Amazon Rainforest, meanwhile its located 420m above sea level. These all, affect on the climate which is rainy, humid and warm, with rainfall year-round and the heaviest in April, May, and June. Therefore, providing the perfect environment for the plants and the wildlife.



Project Site - Topography

Area around the selected site is characterized mainly by low-rise vegetation closer to the river Rio Pano and with high-rise vegetation on the higher elevation points of the Amazon Rainforest.

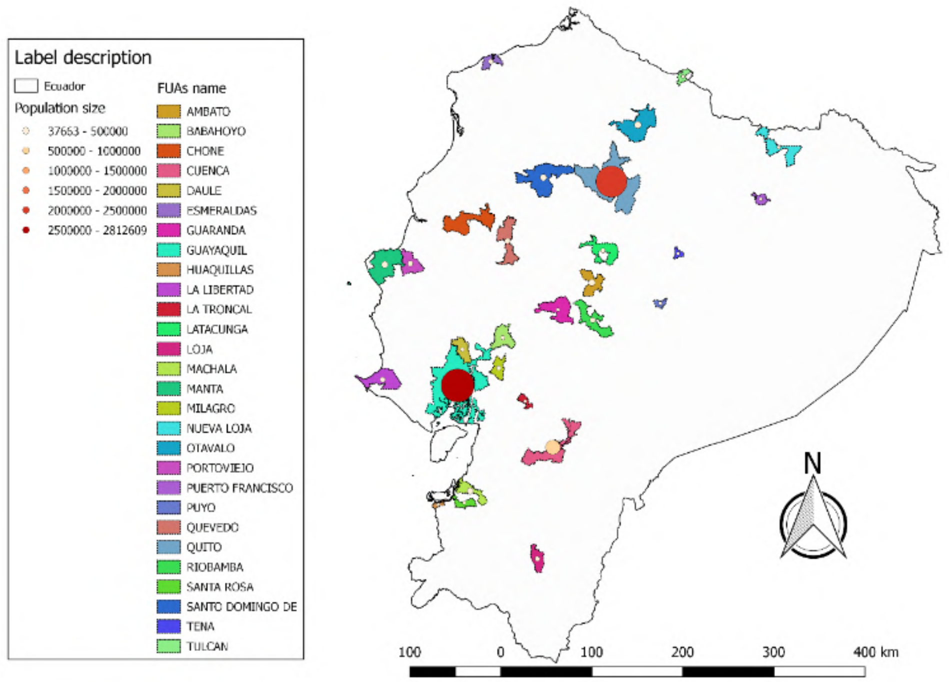




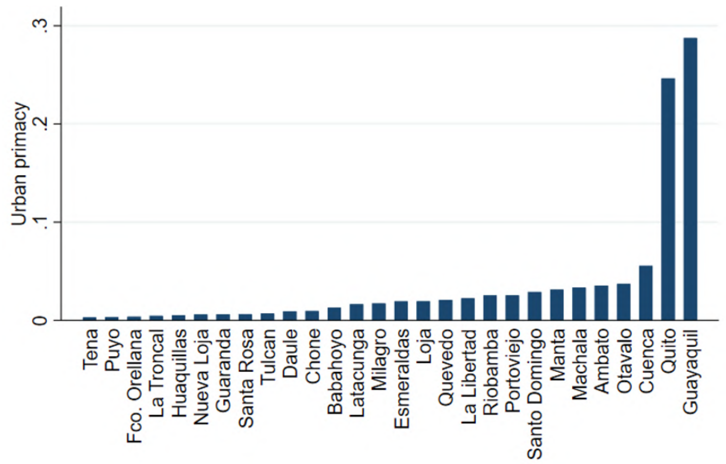
Urbanisation

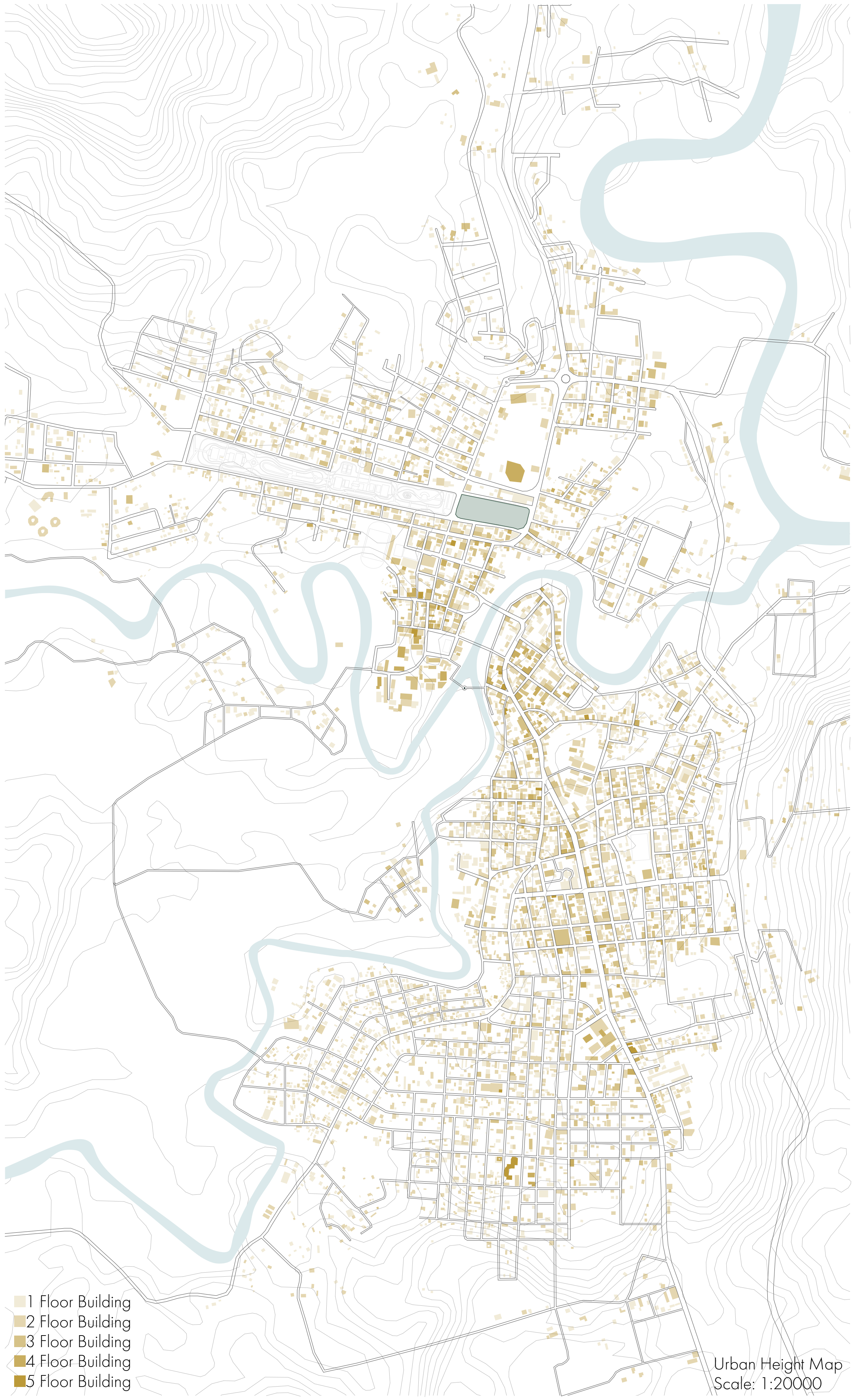
Urbanisation in Ecuador, and in particular in the Amazonian Region, has faced the highest increase of population between 1960 and 1980, after the discovery of oil in 1967. From that time the region has thus become increasingly occupied by agriculture settlers and continues to be seen by some as an "open frontier", attracting migrants from other parts of Ecuador. But the highest increase of population in recent decades is mostly driven by the urban growth of small FUAs. TENA is one of the Functional Urban Areas (FUAs) of Ecuador, 28 in total that allows to recognize the new representative urban cores in the Amazon.

"Tena has evolved to become the Ambassador of the Ecuadorian Amazon" (Lonely Planet (2006).



FUAs in Ecuador. From: INEC-Ecuador, and Obaco et al. (2017). Administrative boundaries and population based on the year 2010 -2014.

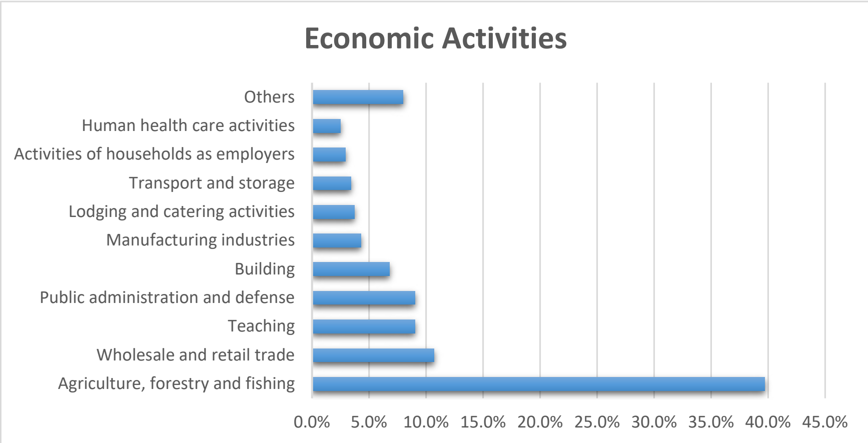



1 Floor Building
2 Floor Building
3 Floor Building
4 Floor Building
5 Floor Building
Urban Height Map
Scale: 1:20000


Recreation
Public Administration
Cultural - Churces
Education
Health
Mix Use (House + Commerce)
Land Use Map
Scale: 1:20000

The main public functions are in the city center of Tena. As can be observed, there are many areas that relate to educational purposes, various parks and recreational spaces and some health facilities. It is of great importance that the rivers separate the city creating interesting connections inside the city. There are some main roads that connect not only Tena to the other towns - cities, but also the city itself. Where there is not a network of main and express roads such as Tramo Tena - Archidona (E45), there are local roads that help transportation. Also, there is a network of four bus lines and taxis. Unfortunately, there is no infrastructure for trains and metro.

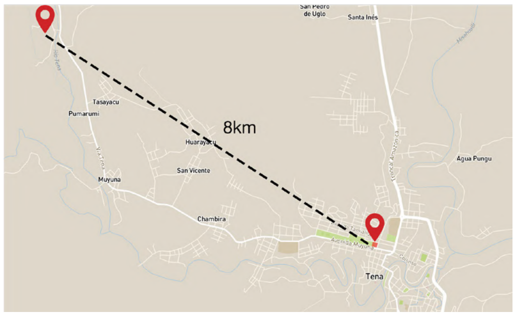
Tena is a city of extensive commercial activity. The city is the largest economic and commercial center in the province of Napo and one of the main ones in the Amazon region. It houses large financial and commercial organizations of the country. Its economy is based on trade, tourism and agriculture. The largest extractive industries in the city are made up of lumber and agriculture (fish farming, poultry farming, etc.). The main income of local people is formal and informal trade, business, agriculture and aquaculture; The trade of most of the population consists of SMEs and microenterprises, adding significantly to the informal economy that employs thousands of people. Almost 40% of the economically active population is engaged in agricultural and livestock activities. In the city of Tena, the provincial public administration is concentrated, in which there is good economic activity that is concentrated in the installation of different types of commerce such as stores, warehouses, restaurants, hotels, taxi cooperatives, vans, pharmacies, etc.



Projects of Urban Development

Ikiam - Regional Amazon University

"A laboratory for changing the Amazon" In 2013, the Government of Ecuador launched projects for four new public universities to strengthen higher education in underserved parts of the country.



Ikiam Regional Amazon University From: Cortesía de Ikiam. https://es.mongabay.com/2016/10/conoces-la-universidad-funciona-corazon-la-amazonia-ecuatoriana/

Ikiam is one of them and focuses on research related to challenges and opportunities in the Amazon Region. The site for this university is located 8km north of the city of Tena, at the border of the highly biodiverse Colonso-Chalupas Natural Reserve. Its name comes from the idea of "Ikiam", which means "jungle" in the indigenous Shuar language and is conceived as an institution of higher education, intended to contribute to the transformation of the social, productive and environmental structure, to train professionals and academics, with skills and knowledge, that respond to the growing needs related to national and international development and the construction of citizenship.

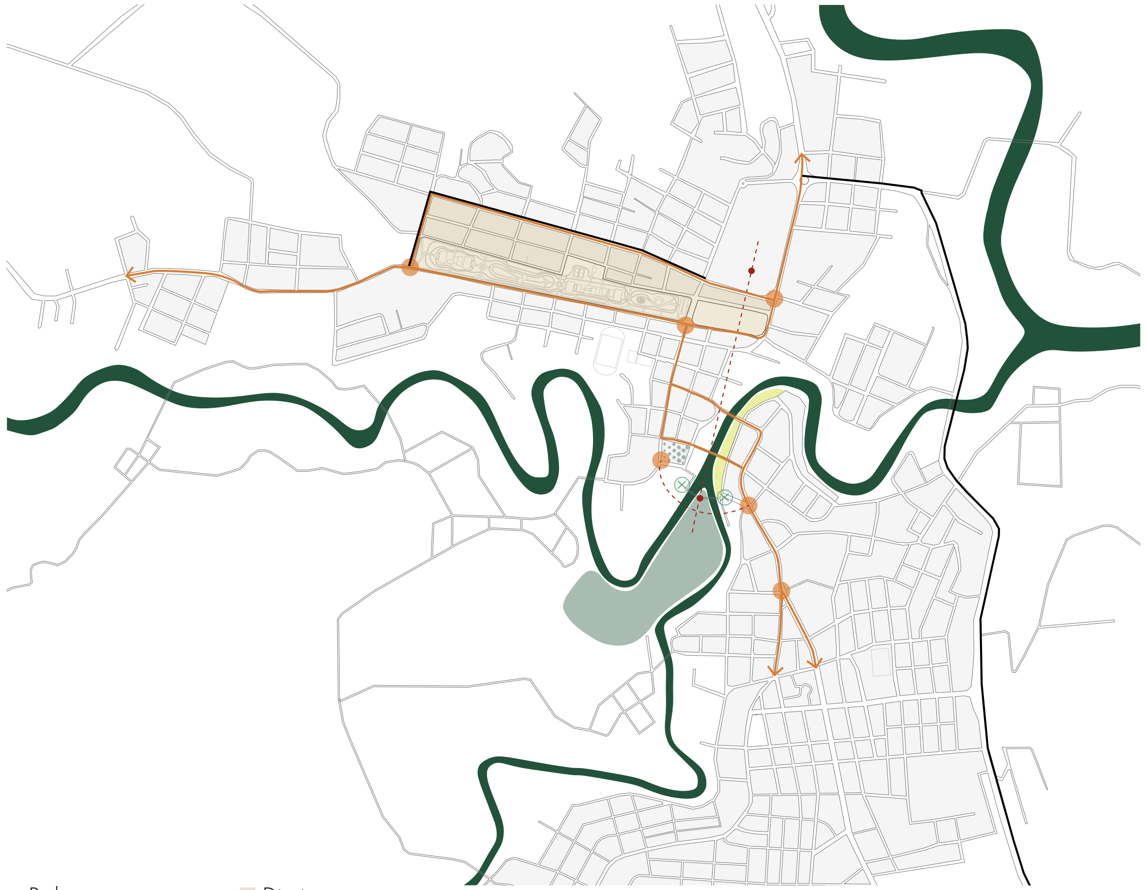
Linear Urban Park

"A social fabric through greenery" In a total area of 11.1 hectares, the project is located within the consolidated area of the city of Tena between two important roads of cantonal connection. Since the relocation of the old "Mayor Galo de la Torre" airstrip in 2001 (to the Zancudo community), the site has become an underutilized space that disconnects the urban fabric from the surrounding areas and were used for improvised activities by the inhabitants, such as sports, recreational activities, street vending, among others. The approach of the Tena Urban Park arises from the recycling of a void or large-scale open space, which changes its use and has a strategic location in the canton. It provides a new service centrality with:

Urban grid connection and accessibility,
Natural platform and interlaced green slab
Zoning
Internal routes

Linear Urban Park

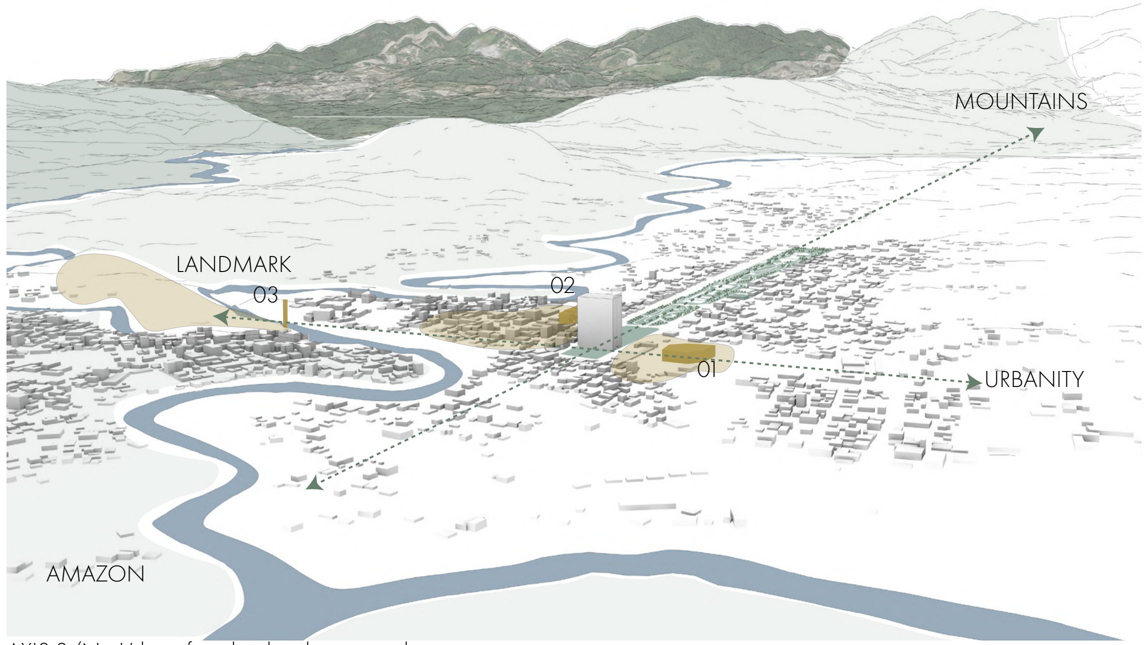
Cognitive Maps



- Paths
- Edge
- Natural Edge
- Relationship channels
- District
- Nodes
- New urban development
- Landmark

- Main paths
- Edge
- District
- Relationship channels
- Axis of fragmentation
- Nodes

Generative Axis Map



AXIS S/N - Urban, from landmark to new urbanity
AXIS E/W - Nature, from mountains to Amazon rainforest

Main axis

01 Sports Hall
02 Market
03 Observation Tower

Linear Park
Project Site
Natural edge

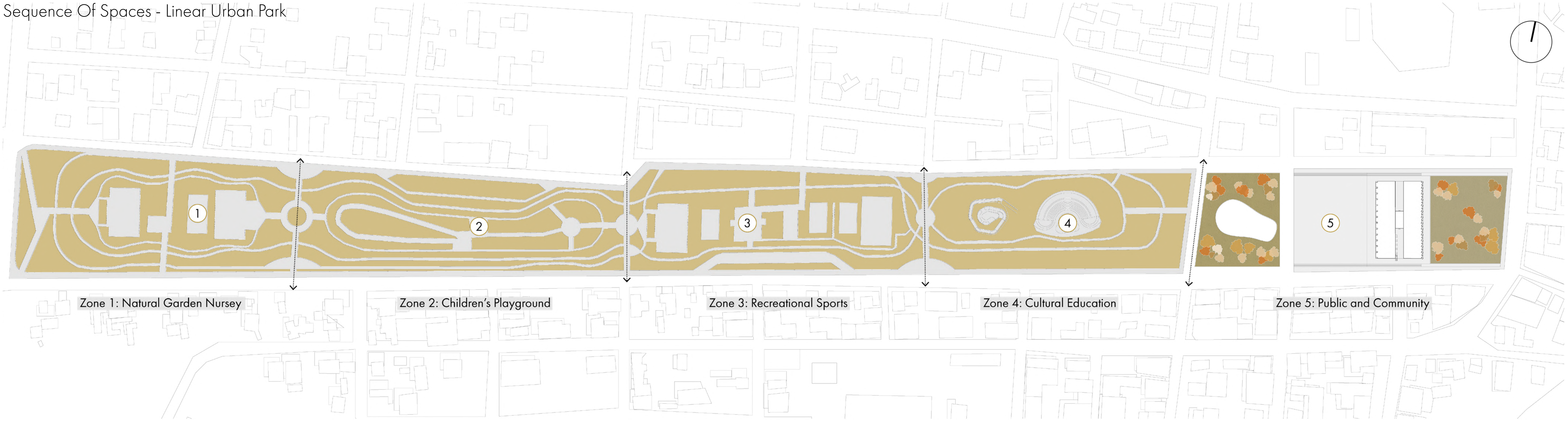
Mountains

Urbanity

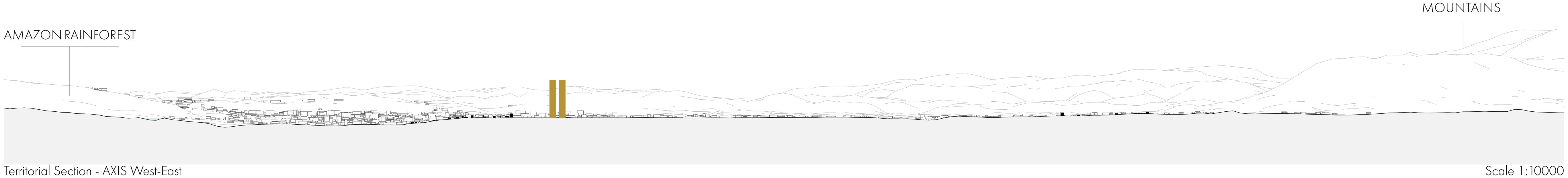
Amazon

Landmark

Sequence Of Spaces - Linear Urban Park

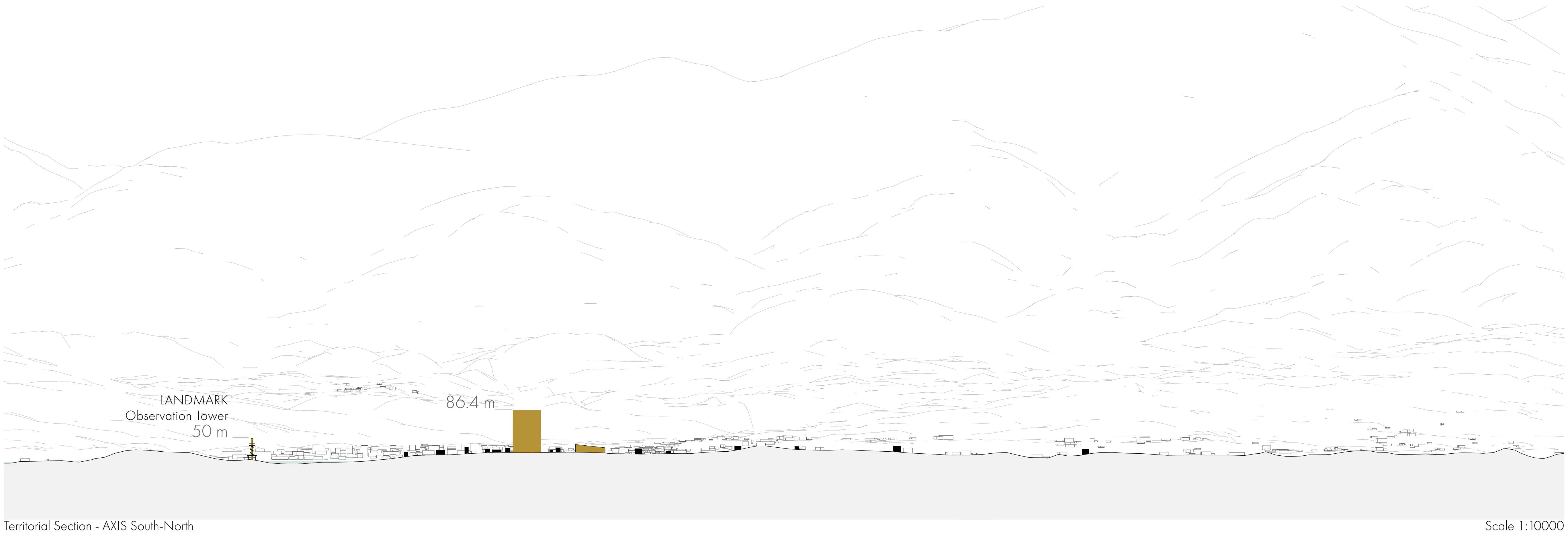


URBAN ANALYSIS



Territorial Section - AXIS West-East

Scale 1:10000



Territorial Section - AXIS South-North

Scale 1:10000

ROLE

Designing in such a natural, tangible and sensitive context which is in the Ecuadorian Amazon Region needs a significant consideration of sustainability, functionality, socio-cultural and socio-economic effects in that area. Timber tall building is designed to minimize its environmental impact and to promote sustainability by material selection, active and passive actions. The building reflects and respects the local culture by incorporating the local art and design elements and with the relation between public and private shared activities.

Amazon Healing Tower

Amazon Healing Tower is an 86.7 meters high tall building with a construction of timber which is a local and renewable material. The introduction of the wood is the necessity to intervene in this reality with a general vision of sustainability which also defines the suitable architectural and constructional type. The building consists of two simple volumes that are connected by special spaces in between them. While one of the volumes defines a relation with the linear park, the other one with the mountains. The special volumes in the building are located according to the relation with the city such as Central Market of Tena, Sports Hall, and Linear Park. There are seventeen floors with a height of 4.8 meters for each level and double height for the ground level. It is a public building with the functions of co-working areas, library, reading areas, arts and crafts ateliers, offices, conference room, research labs, café and observatory.

The tower is embedded with a strong symbolic meaning. It creates a big screen that connects the long linear park of the city with the mountains. The tower looks from a distance as configuration of two simple boxes to emphasize the location and the importance of the connection between nature and the city. The internal complexity is more obvious with the special spaces. As Bernard Tschumi indicates in the book of Architecture & Disjunction (1994), 'Space is not simply the three-dimensional protection of a mental representation, but it is something that is heard and acted upon'(p.). It improves the quality of life by offering the opportunity for creating open spaces as piazzas and parks and influences the city fabric by its existence. In other words, it is a civic monument for the city.

Goals

Amazon Healing Tower is designed as a part of the urban system in Tena. There are several goals to improve this system respectfully to the natural context. The goals for the new tall building in the development of the city Tena can be categorized as:

Sustainable development: using timber construction for a tall building in a fragile context is one of the challenges and aims to improve sustainability and to minimize the ecological impact on Amazon rainforest by improving the quality of life in Tena.

Resource conservation: Tena Tower uses the local wood which is obtained by sustainable forest management and sustainable logging. The fact that the material is recyclable minimizes resource consumption.

Cultural conservation: the tower contains arts and crafts ateliers to honor and preserve the cultural heritage of indigenous communities in Amazon region and the Ecuadorian people.

Research and Education: to provide facilities for research and education, the research labs and co-working areas are designed in the tower. One of the aims is to address the problem of lack of education in Tena.

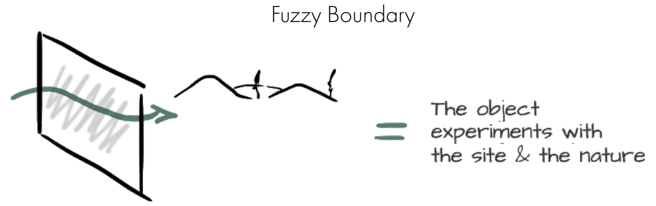
Community engagement: the building itself will create a social hub by connecting local people, researchers, artists and craftsmen, students and workers.

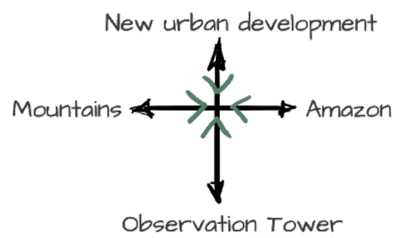
Landmark: In a low-rise building city context, the existence of tall tower with the height of 86.7 meters creates a landmark that symbolize the importance of Amazon and the Ecuadorian rainforest.

Strategies

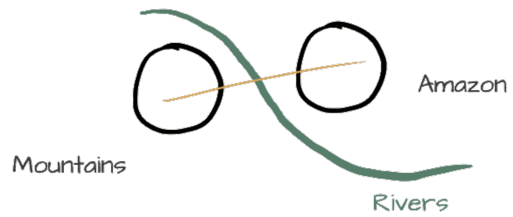
The tall building is strategically located on the intersection of an axis between Amazon rainforest and mountains in the west-east direction and the new urban development and observation tower of the city on north and south. In that orientation the building has maximum daylight and shadow control, and natural ventilation. The tallness of the building provides not only social empowerment but also a new typology for the city. Therefore, to apply these strategies the local context is analyzed carefully in terms of morphology, site belonging, structure and tectonics to achieve the most suitable design in that area.

Fuzzy Boundary

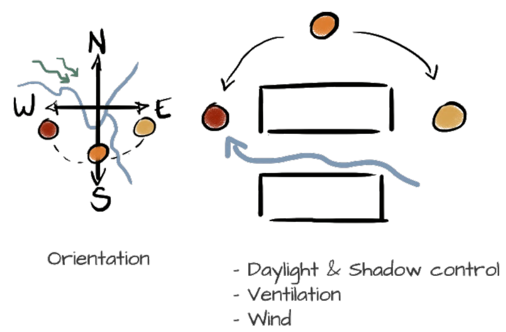




Visual Connections

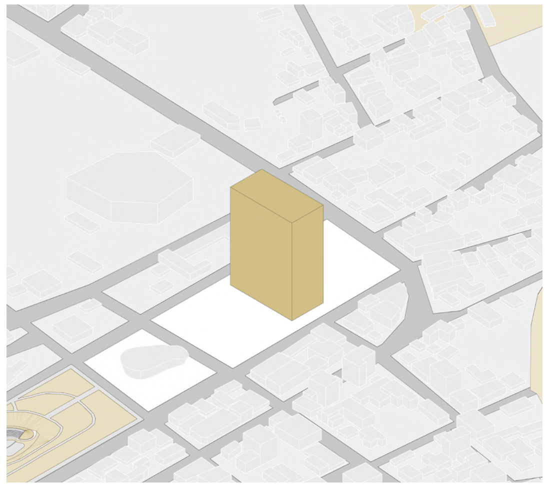


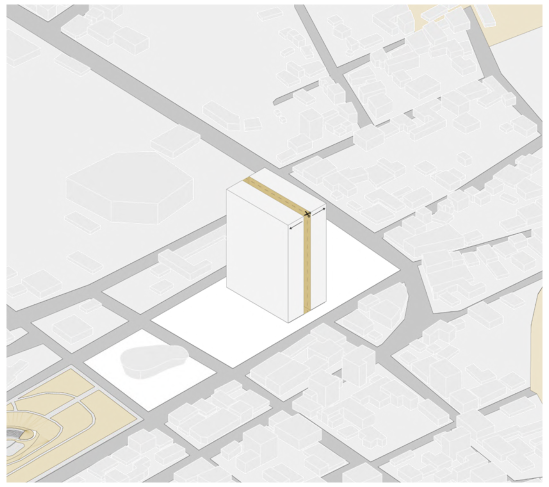
Connection with Nature



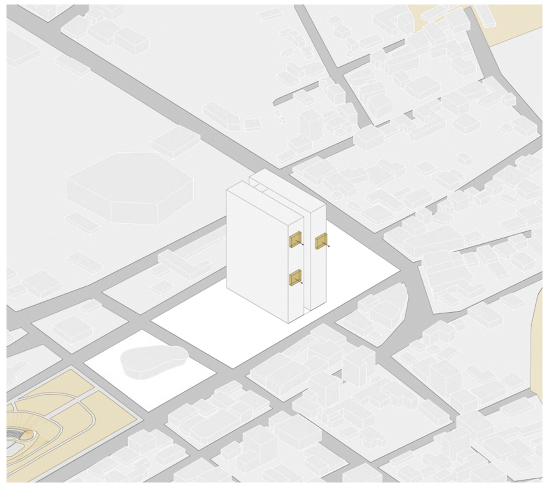
Sustainability

Morphology


Tall Building As A Big Screen


From One Building To Two


Special Spaces That Connects Two

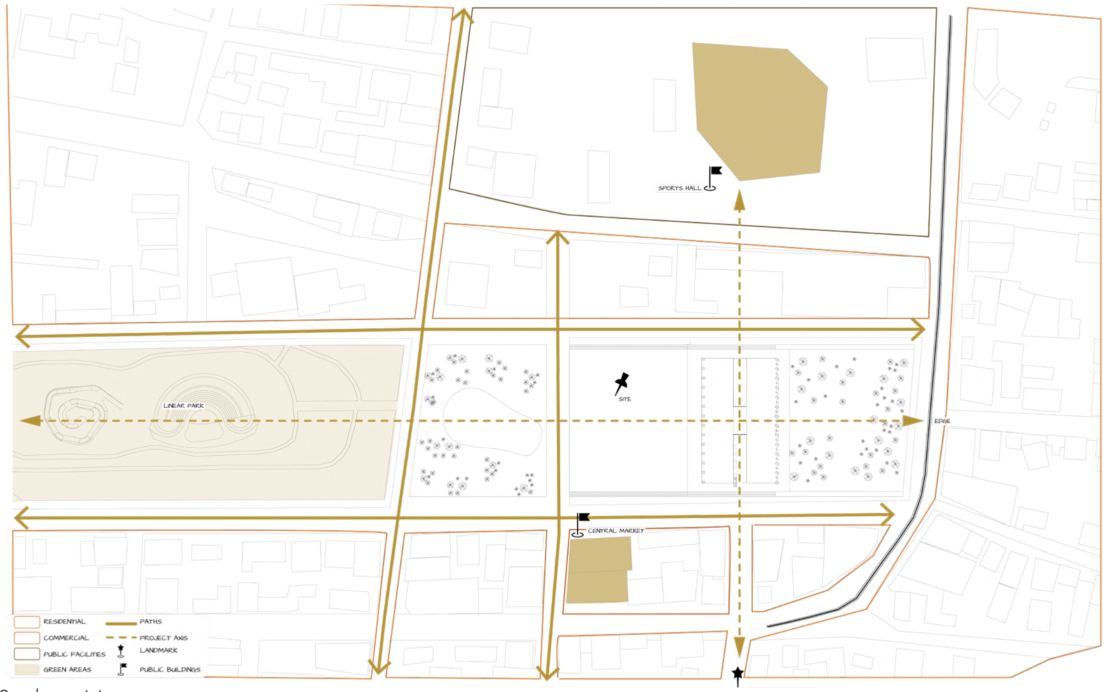

Bow Windows For Views

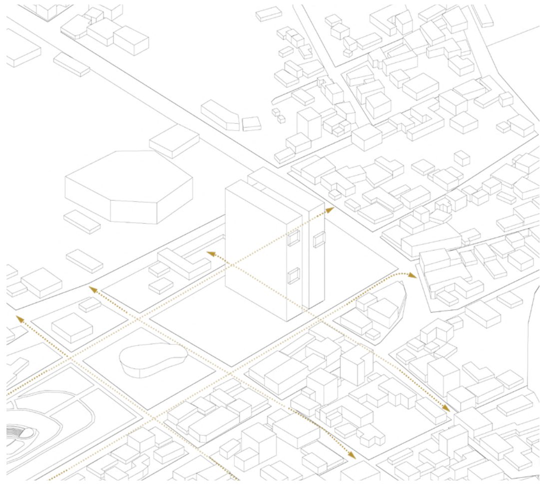
The tall building's form is given by the two volumes. Each of them define a relation with the linear park, Amazon rainforest, mountains and the urban development. It behaves as a big screen from the axis of east and west.

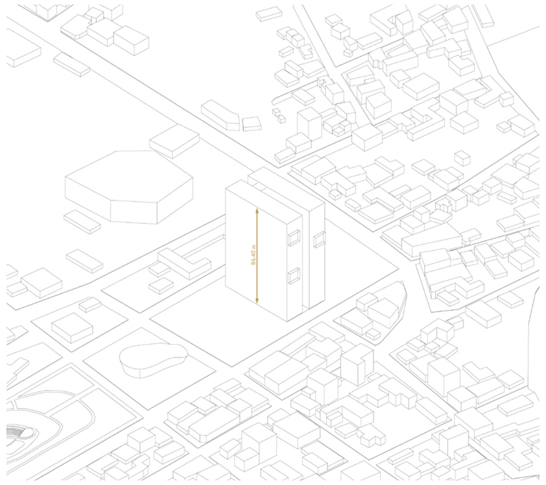
The special spaces in between the volumes provide not only horizontal connection, but also the vertical connection with the configuration of internal stairs.

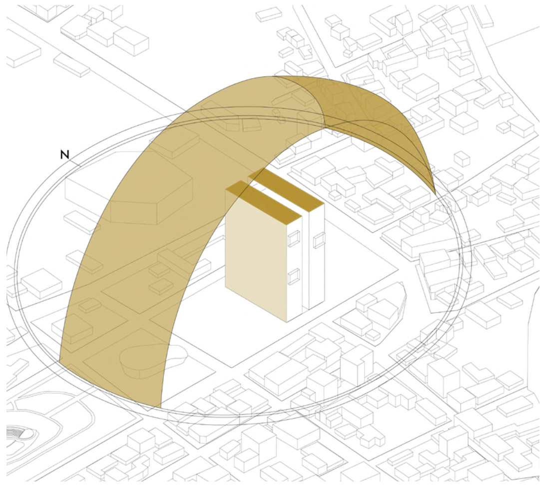
In addition to the special spaces, the bow windows on the south facade of building provides visual conection with the views to the urban development and the landmark Observation Tower.

Site Belonging


Synthesis Map


Accessibility


Relation In Height


Sun Path

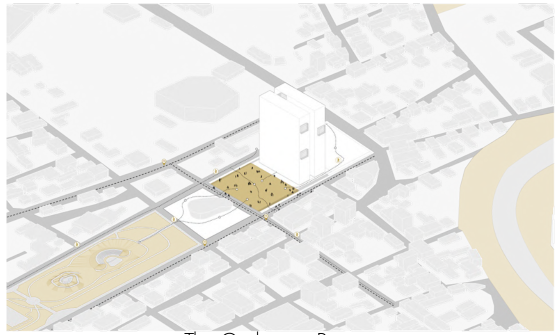

Wind

The building, directly connected to the piazza. The gap between the towers allows the connection north - south and also emphasizes a relation with the current landmark, the observatory tower. The bow windows and the special spaces in between the volumes provide visual connections to the observation tower and the urban development.

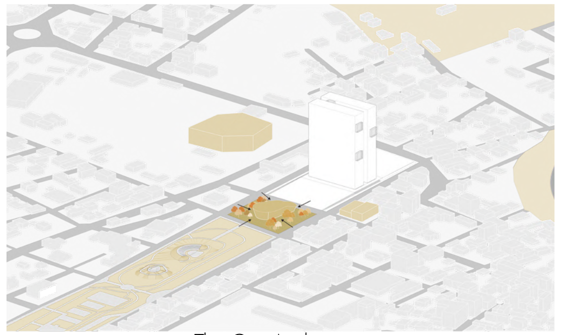
Visual Connections

The Buffer Zone

The so called "buffer zone" a piazza that act as a barrier that keep pedestrians away from the high speed road. It represents a piazza with a different language and purpose than the central one, its aim is to enclose the flows around the project and separates it from the city caos.



The Gathering Piazza



The City Auditorium

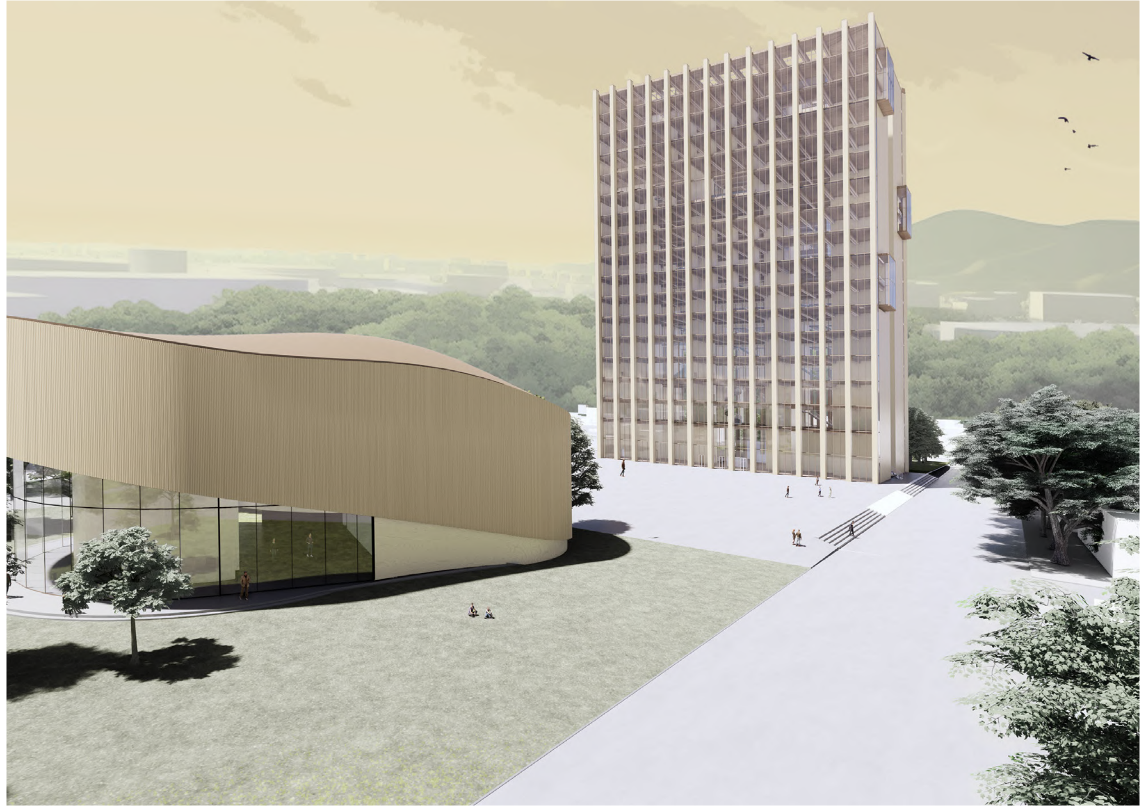
The main piazza as a place to gather people and collects pedestrian flows. As an open space it brings the possibility of different activities. Its left down corner has stairs which angle corresponds to the idea of receiving people coming from the park and the Tena central market. This free space gives the possibility of temporary extension of the market for fairs and local events. The north stairs allow the pedestrians to continue its way to the Sports Hall or residences buildings.

The green area as a transition from the organic park, including a City Autditorium which concept consist in an opac-transparent volume with visual connections towards the green areas and with its access from the piazza.

Sturcture and Tectonics

The building consists of two volumes with timber structure with the grid of 4.8 meters by 4.8 meters. The structure consists of vertical supports that are CLT cores and glulam timber columns, and horizontal elements that are glulam beams and CLT slabs.

The strcuture of the building is designed to provide the relation between the architectural concept and the structural design. To adress diferent concepts on the facade, the structural elements differ in the east and west facade by straight columns and skewed columns.

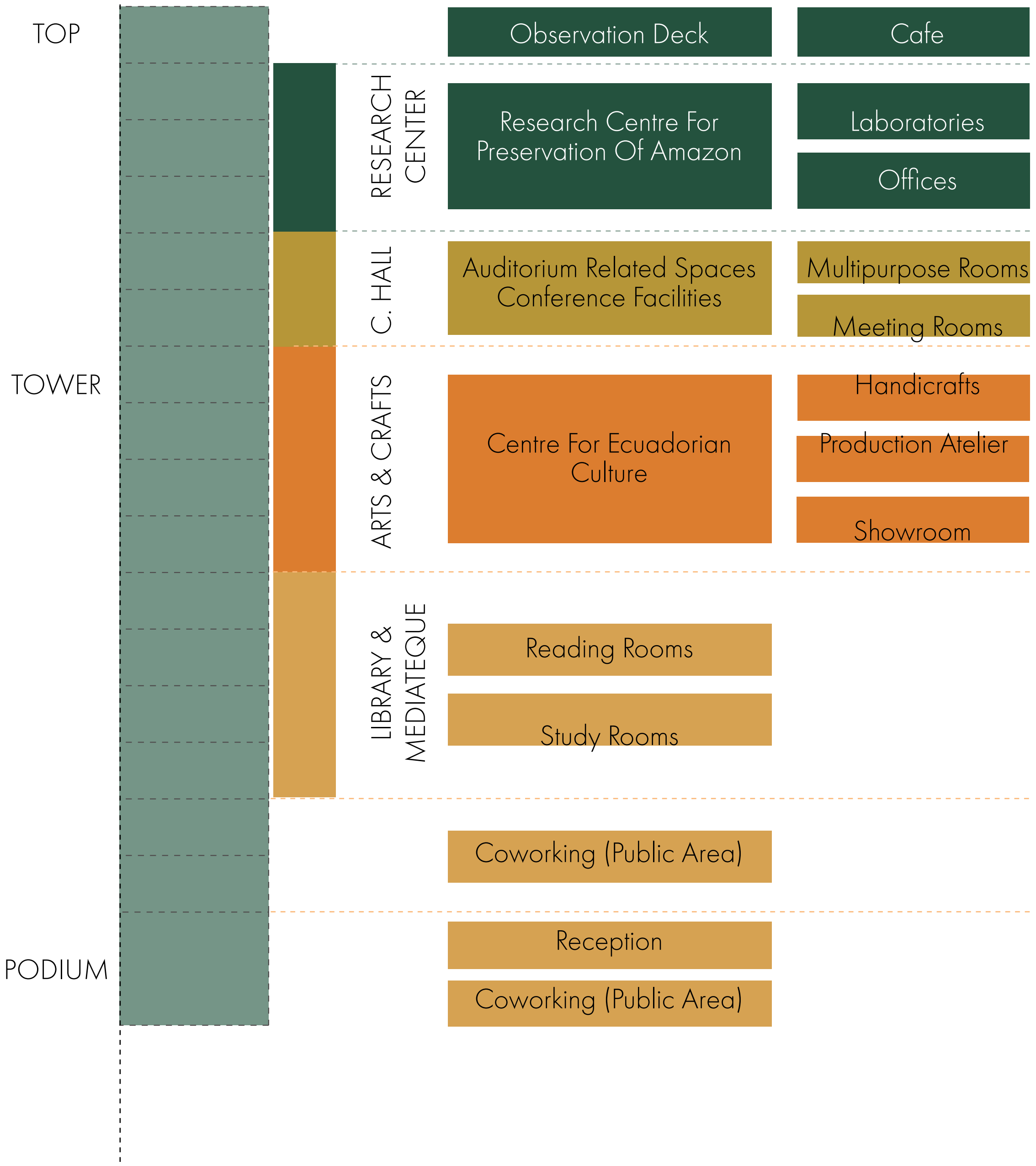


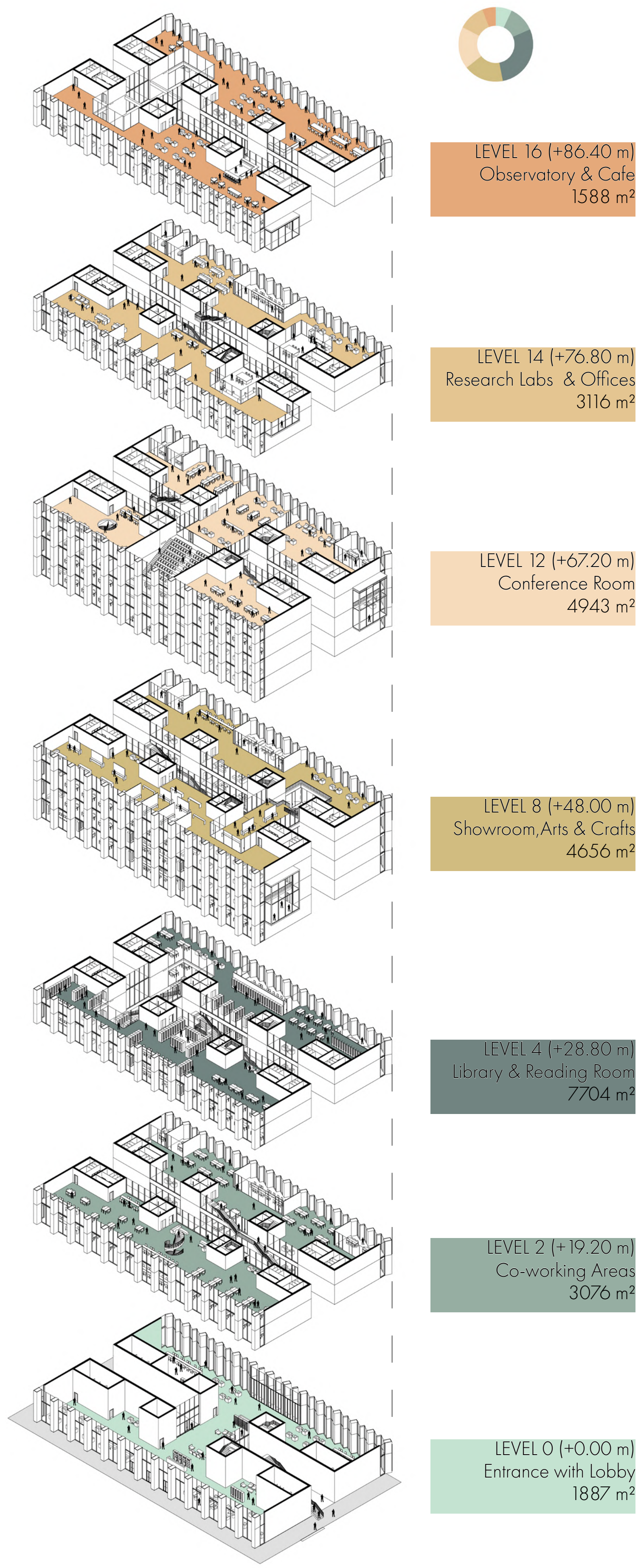
03 ARCHITECTURAL PROJECT

PROGRAM

In pursuit of cultural empowerment and appreciation of the ecological variety of the region, Amazon Healing's architectural programme comprises study and coworking spaces, a library, an area for the production and exhibition of arts and crafts, research laboratories and an observation space.

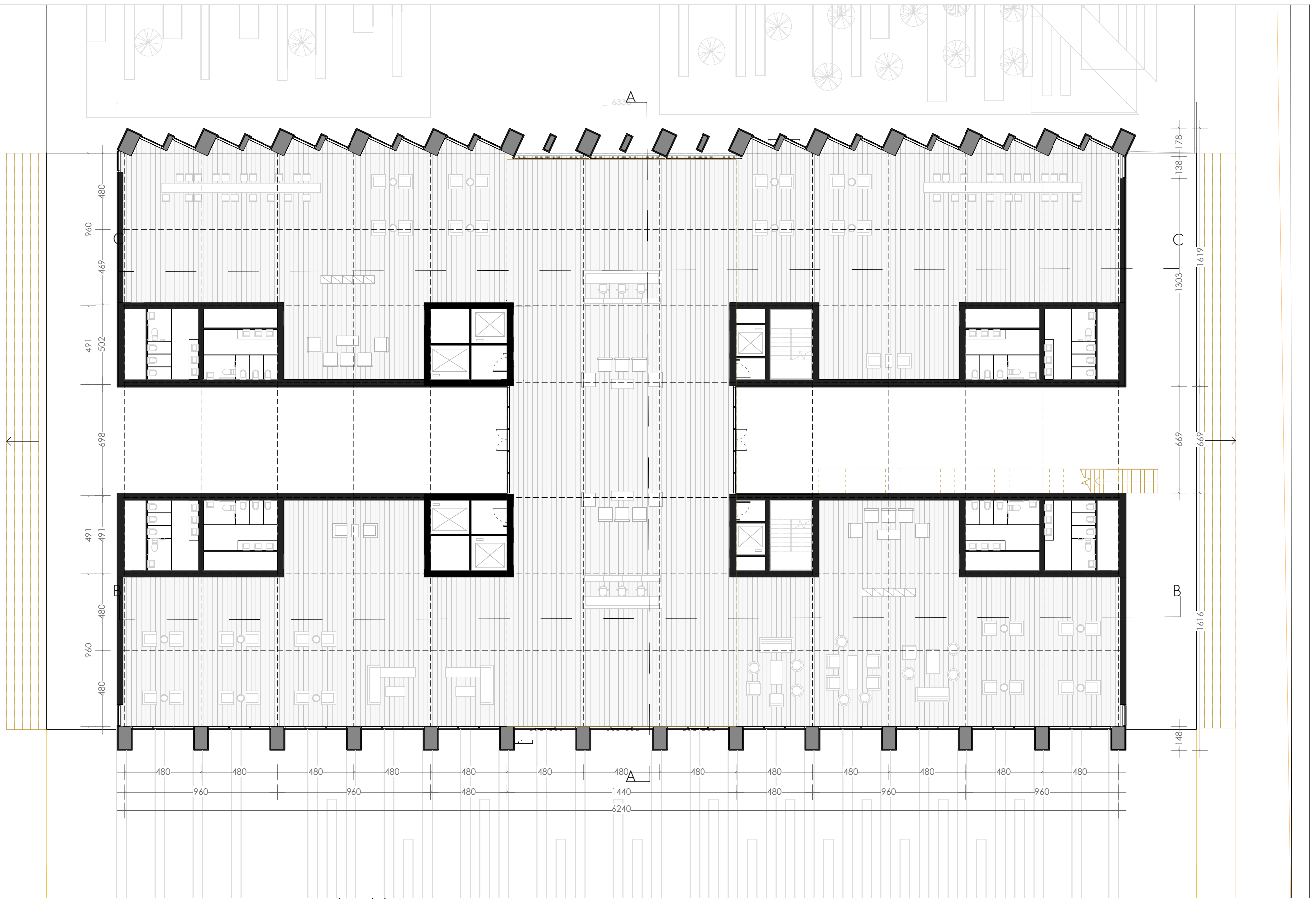
Each volume has 4 CLT cores that allow the vertical connection from ground floor to top, while the internal and external stairs allow for interaction and articulation of the different spaces. The idea of having cores located at one side of the volume responds to the idea of maximizing the available space that is already limited by the timber material modules.





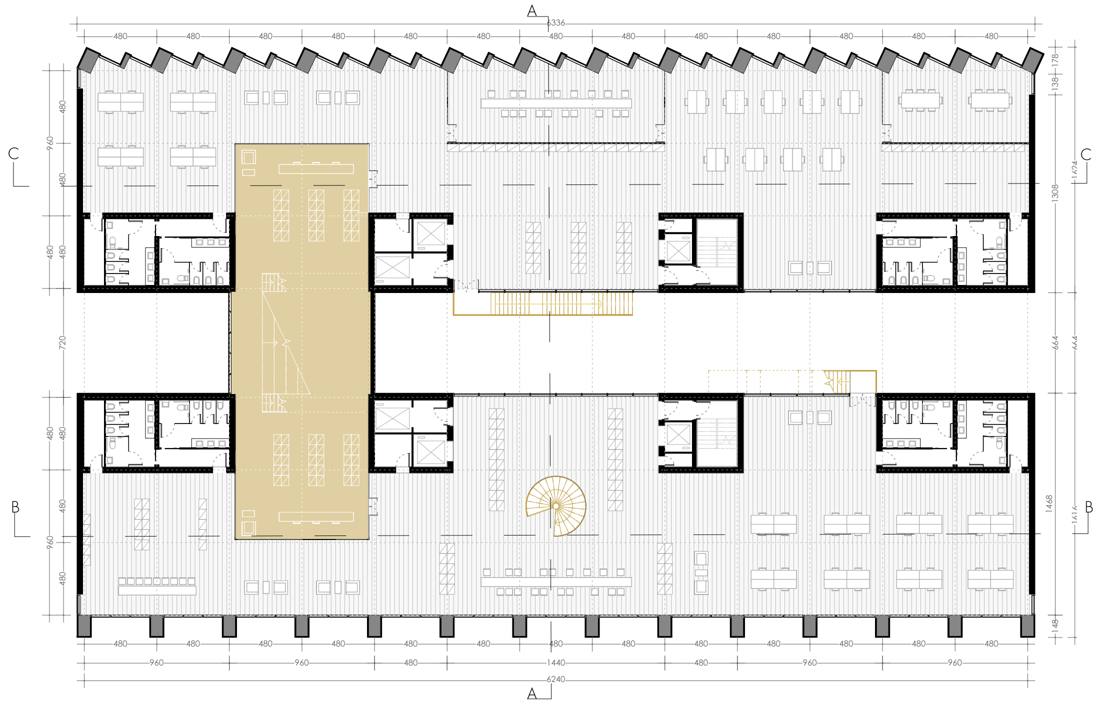
MASTER PLAN

ARCHITECTURAL PLANS



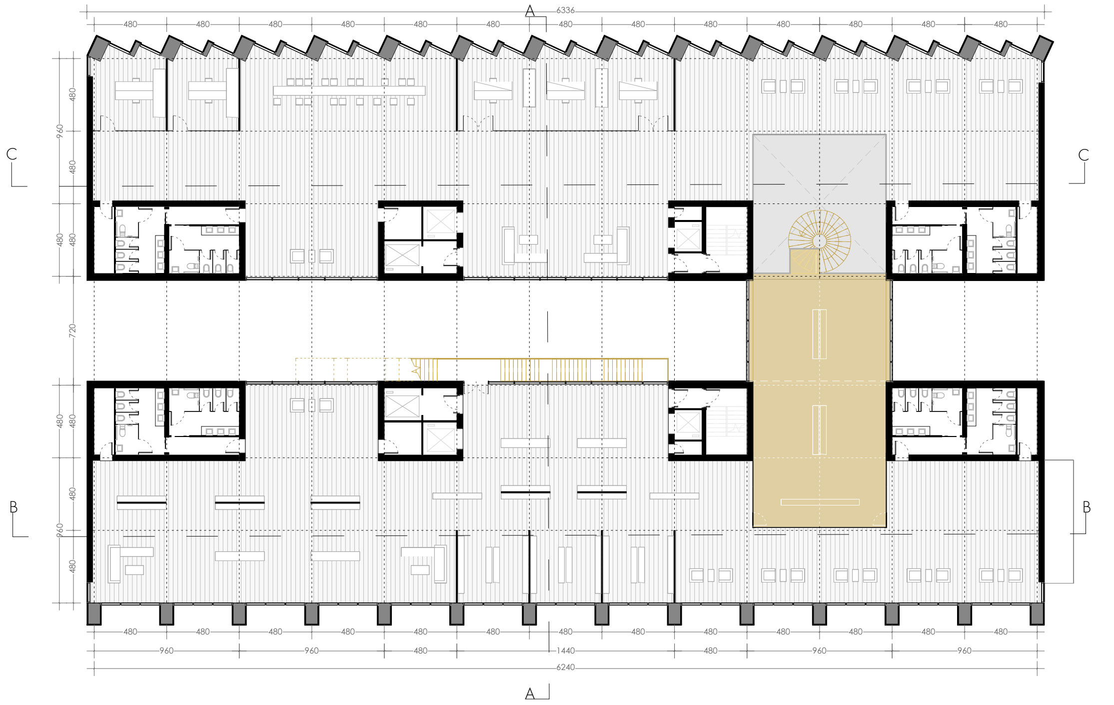
PLAN GROUND LEVEL | Lobby
+ 0.00 m

PLAN LEVEL 1 | Co-working Space
+ 9.60 m



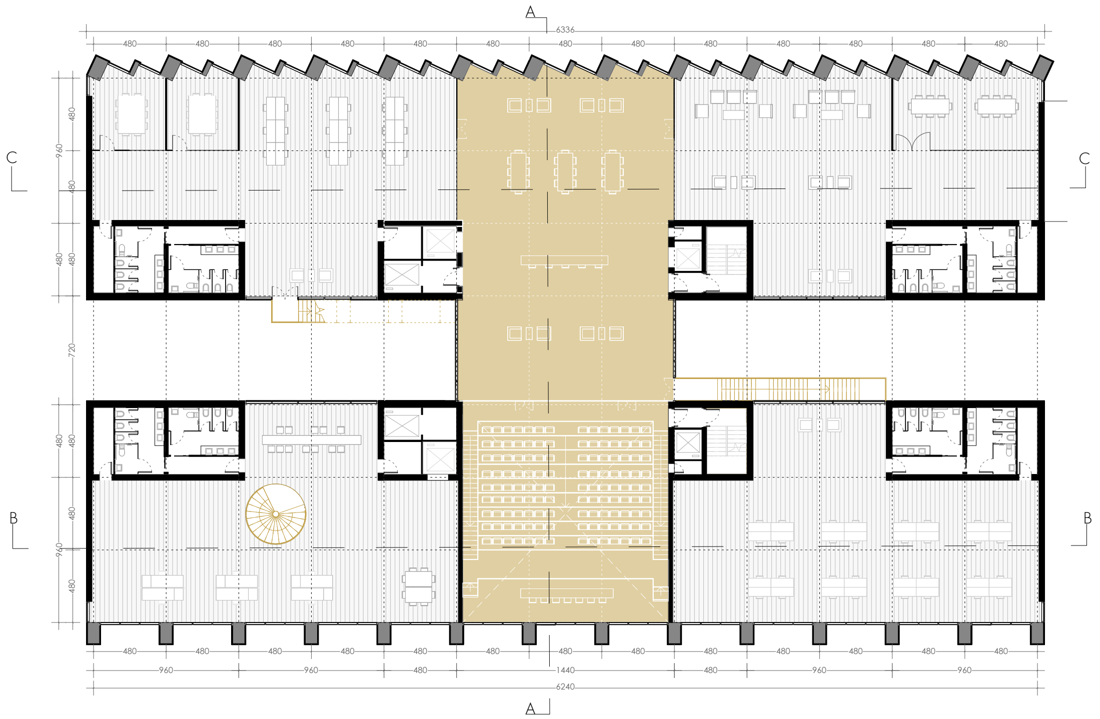
PLAN LEVEL 3 | Library
+ 19.20 m

PLAN LEVEL 7 | Library
+38.40 m



PLAN LEVEL 8 | Exhibition Space
+43.20 m

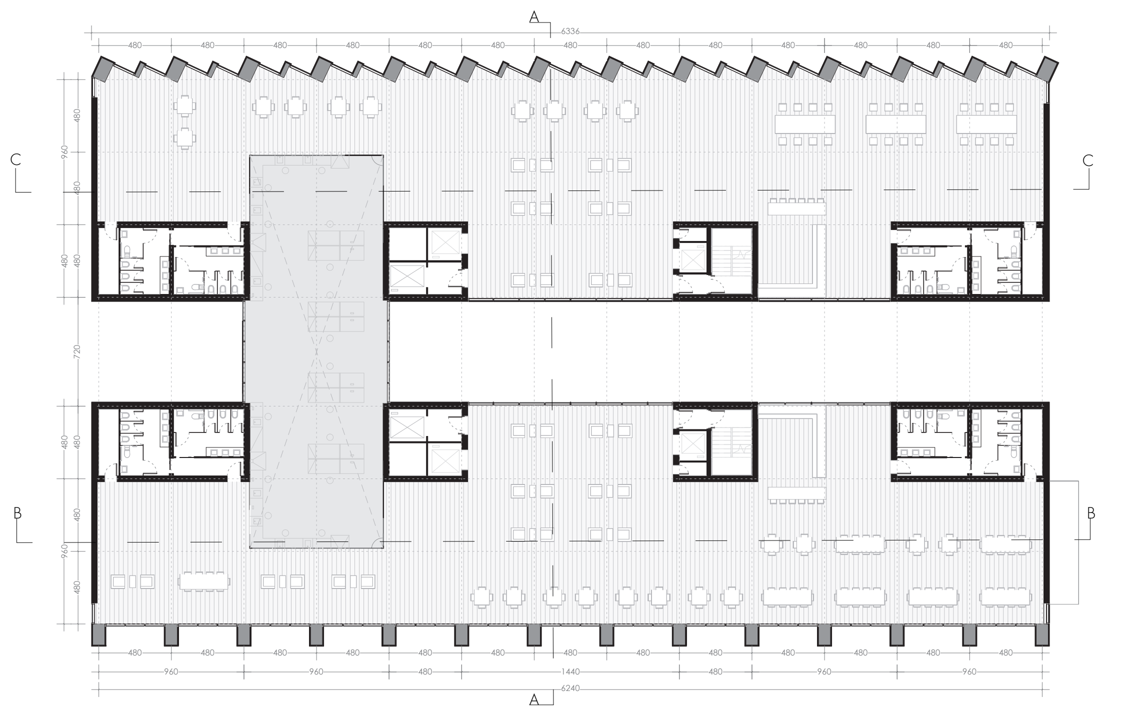
PLAN LEVEL 11 | Conference Space
+57.60 m



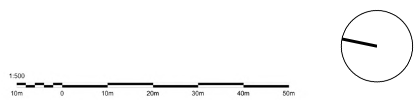
PLAN LEVEL 12 | Conference Space
+62.40 m

PLAN LEVEL 14 | Labs & Research Centre
+72.00 m

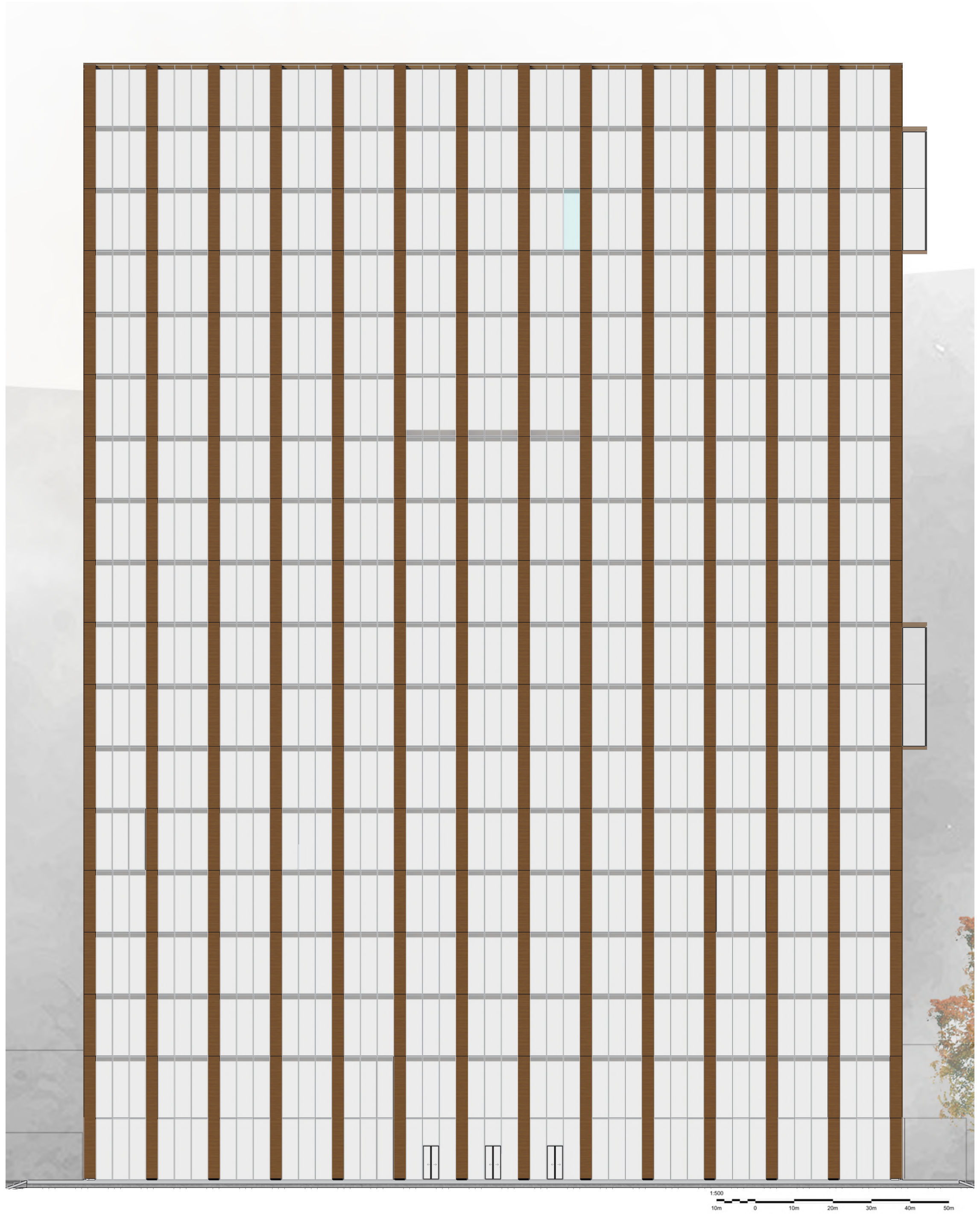
PLAN LEVEL 15 | Labs & Research Centre
+76.80 m

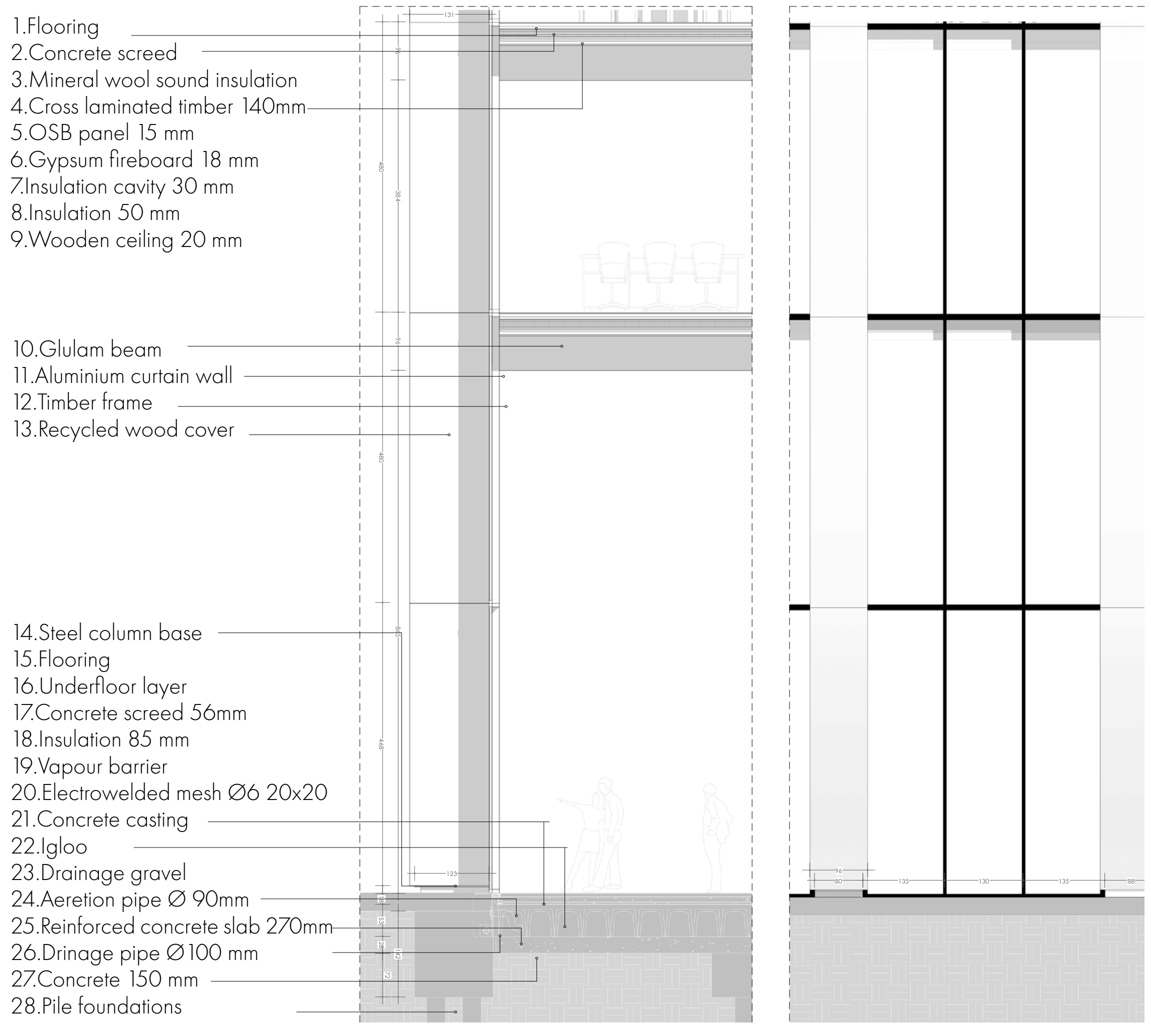


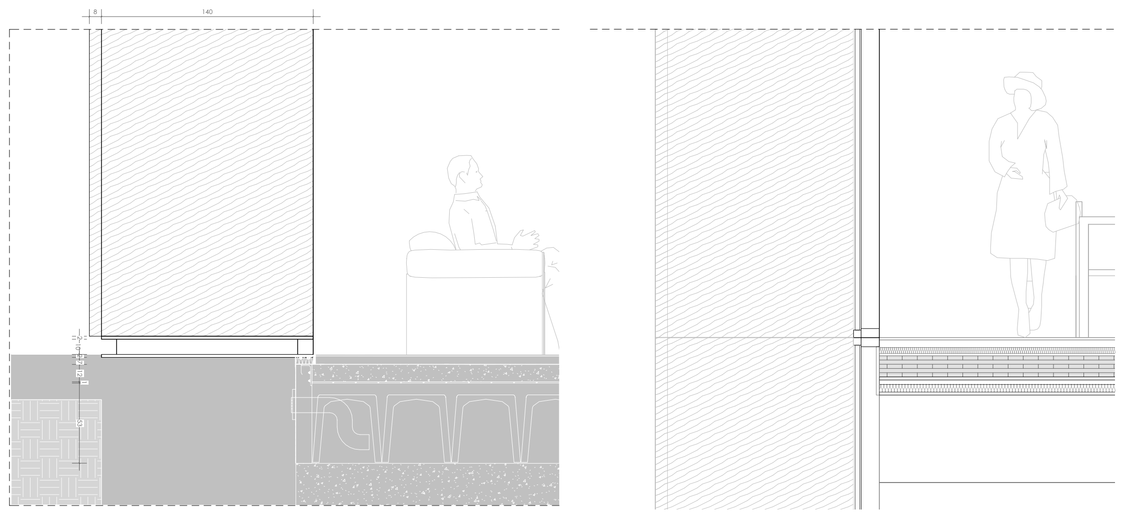
PLAN LEVEL 16 | Cafe & Observatory
+81.60 m



STRAIGHT FACADE



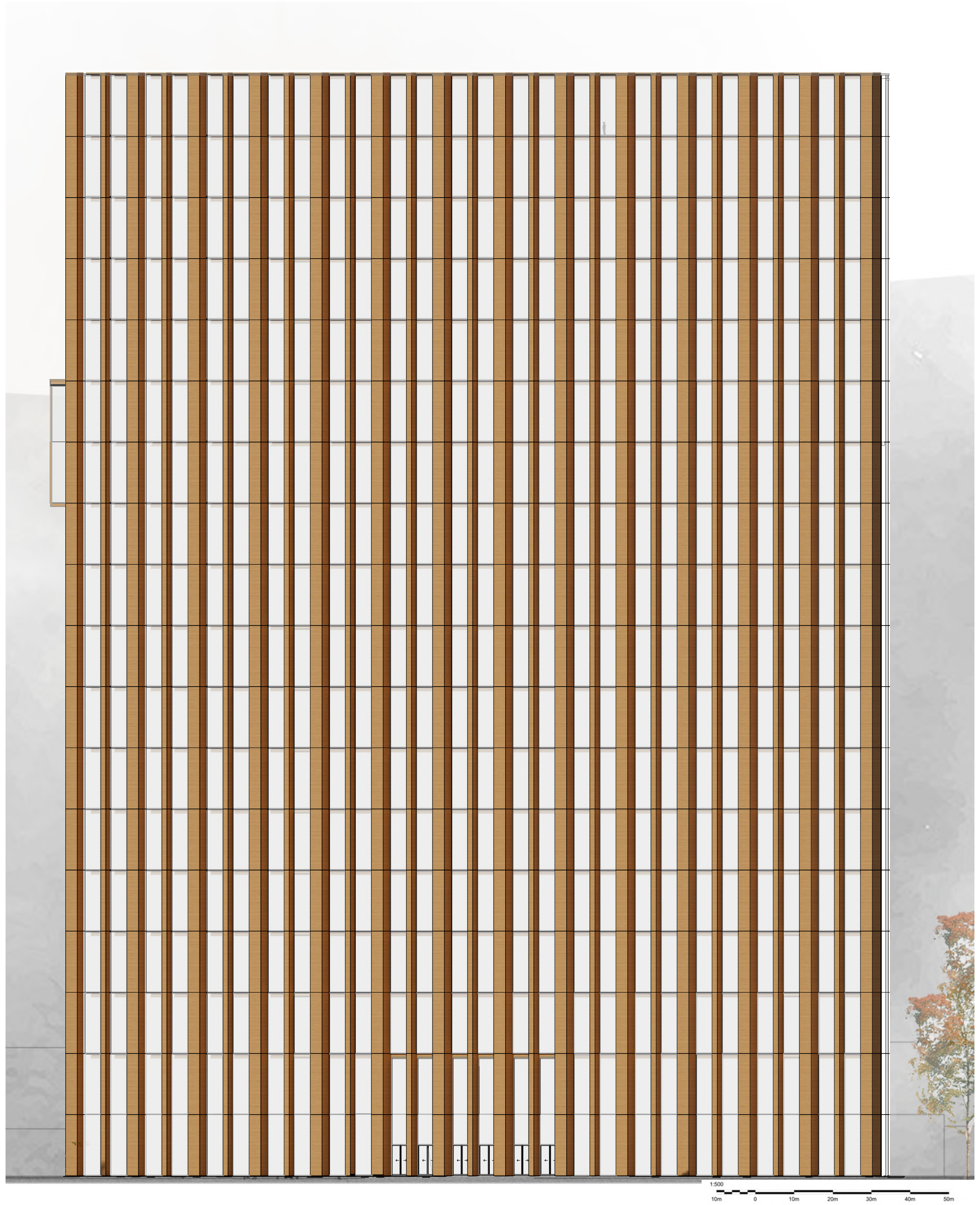


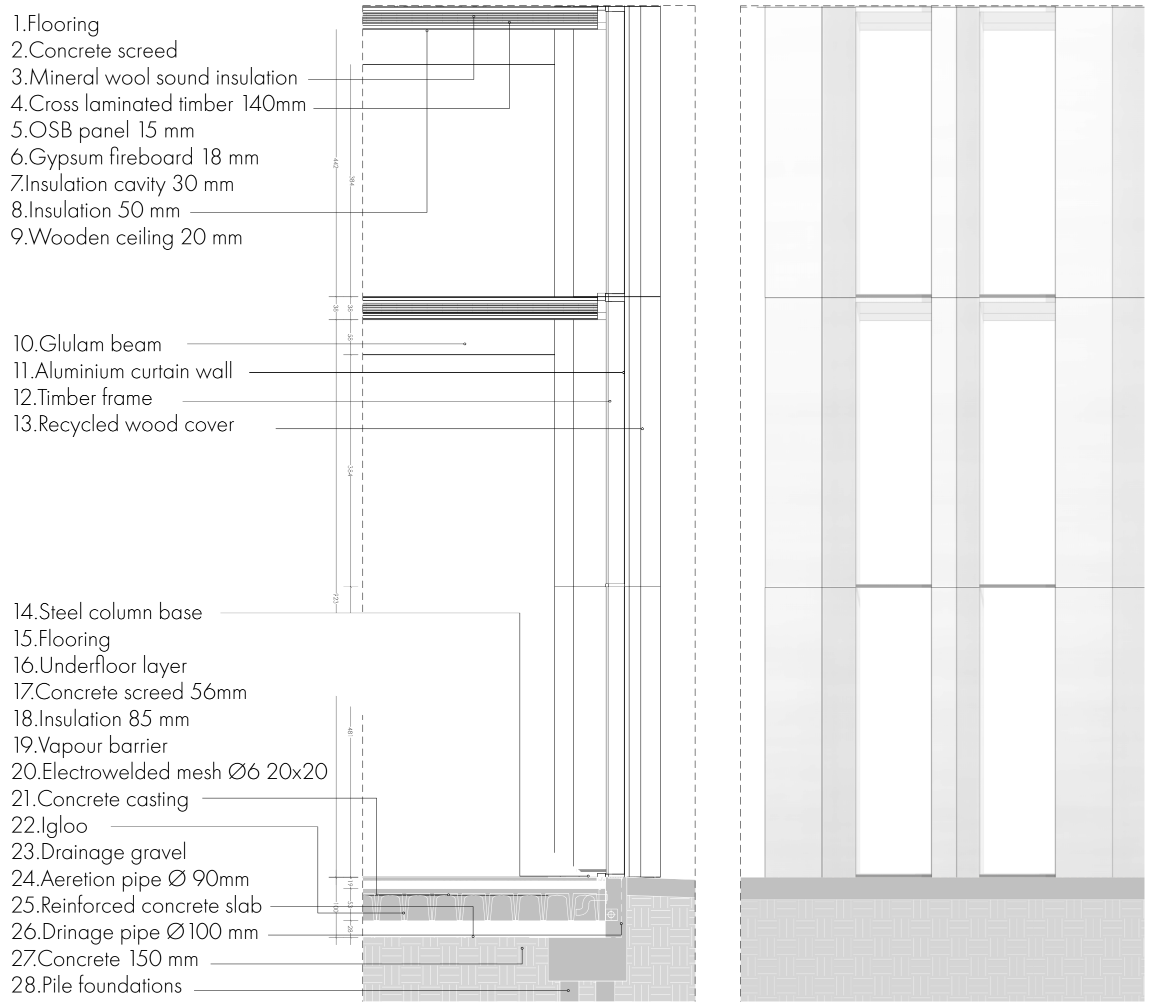


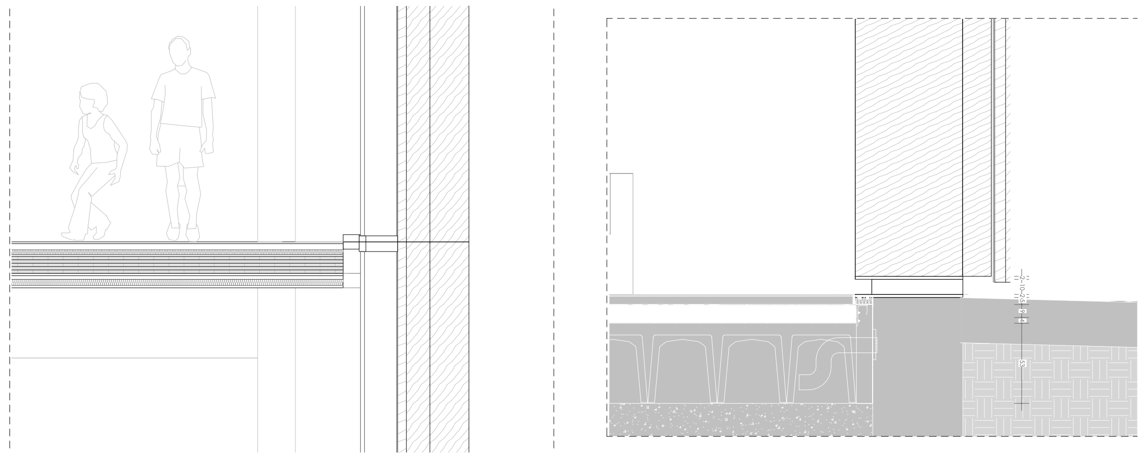
The design proposes different facades in east and west sides of the building as a response to daylight analysis, and site analysis. The initial studies of the city demonstrated the qualities of the visuals towards the park at the west and the noisy edge at the east side.

The west facade is characterized by the straight vertical structural elements with a distance of 4.80 m between them. This allows a greater passage of sunlight and a broader view towards the plaza, the city auditorium and the linear park.

SKEWED FACADE





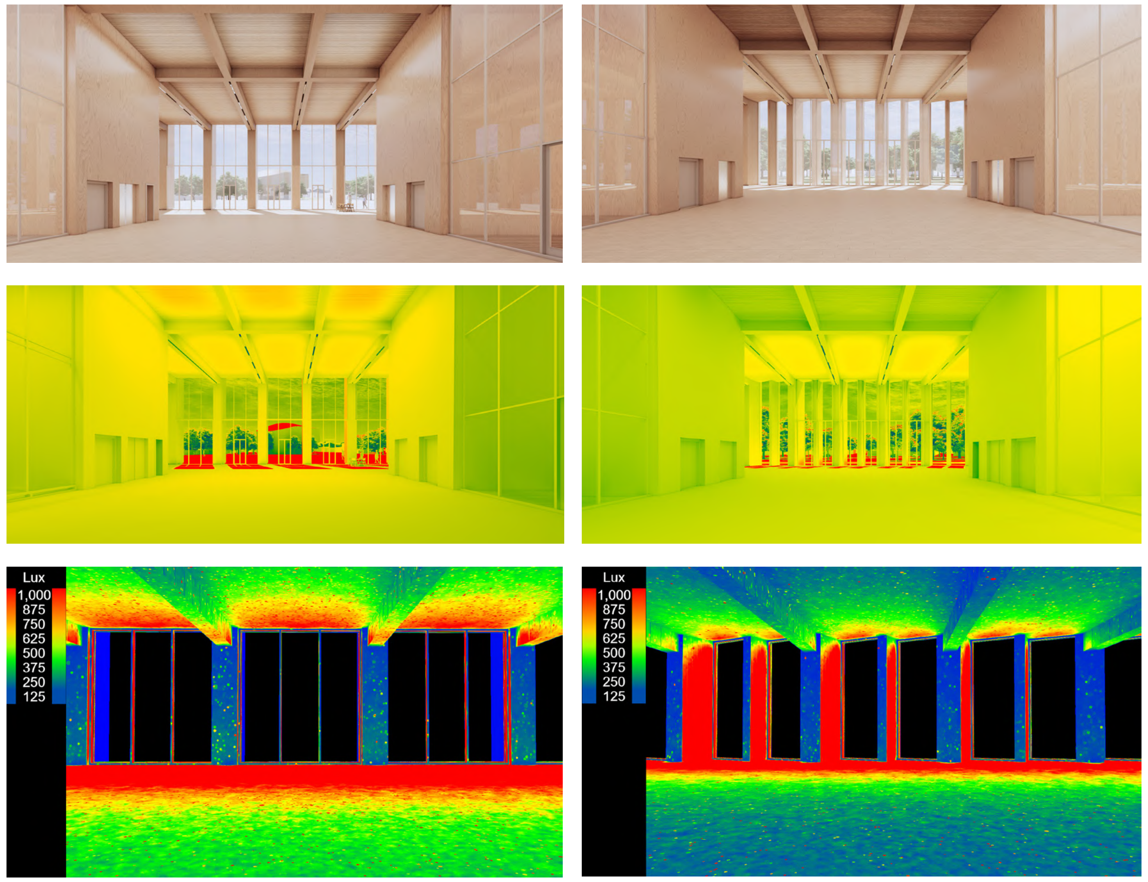


On the other hand, due to the functions inside the tower, the sun light management and the visual connections to the surroundings, in the east facade the vertical elements are skewed, the distance between them is 4.80m but inbetween smaller elements are located, densifiying the facade by each 2.40m. Consequently, there is a limitation of the light passage and a filter to the views towards the high speed street and the city buildings.

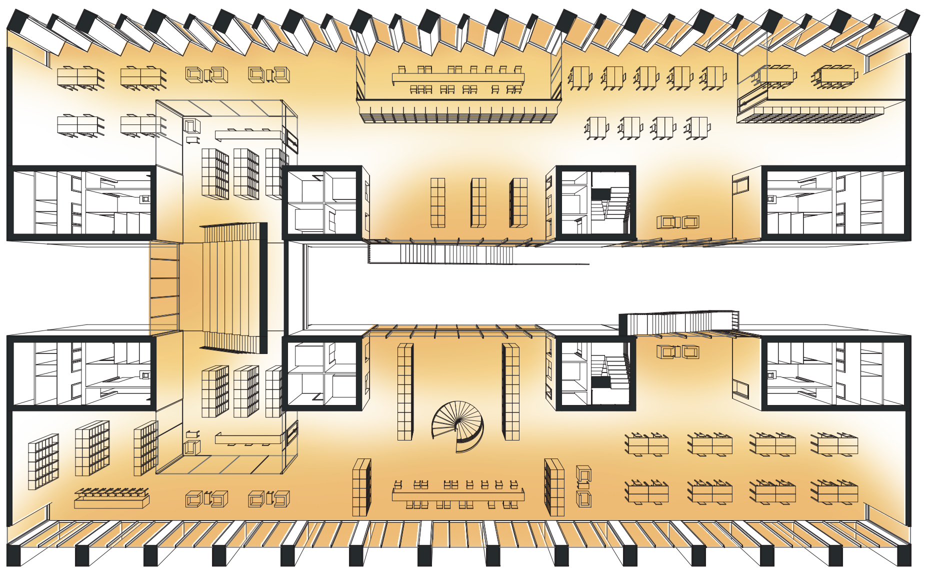
Daylight Analysis

As mentioned, it was important to consider a daylight analysis to better understand the densification and rotation of the vertical elements.

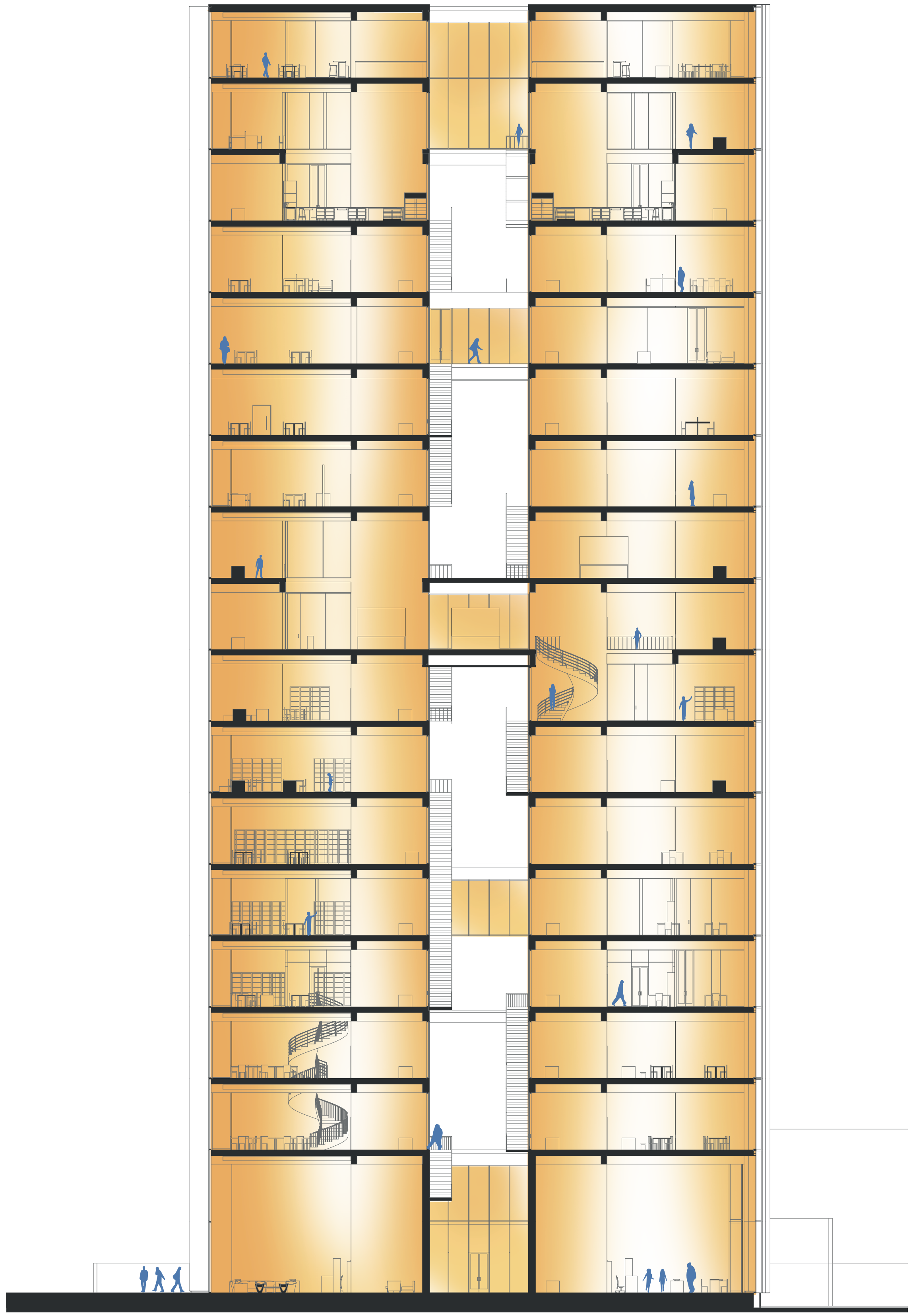
This analysis show the comparison between the east and west facade, from the perspective images it is possible to identify how the skewed facade generates shorter openings and filters the light inside the tower.



Straight facade **Skewed facade**

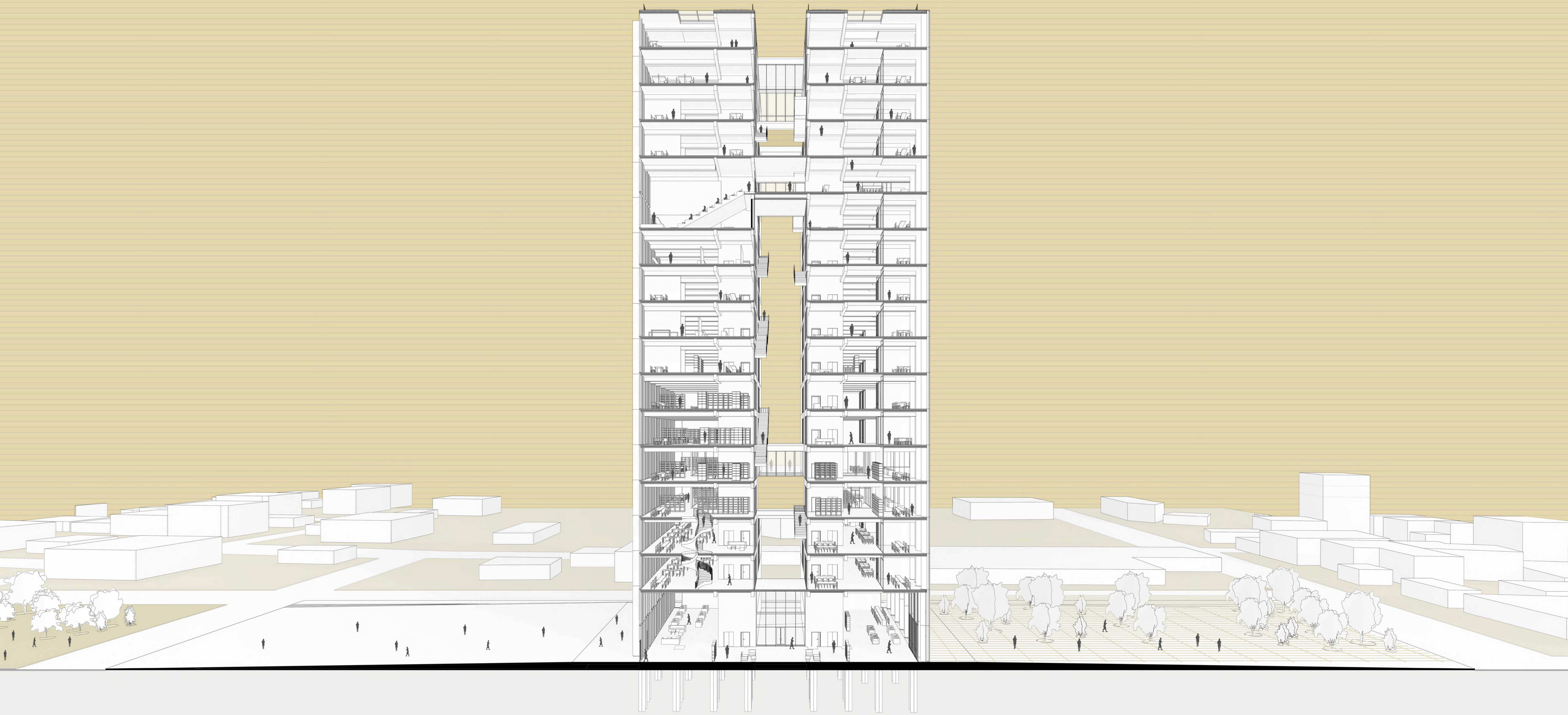


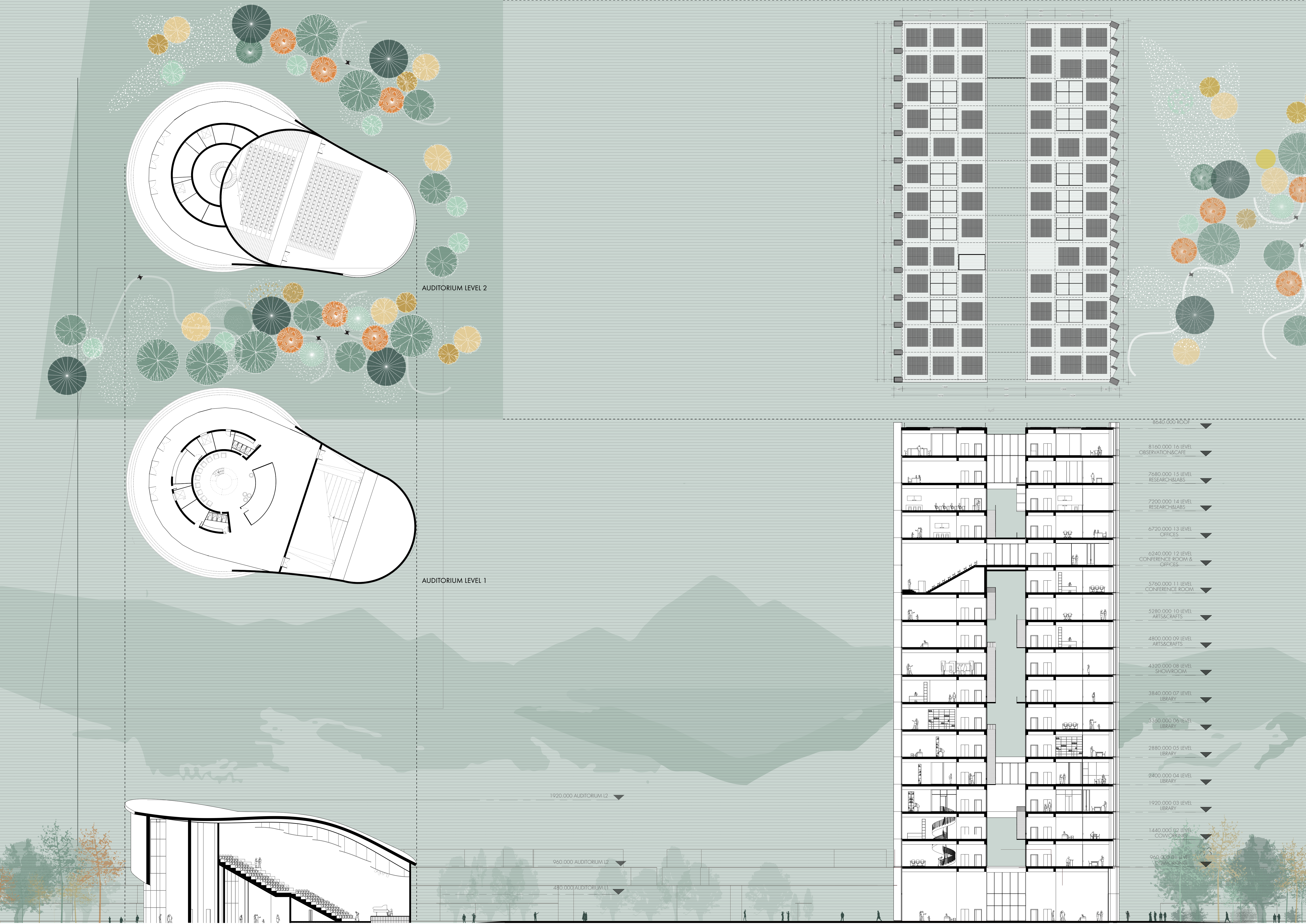
The software analysis helped also in the distribution of functions by placing the activites that require more light closer to the facade and more closed spaces next to the cores. To guarantee light in the middle spaces the facades that face the gap include oppenings and the bridges are glazed..



LONGITUDINAL SECTION (N-S)

TRANSVERSAL SECTION (W-E)




AUDITORIUM LEVEL 2
AUDITORIUM LEVEL 1
8640.000 ROOF
8160.000 16 LEVEL
OBSERVATION&CAFE
7680.000 15 LEVEL
RESEARCH&LABS
7200.000 14 LEVEL
RESEARCH&LABS
6720.000 13 LEVEL
OFFICES
6240.000 12 LEVEL
CONFERENCE ROOM &
OFFICES
5760.000 11 LEVEL
CONFERENCE ROOM
5280.000 10 LEVEL
ARTS&CRAFTS
4800.000 09 LEVEL
ARTS&CRAFTS
4320.000 08 LEVEL
SHOWROOM
3840.000 07 LEVEL
LIBRARY
3360.000 06 LEVEL
LIBRARY
2880.000 05 LEVEL
LIBRARY
2400.000 04 LEVEL
LIBRARY
1920.000 03 LEVEL
LIBRARY
1440.000 02 LEVEL
COWORKING
960.000 01 LEVEL
COWORKING
1920.000 AUDITORIUM L2
960.000 AUDITORIUM L2
480.000 AUDITORIUM L1

04 TECHNOLOGICAL SOLUTIONS

GENERAL SCHEME

Choosing appropriate materials and sustainable solutions for designing a tall building in the natural context of Ecuadorian Amazon rainforest involves considerations that balance environmental sustainability, resilience to the local climate, and integration with the surrounding ecosystem.

The selection of the materials and the producer companies, the use of enginereed woods by sustainable foresty, the use of bio-based adhesives for CLT and glulam are some of the attemps for more sustainable design.

SUSTAINABILITY AND INNOVATION

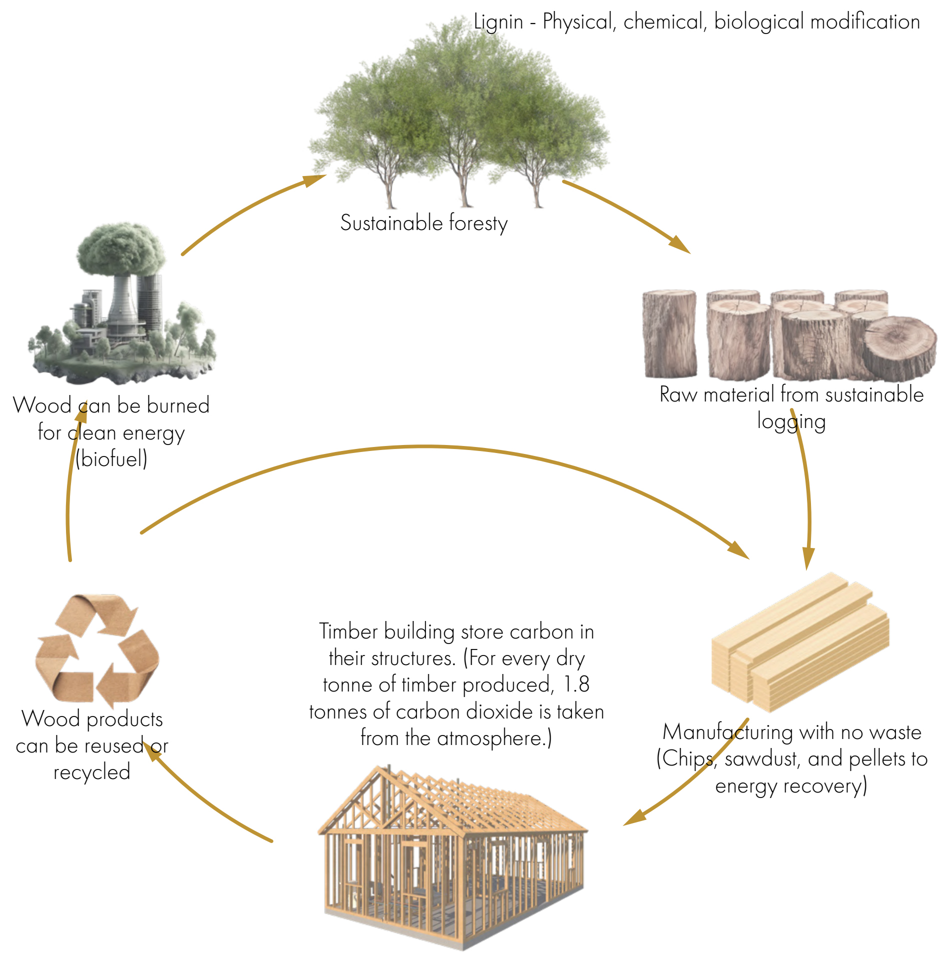
In 2016, the Food and Agriculture Organisation of the United Nations said that wood products would help tackle global warming, but only if made from sustainably managed forests. Using wood means avoiding other, more energy-intensive materials, such as PVC, aluminium, concrete and steel. As the report explains, 'the carbon footprint of a wooden building is only half that of a concrete structure'. (EcoTree. (n.d.). Cutting wood helps us renew forests and give them vitality.)

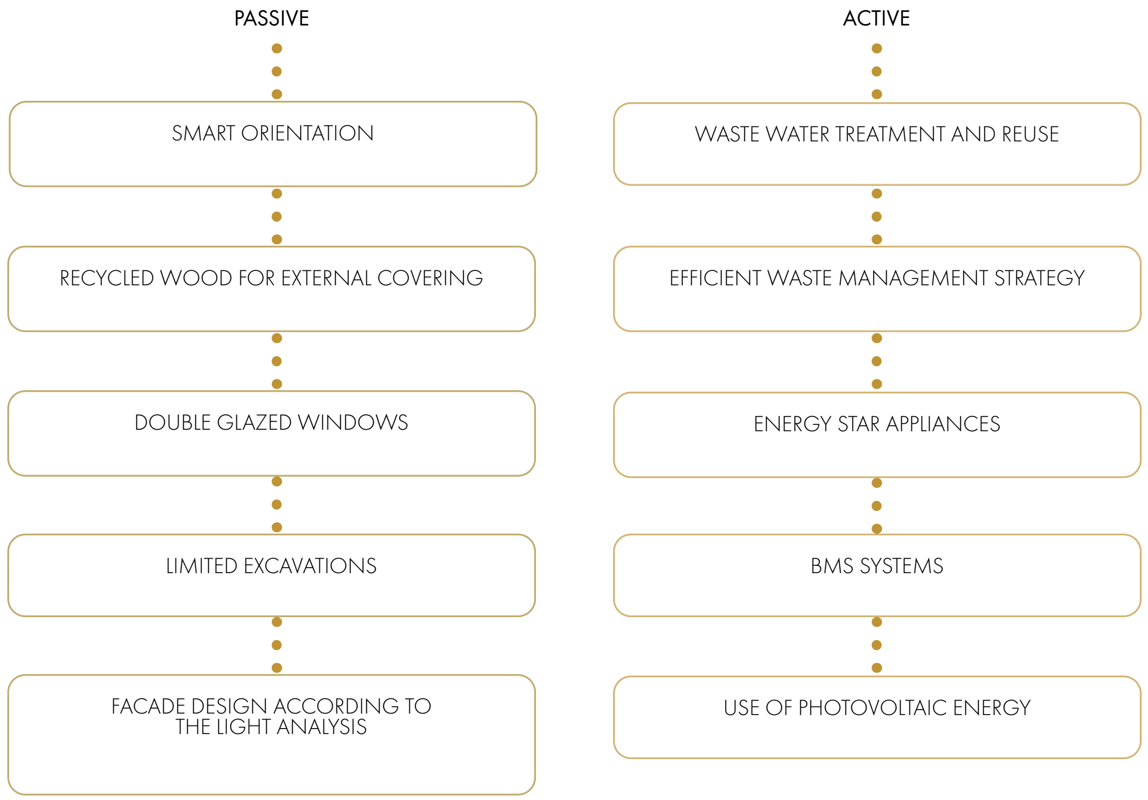
Logging and replanting is selective logging of mature trees ensures that the rainforest canopy is preserved. This method allows the forest to recover because the younger trees gain more space and sunlight to grow. Planned and controlled logging ensures that for every tree logged another is planted.

Sustainable logging is a subset of sustainable forest management that specifically focuses on the responsible extraction of timber and other forest products with practices of:

Selective Harvesting
Reduced Impact
Reforestation and Regeneration
Protection of Sensitive Areas
Certification with Standards

"According to CORRIM Life Cycle Assesment study, wood is better for the environment than steel or concrete in terms of embodied energy, global warming potential, air emissions, water emissions and solid waste production.Wood products require much less energy in manufacturing them compared to the other industrial raw materials and act as carbon sinks." - World Conference of Timber Engineering





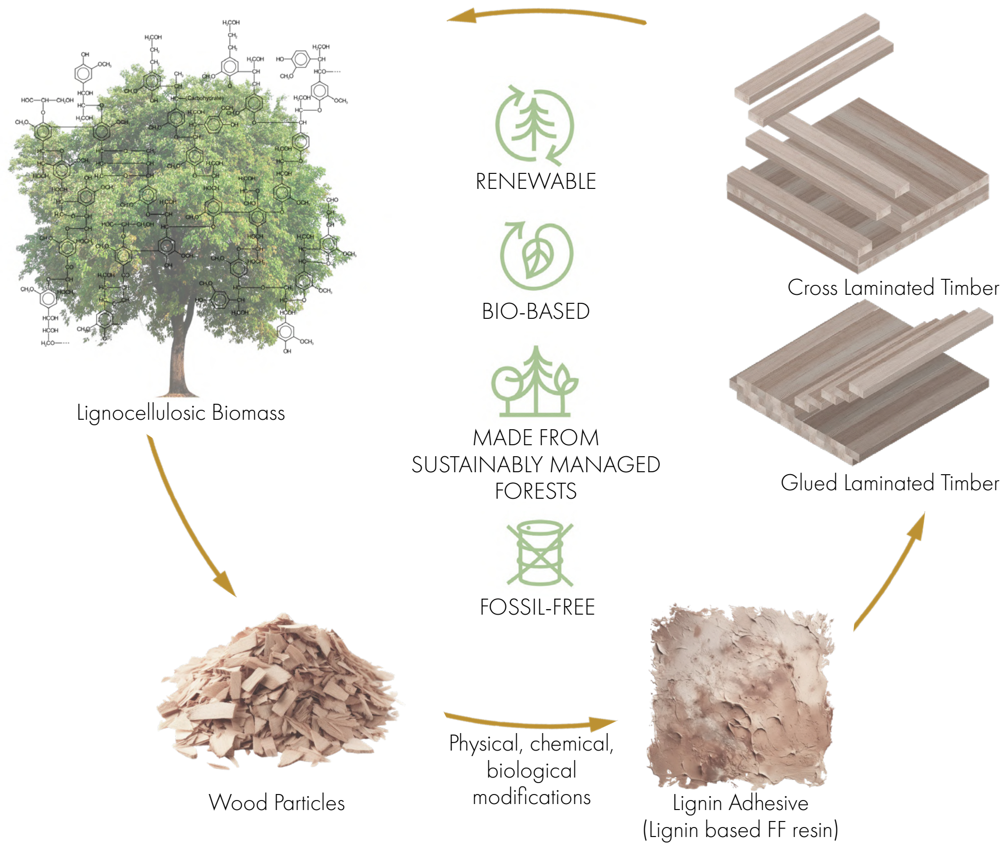
Sustainability Actions

Sustainable Lignin Based Adhesive for Glulam Timber

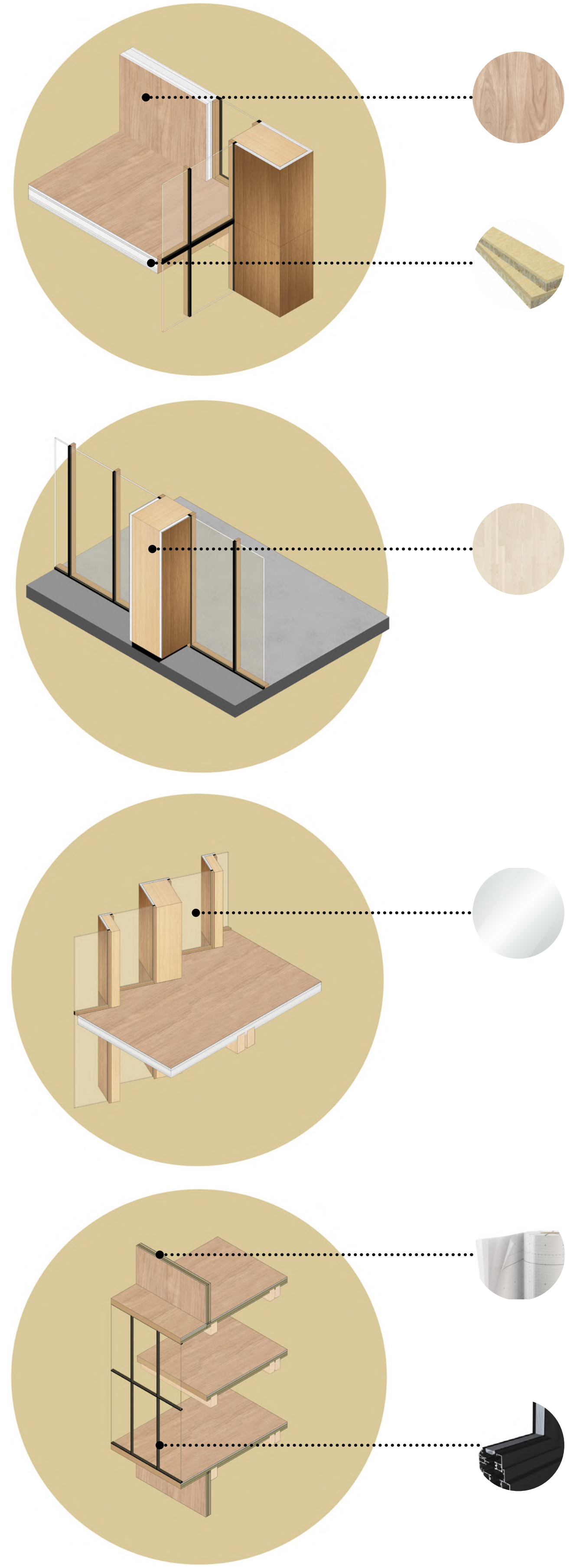
The adhesive is one of the most important parameter in the production of engineered wood. products. Although, the adhesives used today for engineered wood production are still mostly based on synthetic resins which are derived from petroleum, bio-based adhesives are a type of adhesive that is derived from renewable resources such as plants, animals, or microorganisms. These adhesives offer several benefits compared to traditional adhesives that are derived from petrochemical sources.

The research and development team at CHIMAR HELLAS has explored the utilization of diverse biomass products sourced from forest and agricultural wastes for manufacturing adhesives used in wood-panel production, aiming to deliver wood products that are both safe and emission-free.

The experimental outcomes reveal that the newly devised bio-based adhesive system exhibits performance levels deemed acceptable for the production of glulam beams. It performs equivalently or even surpasses conventional bonding systems in terms of efficacy. (Nakos, P., et. al, 2016)



MATERIALITY



Glulam Timber
PRECIOUS WOODS
'Piquia'
Origin: Amazon region of Brazil

Rock Mineral Wool Insulation
THERMAX® mineral wool (basalt rock fibers)
Origin: São Paulo, Brazil

Clt Timber
PRECIOUS WOODS
'Guariuba'
Origin: Amazon region of Brazil

Double Glass Facade
Vetriko-IG, Insulated Glass
Origin: Ecuador

Self Adhesive Vapor Barrier
VYCOR® enV-S™ Weather Resistive Barrier
Origin: Brazil

Aluminum Window Frame
Europeo
Origin: Ecuador

ubakus

All statements without guarantee

GROUP 02 EXTERNAL WALL FACADE TENA TOWER

Exterior wall
created on 26.5.2023

Thermal protection

U = 0,21 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

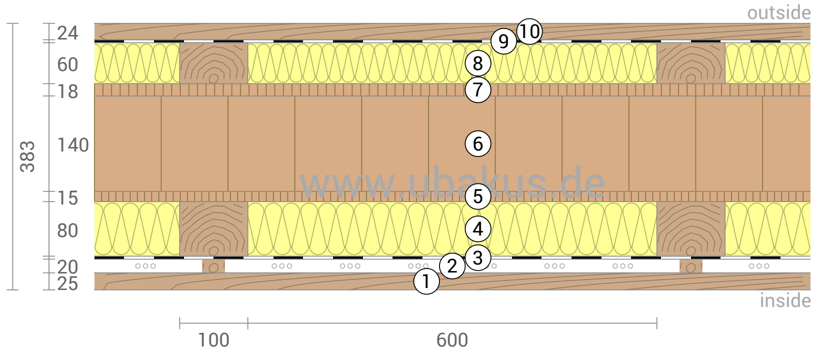
No condensate

excellent insufficient

Heat protection

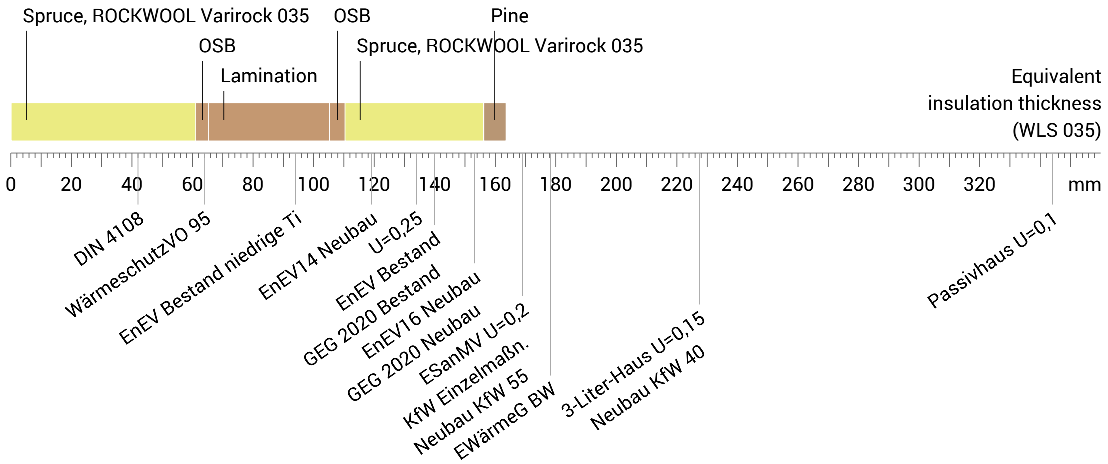
Temperature amplitude damping: 55
phase shift: 14,8 h
Thermal capacity inside: 80 kJ/m²K

excellent insufficient



1. Oak (25 mm)
2. Rear ventilated level (20 mm)
3. Vapor retarder sd=2,3m
4. ROCKWOOL Varirock 035 (80 mm)
5. OSB (15 mm)
6. Lamination (140 mm)
7. OSB (18 mm)
8. ROCKWOOL Varirock 035 (60 mm)
9. BITUMAT PVC Waterproofing Membrane
10. Pine (24 mm)

Impact of each layer and comparison to reference values

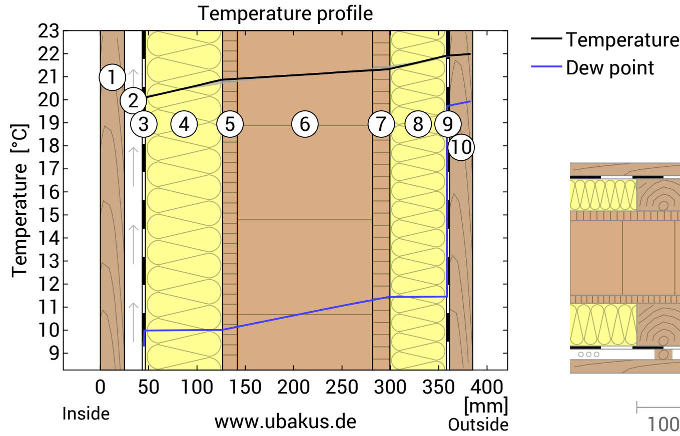


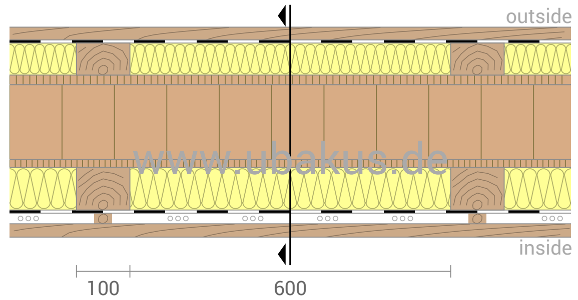
Inside air : 20,0°C / 50%
Outside air: 22,0°C / 88%
Surface temperature.: 20,1°C / 22,0°C

sd-value: 49,1 m

Thickness: 38,3 cm
Weight: 136 kg/m²
Heat capacity: 188 kJ/m²K

Temperature profile





1. Oak (25 mm)
2. Rear ventilated level (20 mm)
3. Vapor retarder sd=2,3m
4. ROCKWOOL Varirock 035 (80 mm)
5. OSB (15 mm)
6. Lamination (140 mm)
7. OSB (18 mm)
8. ROCKWOOL Varirock 035 (60 mm)
9. BITUMAT PVC Waterproofing Membrane
10. Pine (24 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
1	2,5 cm	Oak				20,0	17,3
2	2 cm	Rear ventilated level (room air)				20,0	0,0
		Thermal contact resistance*		0,130	20,0	20,2	
3	0,05 cm	Vapor retarder sd=2,3m	0,220	0,002	20,1	20,2	0,1
4	8 cm	ROCKWOOL Varirock 035	0,035	2,286	20,1	20,9	2,7
	8 cm	Spruce (14%)	0,130	0,615	20,2	20,7	5,1
5	1,5 cm	OSB	0,130	0,115	20,7	20,9	9,8
6	14 cm	Lamination	0,130	1,077	20,8	21,4	70,0
7	1,8 cm	OSB	0,130	0,138	21,3	21,5	11,7
8	6 cm	ROCKWOOL Varirock 035	0,035	1,714	21,3	21,9	2,1
	6 cm	Spruce (14%)	0,130	0,462	21,4	21,8	3,9
9	0,05 cm	BITUMAT PVC Waterproofing Membrane	0,170	0,003	21,8	21,9	0,5
10	2,4 cm	Pine	0,130	0,185	21,8	22,0	12,5
		Thermal contact resistance*		0,040	22,0	22,0	
	38,3 cm	Whole component		4,829			135,6

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max): 20,1°C 20,1°C 20,2°C
Surface temperature outside (min / average / max): 22,0°C 22,0°C 22,0°C

Moisture proofing

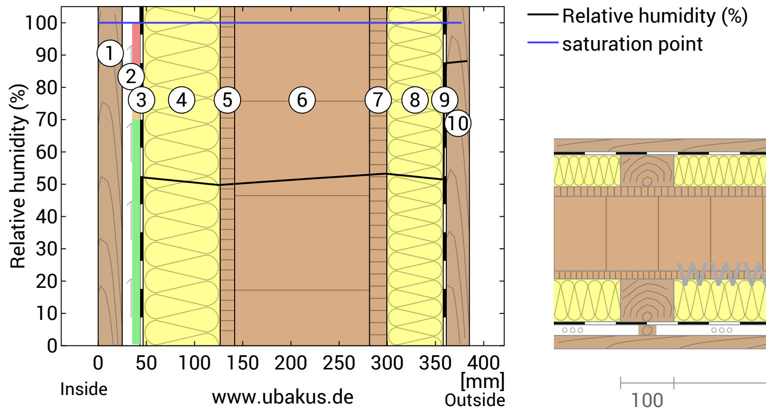
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: 22°C und 88% Humidity (Climate according to user input).

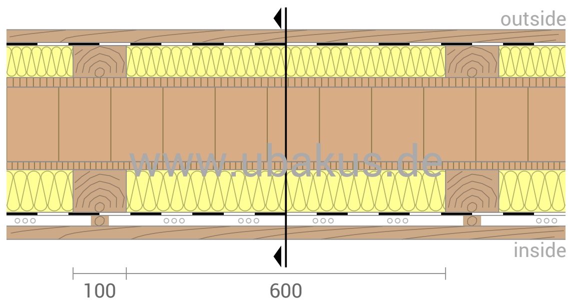
This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
3	0,05 cm	Vapor retarder sd=2,3m	2,30	-		0,1
4	8 cm	ROCKWOOL Varirock 035	0,08	-		2,7
	8 cm	Spruce (14%)	1,60	-	-	5,1
5	1,5 cm	OSB	0,45	-	-	9,8
6	14 cm	Lamination	4,20	-	-	70,0
7	1,8 cm	OSB	0,54	-	-	11,7
8	6 cm	ROCKWOOL Varirock 035	0,06	-		2,1
	6 cm	Spruce (14%)	1,20	-	-	3,9
9	0,05 cm	BITUMAT PVC Waterproofing Membrane	40,00	-		0,5
10	2,4 cm	Pine	1,20	-	-	12,5
	38,3 cm	Whole component	49,11	0		135,6

Humidity

The temperature of the inside surface is 20,0 °C leading to a relative humidity on the surface of 50%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



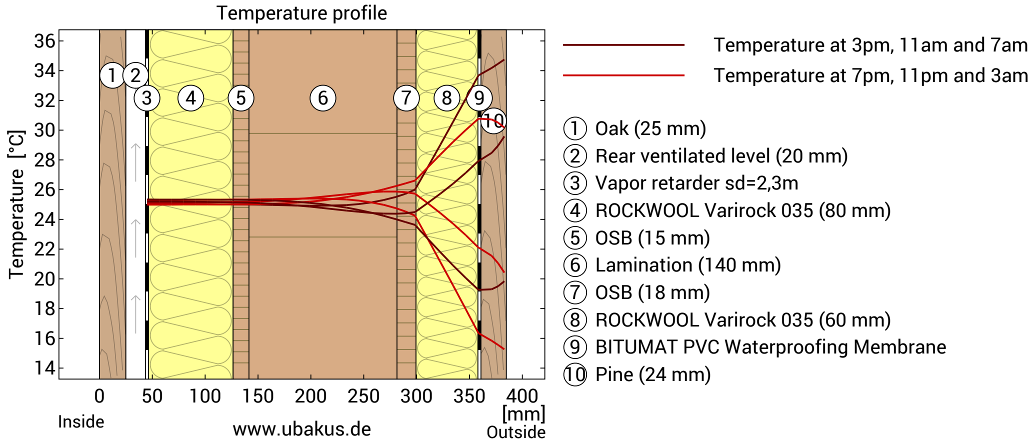


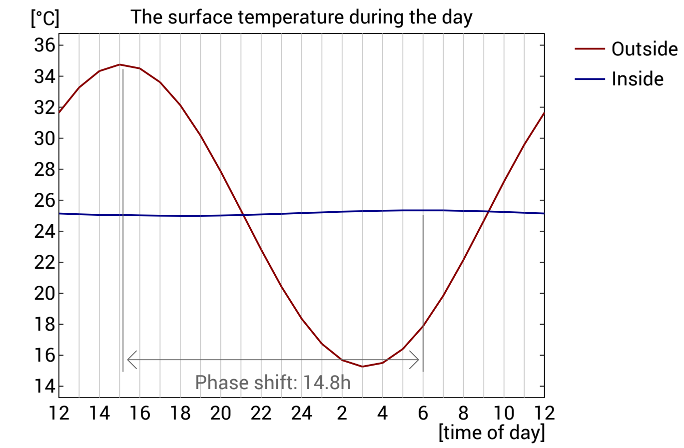
① Oak (25 mm)
② Rear ventilated level (20 mm)
③ Vapor retarder sd=2,3m
④ ROCKWOOL Varirock 035 (80 mm)
⑤ OSB (15 mm)
⑥ Lamination (140 mm)
⑦ OSB (18 mm)
⑧ ROCKWOOL Varirock 035 (60 mm)
⑨ BITUMAT PVC Waterproofing Membrane
⑩ Pine (24 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





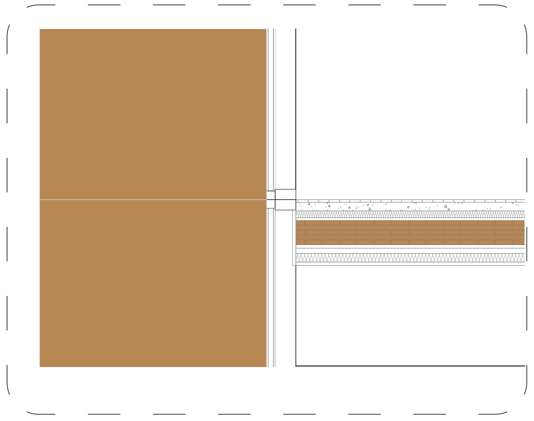
Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	14,8 h	Heat storage capacity (whole component):	188 kJ/m²K
Amplitude attenuation **	55,2	Thermal capacity of inner layers:	80 kJ/m²K
TAV ***	0,018		

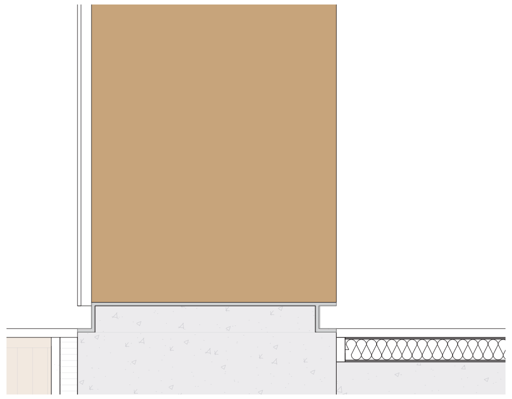
* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

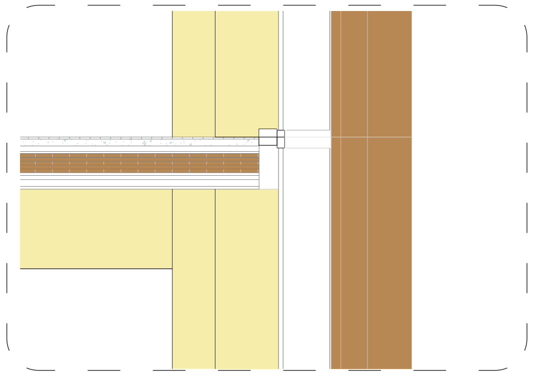
TECHNICAL DETAILS



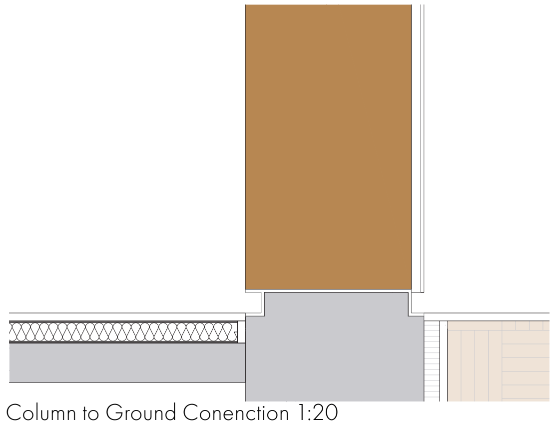
Slab to Column Detail 1:20



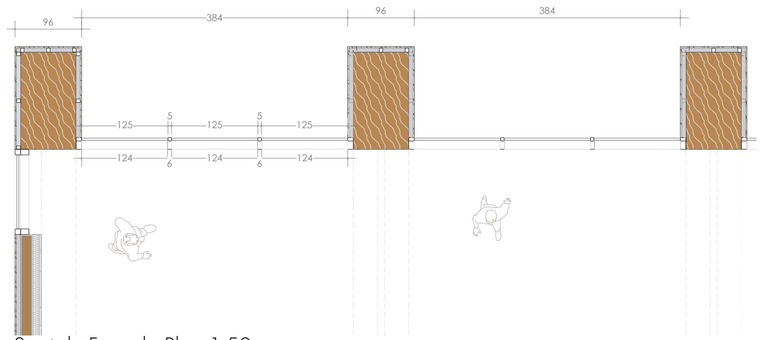
Column to Ground Conenction 1:20



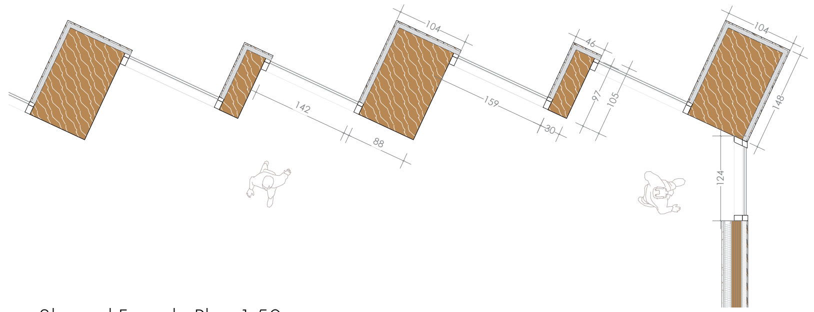
Slab to Column Detail 1:20



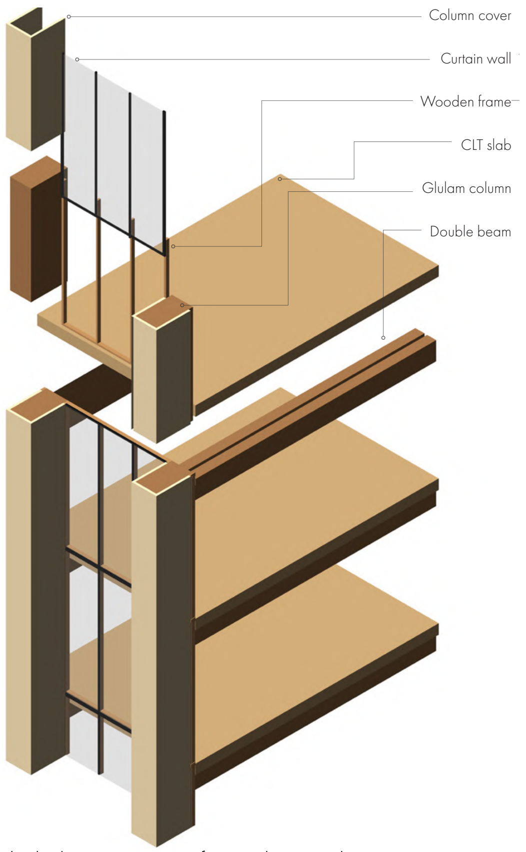
Column to Ground Conenction 1:20



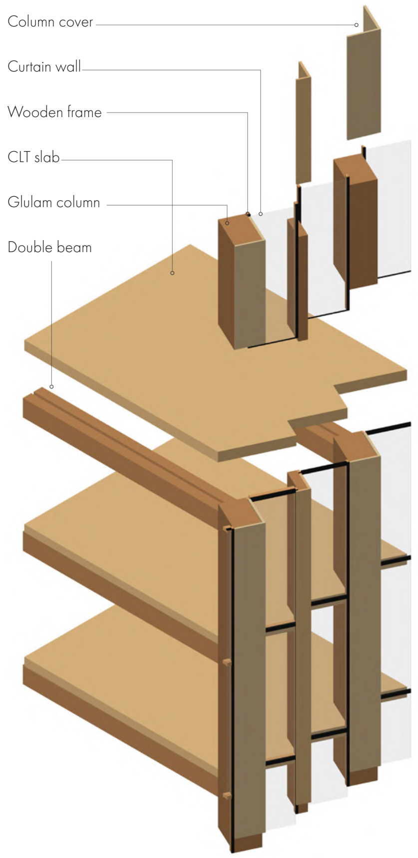
Straight Facade Plan 1:50



Skewed Facade Plan 1:50

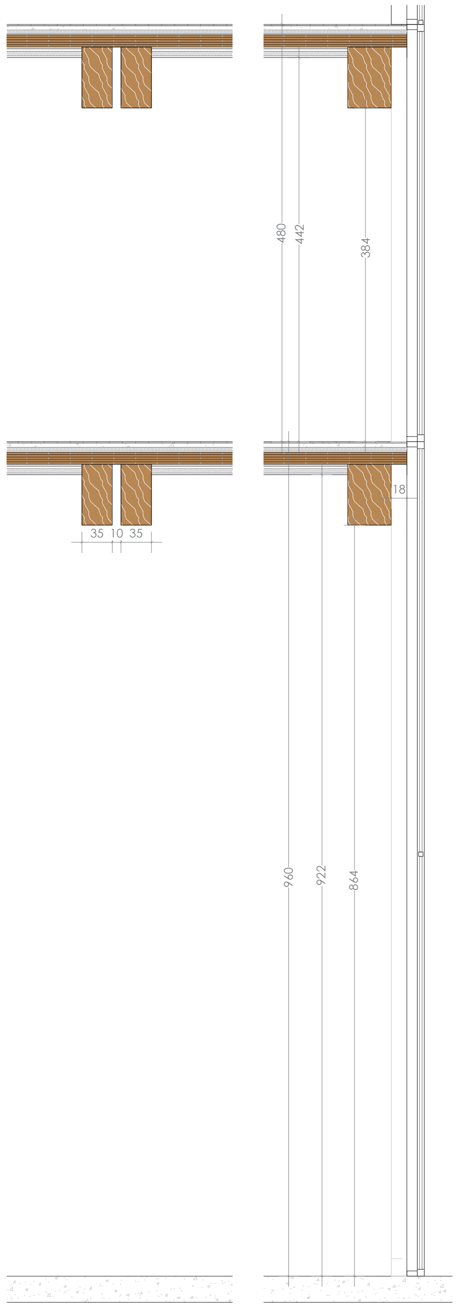


Exploded Axonometry of Straight Facade

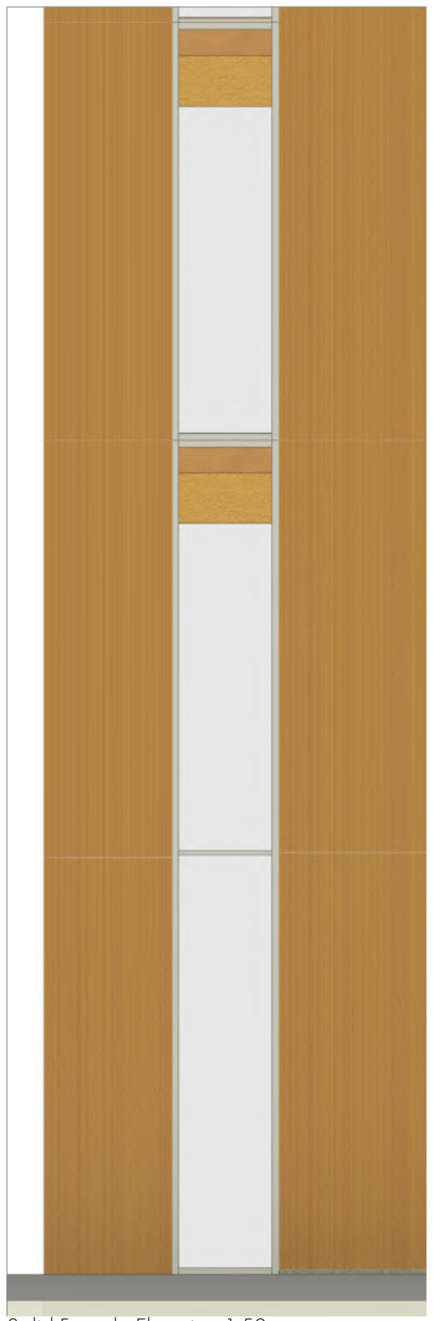


Exploded Axonometry of Skewed Facade

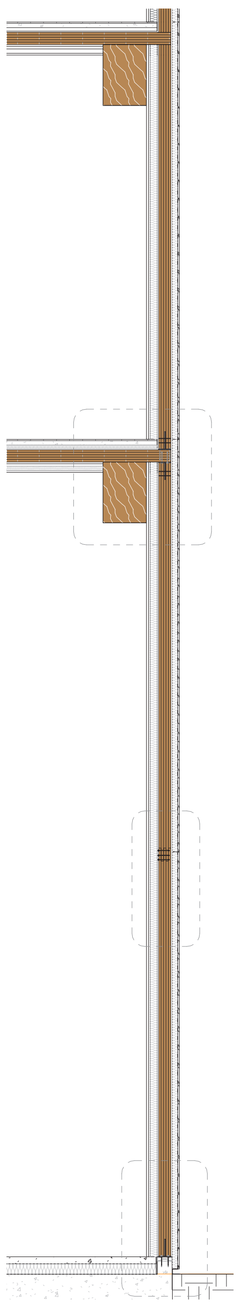
TECHNOLOGICAL SOLUTIONS



Window Detail Section 1:50

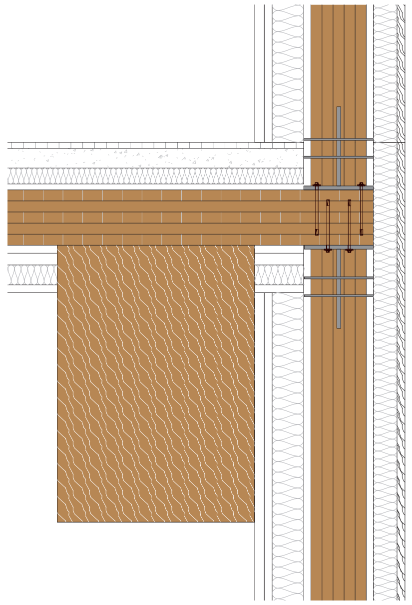


Solid Facade Elevation 1:50

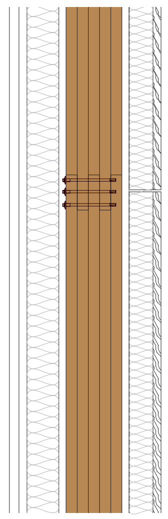


Wall Detail Section 1:50

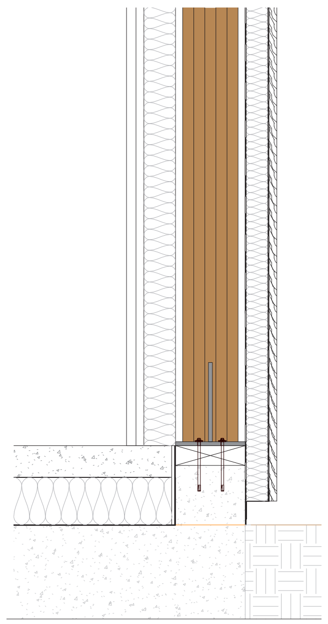
Corner Solution in Plan 1:50



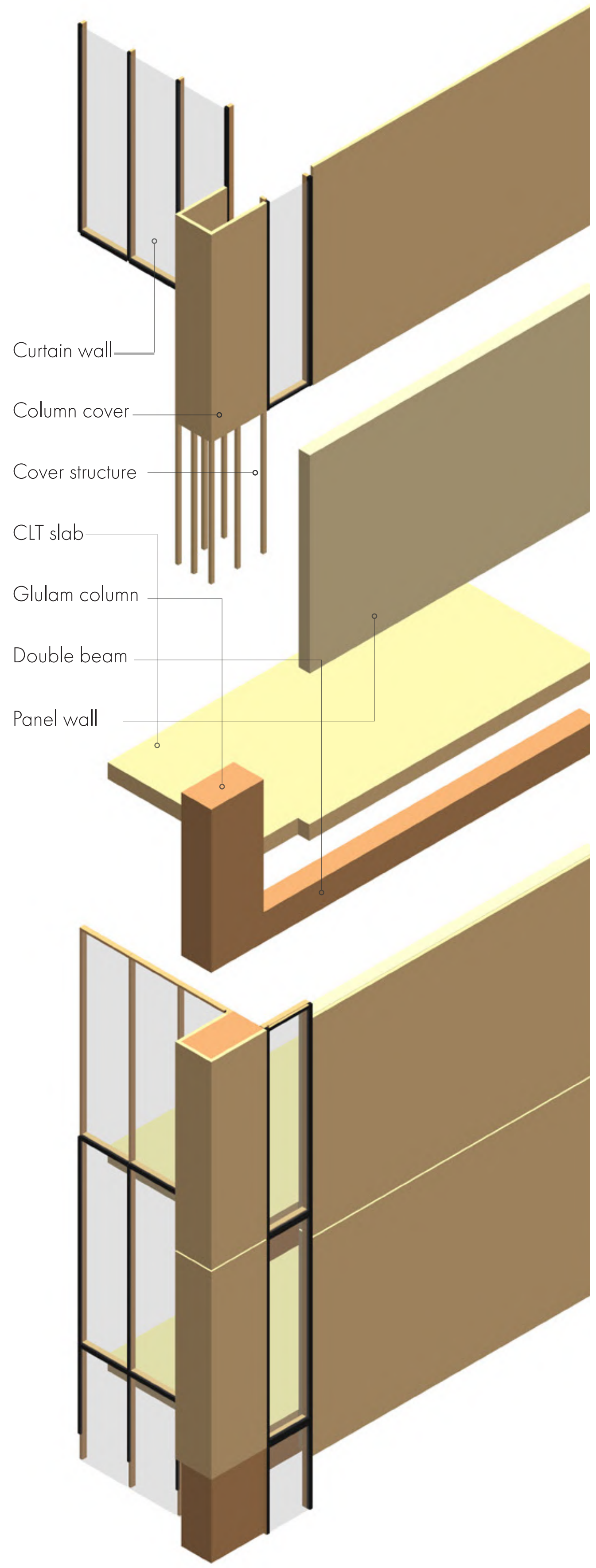
Wall to Slab Detail



Wall to Wall Detail



Wall to Ground Detail



Exploded Axonometric

05 STRUCTURE

STRUCTURE

The present report summaries the developed process during the structural analysis in the design of the tall building "Amazon Healing". The different steps followed as well as the formulas and concepts applied helped us to understand the importance of having structural consideration in the development of an architectural design since it becomes part of the decisions about shape and space. But mainly to apply a structural system that allowed us to keep and strengthen our architectural concept and our commitment to sustainable design using timber. By considering the seismic hazard due to the project location, seismic analysis was also developed in reference to the Ecuadorian law.

CONCEPT

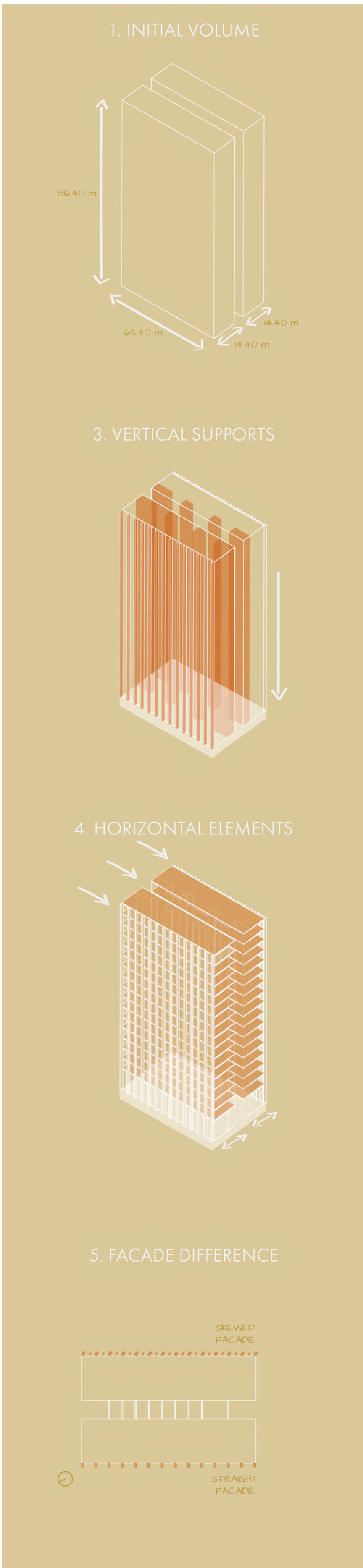
The first keyword represents the issue of sustainability and the site belonging. Therefore, the project makes use of wood not as a covering and decorative material but as a structural and representative one of the immersion of the building into a environment with the strong presence of nature and as a reflection on issues such as oil exploitation and deforestation.

By considering this architectural concept, the structure adapted works with two separated regular volumes. The CLT cores, with steel bracings, the glulam frames (columns and beams), and the CLT slabs, constitute the timber structure of this tower. The adapted configuration allowed us to have greater flexibility within a rigid system such as the wooden structure.

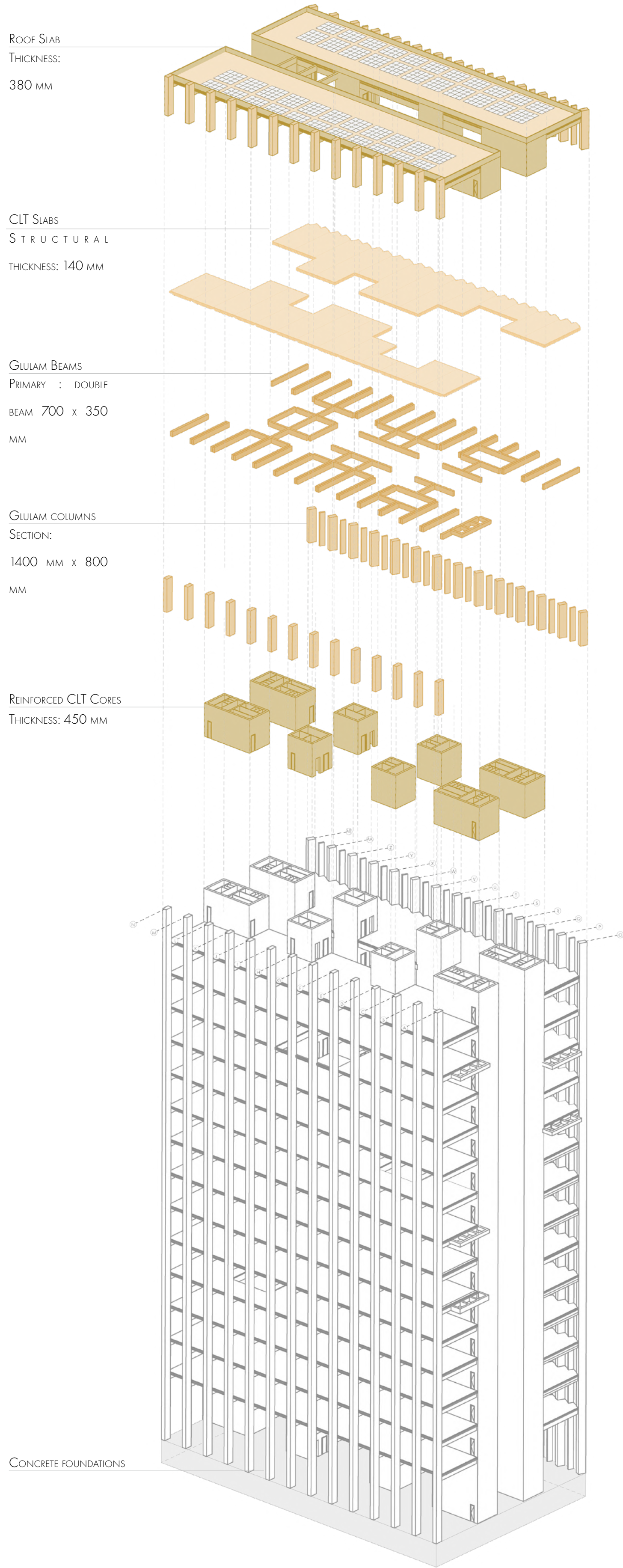
The vertical elements, CLT cores and glulam columns, are connected by glulam beams and support the CLT slabs. The loads are transferred to the foundation by the steel connections between the timber elements to concrete structure.

Materials
Cross laminated timber cores with steel bracings
Glued Laminated timber columns and beams
Structural steel connections
Concrete foundations

Codes Applied
Ecuadorian construction and seismic law

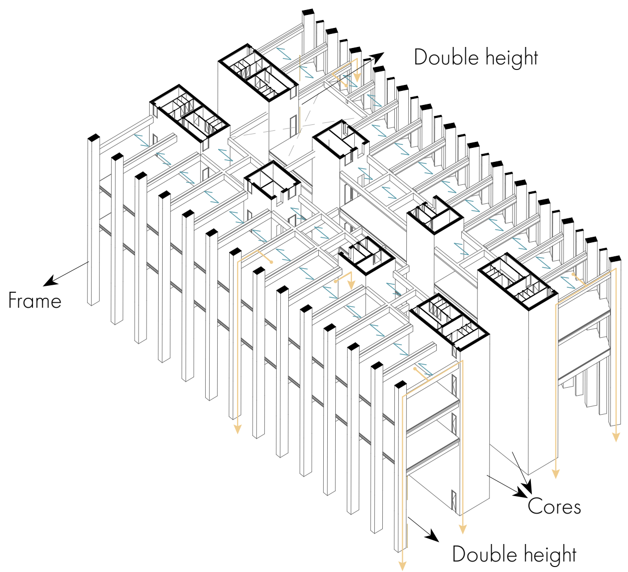


MECHANICAL BEHAVIOUR

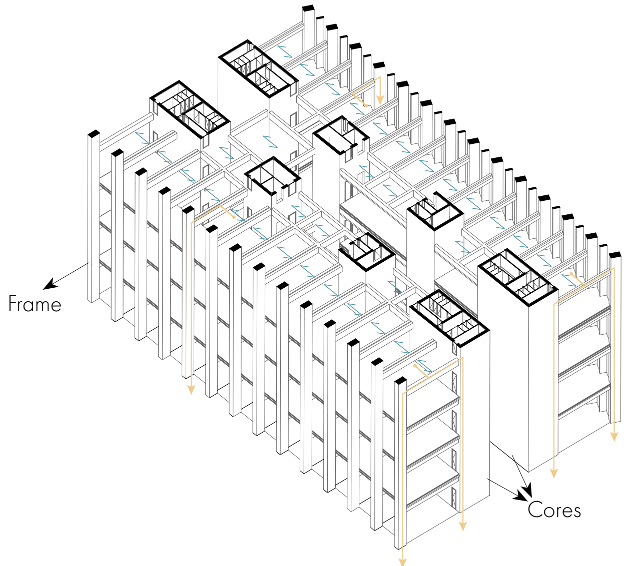


STRUCTURE

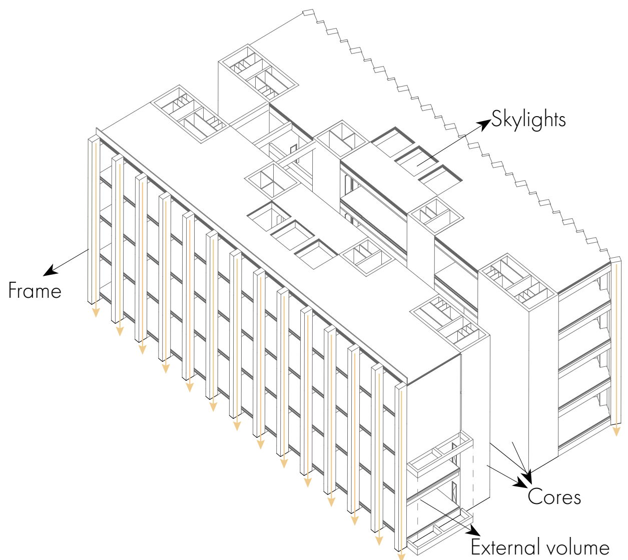
MECHANICAL BEHAVIOUR



LAYOUT OF LOAD'S PATH (DOUBLE HEIGHT SPACES)



LAYOUT OF LOAD'S PATH (TYPICAL FLOOR)



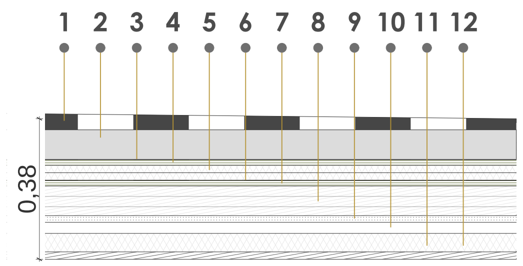
ROOF

LOADS ANALYSIS

To calculate the loads acting in the building there where considered the different dimensions and weights of each material.

Roof

For the Live Load it is consider as an roof with accesibility just for maintenance.



ROOF SLAB SECTION

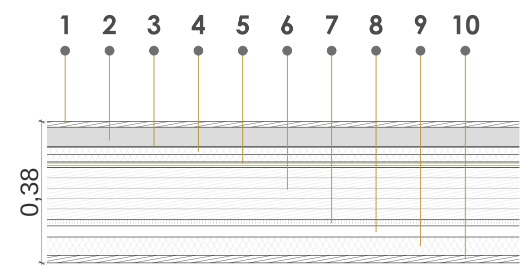
STRUCTURAL LOAD				
Description	Unit Weight (Kg/m3)	Thickness (m)	Weight kg/m2	Weight KN/m2
8. Cross laminated timber slab	500	0.08	40.00	0.40 kN/m2
		TOTAL	40.00	0.40 kN/m2
NON-STRUCTURAL LOAD				
Description	Unit Weight (Kg/m3)	Thickness (m)	Weight kg/m2	Weight KN/m2
1. Flooring (rainproof)	1500	0.03	45.00	0.45 kN/m2
2. Concrete screed	1000	0.08	80.00	0.80 kN/m2
3. Waterproof membrane	0	0.001	0.00	0.00 kN/m2
4. OSB panel	600	0.015	9.00	0.09 kN/m2
5.Mineral wool footfall sound insulation	34	0.04	1.36	0.01 kN/m2
6. Waterproof membrane	0	0.001	0.00	0.00 kN/m2
7. OSB panel	600	0.015	9.00	0.09 kN/m2
9. Gypsum fibreboard	800	0.018	14.40	0.14 kN/m2
10. Instalation cavity	0	0.03	0.00	0.00 kN/m2
11. Insulation	34	0.05	1.70	0.02 kN/m2
12. Wooden ceiling	740	0.02	14.80	0.15 kN/m2
		TOTAL	175.26	1.75 kN/m2
			TOTAL DEAD LOAD	2.15 kN/m2
			TOTAL LIVE LOAD	0.50 kN/m2

ROOF WEIGHT CALCULATION

Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
H-I-K	**Coperture**			
	Cat. H Coperture accessibili per sola manutenzione e riparazione	0,50	1,20	1,00
	Cat. I Coperture praticabili di ambienti di categoria d'uso compresa fra A e D	secondo categorie di appartenenza		
	Cat. K Coperture per usi speciali, quali impianti, eliporti.	da valutarsi caso per caso		

Typical Slab

For the Live Load it is consider the function with the highest value, therefore the access areas to offices, conference room and library.



TYPICAL SLAB SECTION

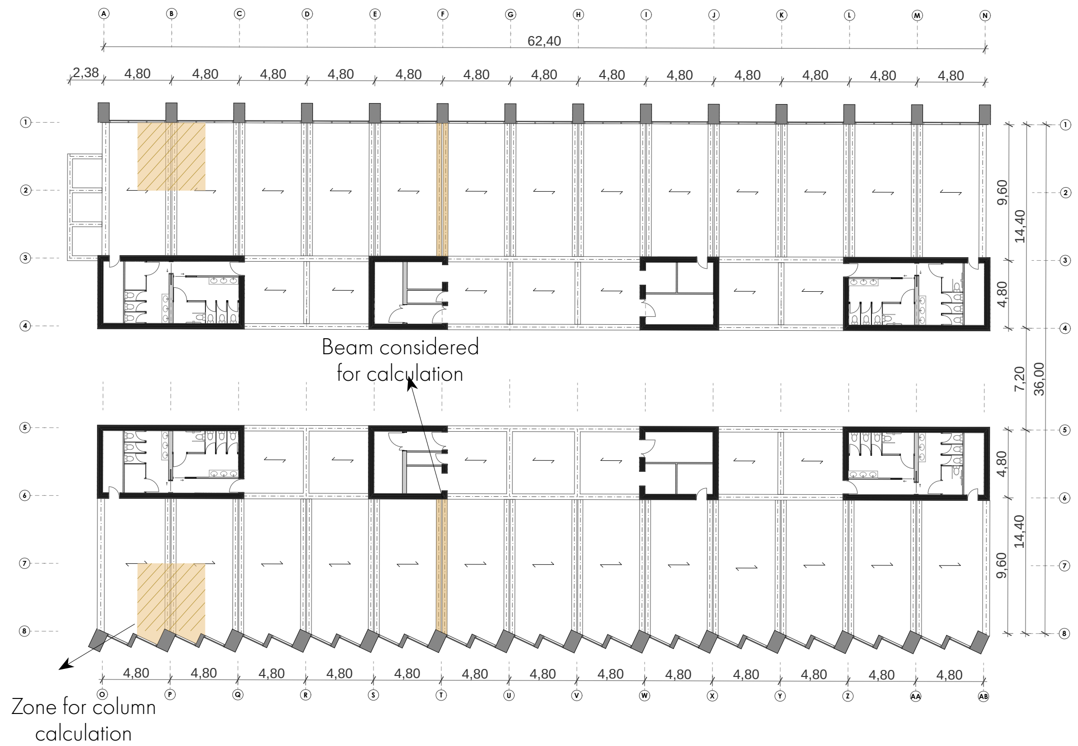
STRUCTURAL LOAD				
Description	Unit Weight (Kg/m3)	Thickness (m)	Weight kg/m2	Weight KN/m2
6. Cross laminated timber slab	500	0.14	70.00	0.70 kN/m2
		TOTAL	70.00	0.70 kN/m2
NON-STRUCTURAL LOAD				
Description	Unit Weight (Kg/m3)	Thickness (m)	Weight kg/m2	Weight KN/m2
1. Flooring (wood layer)	830	0.015	12.45	0.12 kN/m2
2. Concrete screed	1000	0.05	50.00	0.50 kN/m2
3. Waterproof membrane	0	0.001	0.00	0.00 kN/m2
4. Mineral wool footfall sound insulation	34	0.04	1.36	0.01 kN/m2
5. OSB panel	600	0.015	9.00	0.09 kN/m2
7. Gypsum fibreboard	800	0.018	14.40	0.14 kN/m2
8. Instalation cavity	0	0.03	0.00	0.00 kN/m2
9. Insulation	34	0.05	1.70	0.02 kN/m2
10. Wooden ceiling	740	0.02	14.80	0.15 kN/m2
		TOTAL	103.71	1.04 kN/m2
			SLAB DEAD LOAD	1.74 kN/m2
			WALLS DEAD LOAD	0.83 kN/m2
			TOTAL DEAD LOAD	2.57 kN/m2
			TOTAL LIVE LOAD	**5.00 kN/m2**

TYPICAL SLAB WEIGHT CALCULATION

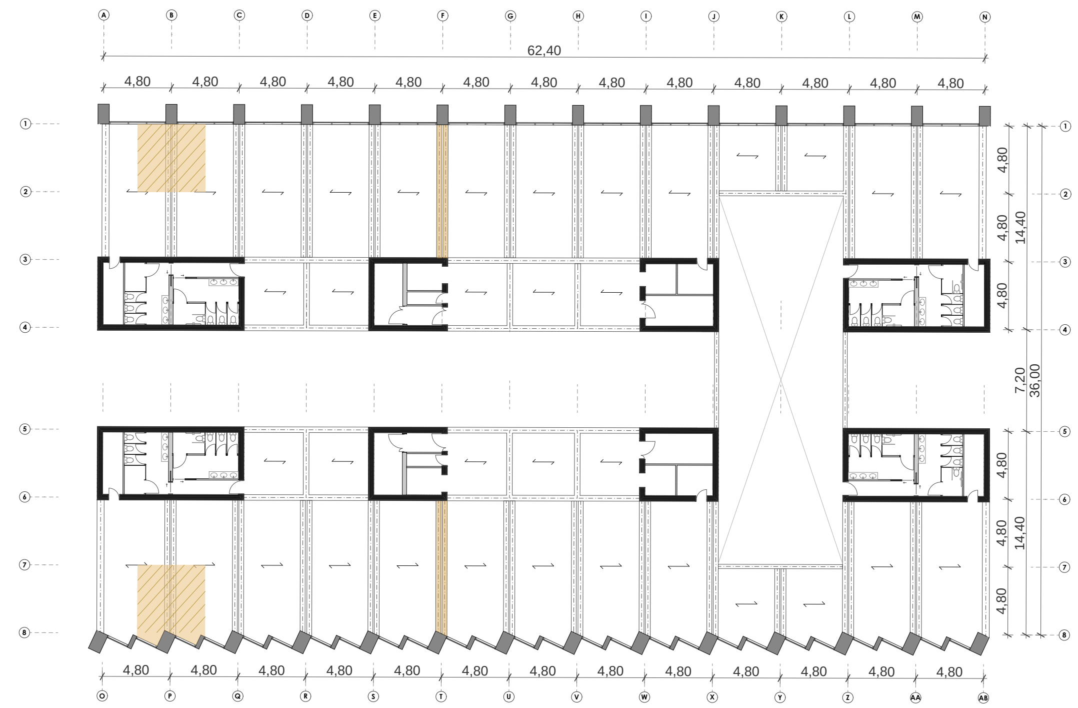
Tab. 3.1.II - *Valori dei sovraccarichi per le diverse categorie d'uso delle costruzioni*

Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
C	Cat. C3 Ambienti privi di ostacoli al movimento delle persone, quali musei, sale per esposizioni, aree d'accesso a uffici, ad alberghi e ospedali, ad atri di stazioni ferroviarie	5,00	5,00	3,00

Structural Plans



TYPICAL FLOOR PLAN



SPECIAL SPACES FLOOR PLAN

Beam Analysis

Actions
Permanent action → g (dead loads)
Variable action → q (live loads)

Ultimate limit state (ULS)

For the design of structural members not involving geotechnical actions, the partial factors for actions to be used for ultimate limit state design are:

Partial factor of permanent actions (yg) = 1.30
Partial factor of variable actions (yq) =1.50

Combination of actions at ULS

q^{uls}= (1.30g + 1.5q) d

Serviceability limit state (SLS)

For the design of structural members not involving geotechnical actions, the partial factors for actions to be used for servieability limit state design are:

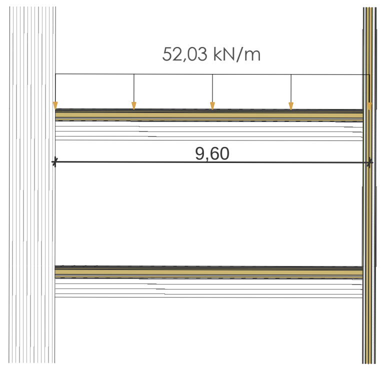
Partial factor of permanent actions (yg) = 1.00
Partial factor of variable actions (yq) =1.00

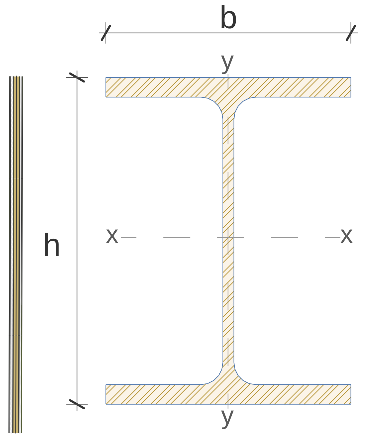
Combination of actions at SLS

q^{sls}=(1.00g + 1.00q) d

The present analysis started with a steel beam approach to have and idea of the possible sections of the structural elements.

Steel Beam Aproach





DATA

h = 0.40 m
b = 0.30 m
L = 9.60 m
E = 210000 N/mm^2
I = 576800000 mm^4
W_{pl} = 3232000 mm^3
A_v = 6998 mm^2

Ultimate limit state analysis
N = (1.30 x g + 1.5 x q) x d = 52,03 kN/m

Bending moment

$$M_{pl} = \frac{W_{pl}\ x\ F_y}{\gamma M_0} = \left(\frac{3232000\ mm^3\ x\ 235\ N/mm^2}{1.05}\right) x\ 2 = 723.35\ kN\ m$$

$$M_{max} = \frac{Q\ x\ l}{8} = \frac{52.03\ kN/m\ x\ (9.60\ m)^2}{8} = 599.35\ kN\ m$$

$$M_{pl} \geq M_{max}$$

Shear force

$$V_{max} = \frac{Q\ x\ l}{2} = \frac{52.03\ kN/m\ x\ 9.60\ m}{2} = 249.73\ kN$$

$$V = \frac{A_v\ x\ f_y}{\sqrt{3}\ x\ 1.05} = \frac{0.006998\ m^2\ x\ 235000\ kN/m^2}{\sqrt{3}\ x\ 1.05} = 904.26\ kN$$

$$V \geq V_{max}$$

Serviciability limit state analysis
N = (1.00 x g + 1.00 x q) x d = 36,33 kN

Allowable deflection

$$\delta_{max} = \frac{}{250} = \frac{}{250} = 38.40\ mm$$

$$\delta_{max} = \frac{5}{384} x\ \frac{q^{sls}\ l^4}{EJ} = \frac{5}{384} x\ \frac{36.33\ N/mm\ \ (9600mm)^4}{210000\ N/mm^2\ x\ 576800000mm^4} = 33.17\ mm$$

$$\delta_{max} \geq \delta$$

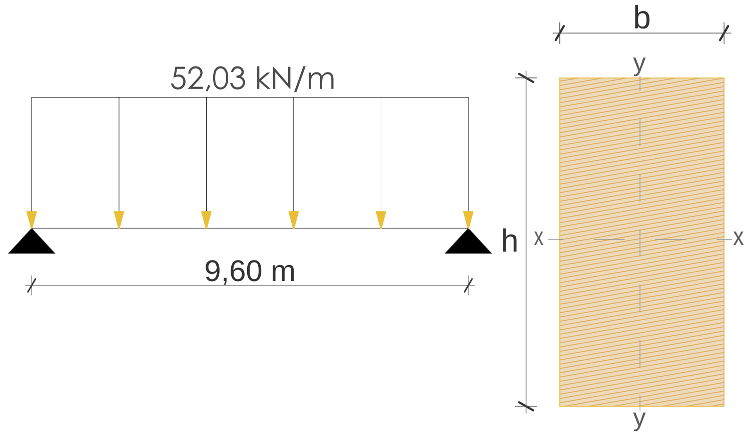
Allowable deflection for live load

$$\delta_{max} = \frac{l}{300} = \frac{9600\ mm}{300} = 32.00\ mm$$

$$\delta_{max} = \frac{5}{384} x\ \frac{q^{LL}\ l^4}{EJ} = \frac{5}{384} x\ \frac{24\ N/mm\ \ (9600mm)^4}{210000\ N/mm^2\ x\ 576800000mm^4} = 21.91\ mm$$

$$\delta_{max} \geq \delta$$

Timber Beam



Data

h = 0.70 m
b = 0.35 m
L = 9.60 m
f_{bx} = 11 MPa = 11000 kN/mm²

Ultimate limit state analysis

N = (1.30 x g + 1.5 x q) x d = 52,03 kN/m

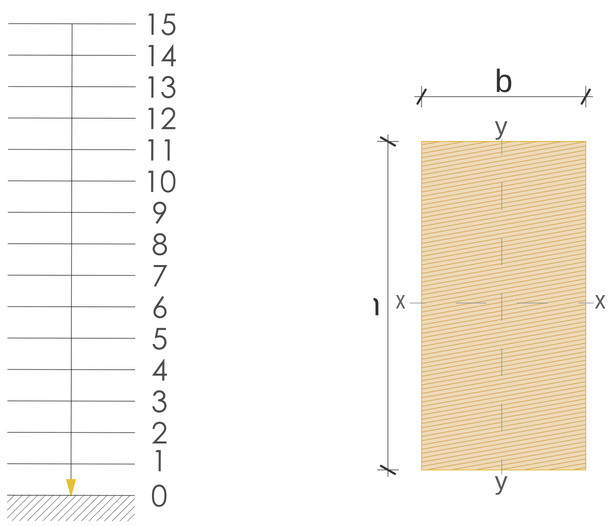
Bending moment

$$M = \frac{f_{bx}\ x\ b\ x\ h^2}{6} = \frac{11000\ kN/m^2\ x\ 2(0.35m\ x\ (0.70m)^2)}{2} = 628.83\ kN\ m$$

$$M_{max} = \frac{Q\ x\ l^2}{8} = \frac{52.03\ kN/m\ x\ (9.60\ m)^2}{8} = 599.35\ kN\ m$$

$$M \geq M_{max}$$

Timber Column



Data

h= 1,40 m
b= 0,80 m
H = 9,60 m
E = 12000 N/mm²
I = 182933333333,33 mm⁴
π = 3,1416
fcd = 19 MPa
β = 0,1 (glulam)

Load

A = (4.80 x 9.60) / 2 = 23.04 m²
N = (1.30 x g + 1.50 x q) x 23.04 x 15 x 1.3 = 5825.65 kN

Critical Load | Euler

$$N_{cr} = \frac{EI\ x\ \pi^2}{8} = 653023.59\ kN$$

Inertia

$$i_{max} = \sqrt{\frac{b\ x\ h^3}{12\ x\ b\ x\ h}} = \frac{1400mm}{2\sqrt{3}} = 404.15\ mm$$

$$i_{min} = \frac{b}{2\sqrt{3}} = \frac{800mm}{2\sqrt{3}} = 230.94\ mm$$

$$l_0 = 0.6\ x\ H = 0.6\ x\ 9600\ mm = 5760.00\ mm$$

$$\lambda = \frac{l_0}{i_{min}} = \frac{5760mm}{203.94\ mm} = 24.94\ mm$$

$$\lambda_{cr} = \pi\sqrt{\frac{E}{f_{cd}}} = \pi\sqrt{\frac{12000\ N/mm^2}{19\ N/mm^2}} = 78.95$$

$$\lambda_{ref} = \frac{\lambda}{\lambda_{cr}} = \frac{24.94}{78.945} = 0.3159$$

$$k = \frac{1 + \beta(\lambda_{ref} - 0.3) + \lambda_{ref}{}^2}{2} = 0.55$$

$$k_{cr} = \frac{1}{k + \sqrt{k^2 + \lambda_{ref}{}^2}} = 0.84$$

Real strenght of the material

$$N_{rd,b} = A\ x\ f_{cd} x\ K_{cr} = 168075.60\ kN$$

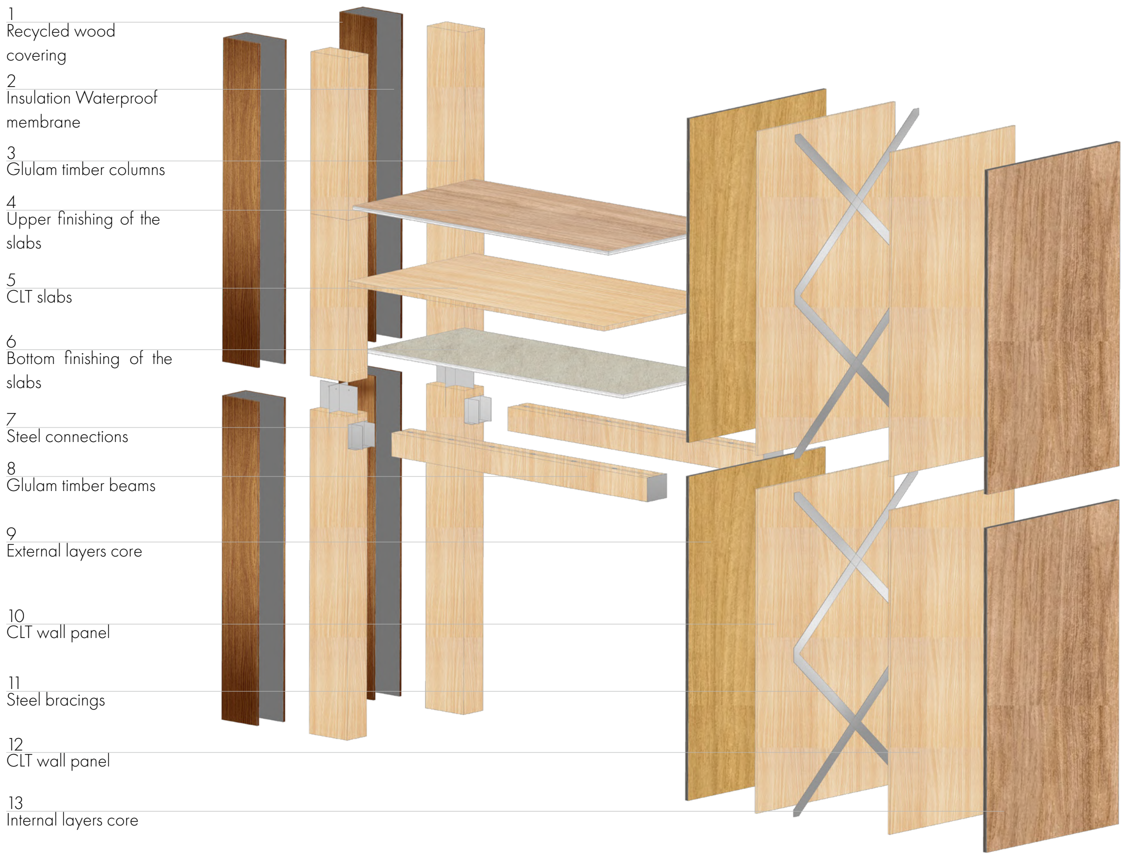
$$\frac{N}{N_{rd,b}} = 1.60\%$$

$$N_{rd,b} > N$$

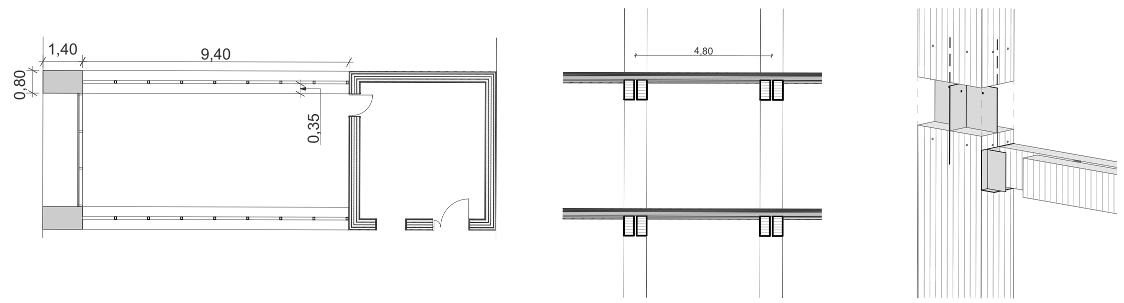
$$N_{cr} > N$$

STRUCTURAL DETAILS

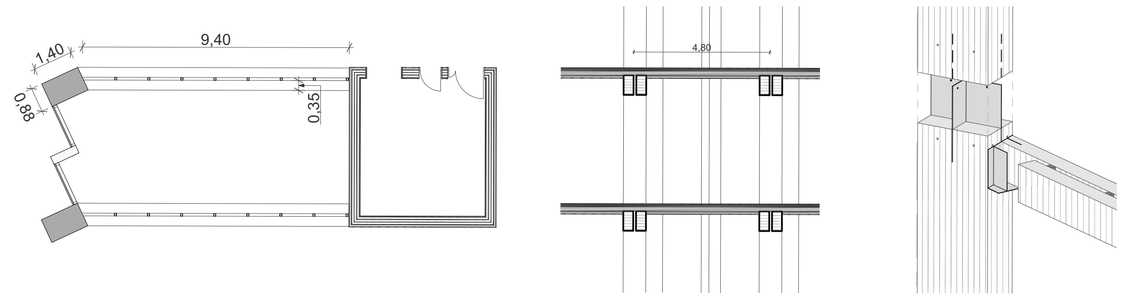
Structural layering



Connection beam - column (straight facade)



Connection beam - column (skewed facade)



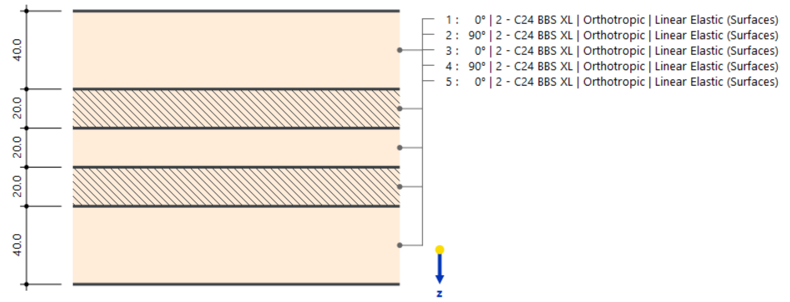
DLUBAL SOFTWARE ANALYSIS

For the structural analysis it was important to choose a software that analyses timber constructions. The Dlubal structural engineering programs RFEM and RSTAB are an efficient solution for structural analysis and design of two- or three-dimensional timber structures. The Timber add-on designs timber members for the ultimate and serviceability limit state according to different standards:

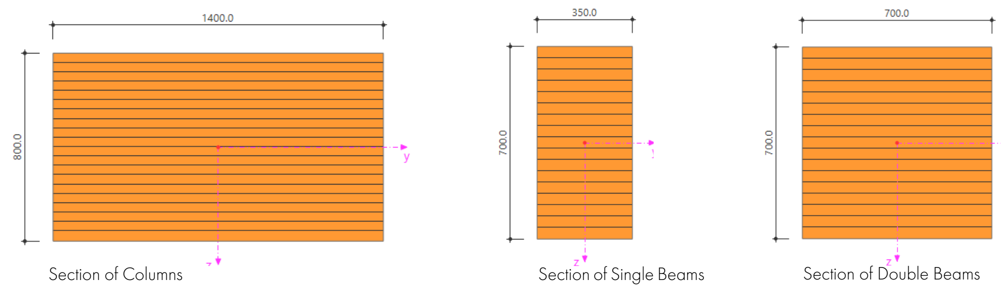
- EN 1995-1-1:2010 (Eurocode 5)
- SIA 265:2015-08 (Swiss standard)
- ANSI/AWC NDS:2018 (US standard)
- CSA 086 (Canadian standard)
- GB 50005 | 2017-11 (Chinese standard)

It its important to mention that the Amazon Healing Tower was analyzed by a trial version with a student licence.

Definition of Materials



Section of CLT Surfaces

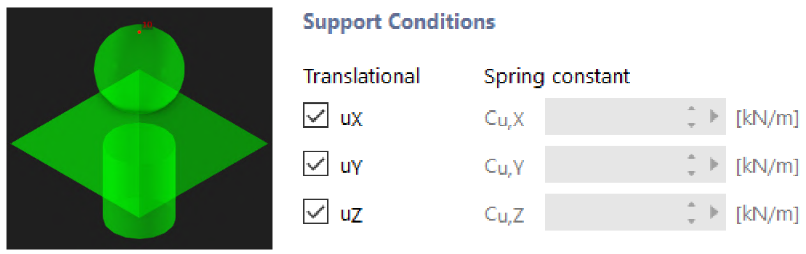


Section of Columns Section of Single Beams Section of Double Beams

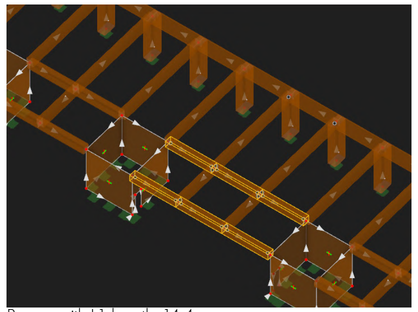
For structural modeling, the surfaces for core walls and slabs are defined with the material of C24 BBS XL. Five layers were used to reach the thickness of 140.0 mm CLT. Glulam timber GL24h is chosen with the section of 800 mm x 1400 mm for columns, 350 mm x 700 mm for single beams and 700 mm x 700 mm for double beams.

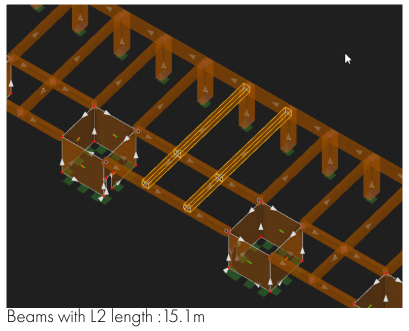
Definition of Connections

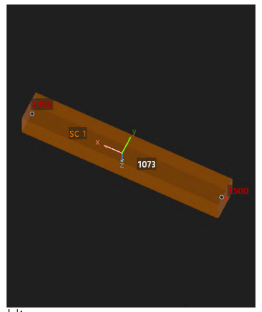
Nodal supports are defined as fixed in each directions for the column - ground connection.

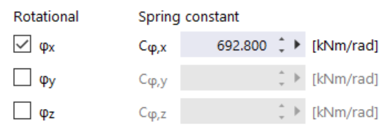


Member hinges are defined for the start and end points of beams with 50 % stiffness of torsion. 50% about stiffness of torsion means there is not an integral continuity about this tangential stress. In this moment the matemathical approach is applied by an automatic code.

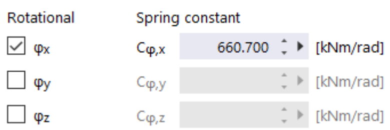

Beams with L1 length : 14.4 m


Beams with L2 length : 15.1m

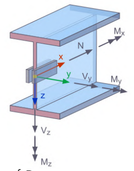

Hinges



Torsional Stiffness for the Beams with L1

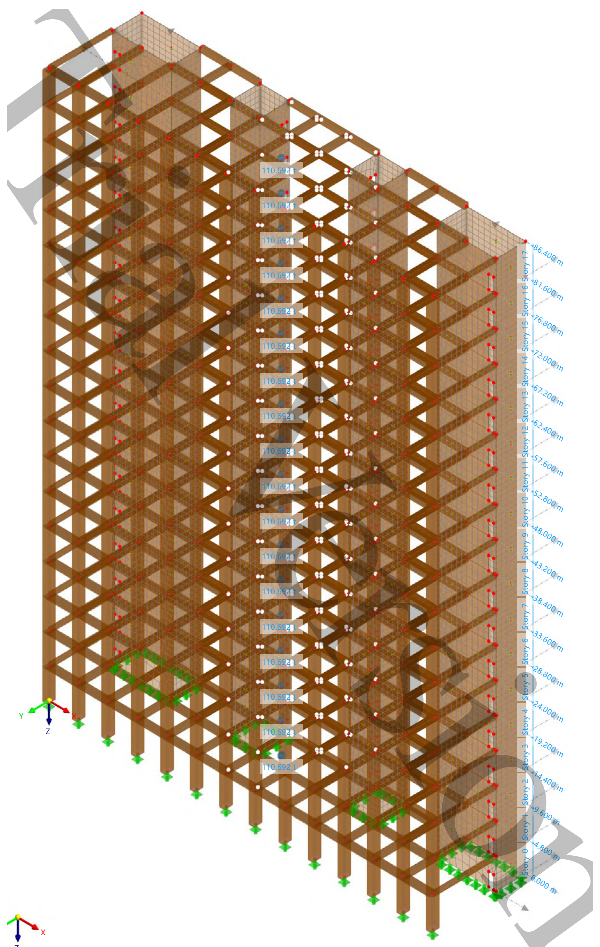


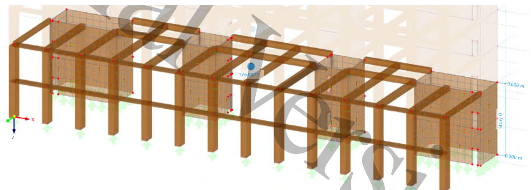
Torsional Stiffness for the Beams with L2

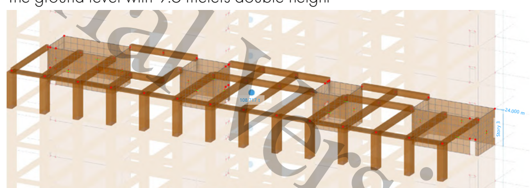

Definition of Directions

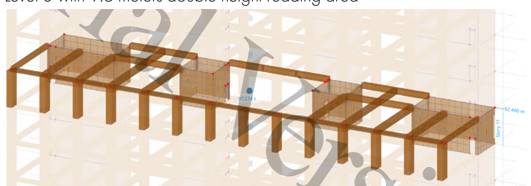
Strucutural Modeling

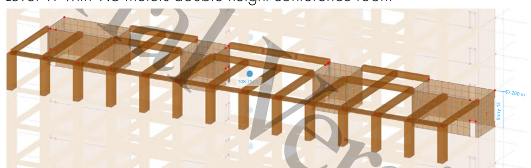
For analysis of the structure, the building is first modeled by simplifying the structure with the regular grid of 4.8 meters x 4.8 meters without considering any special spaces with double height. Then the structure is modified according to the floors with double height.

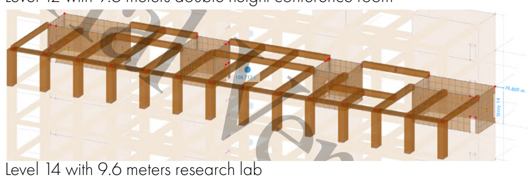

Definition of the floors: 4.8m each floor


The ground level with 9.6 meters double height

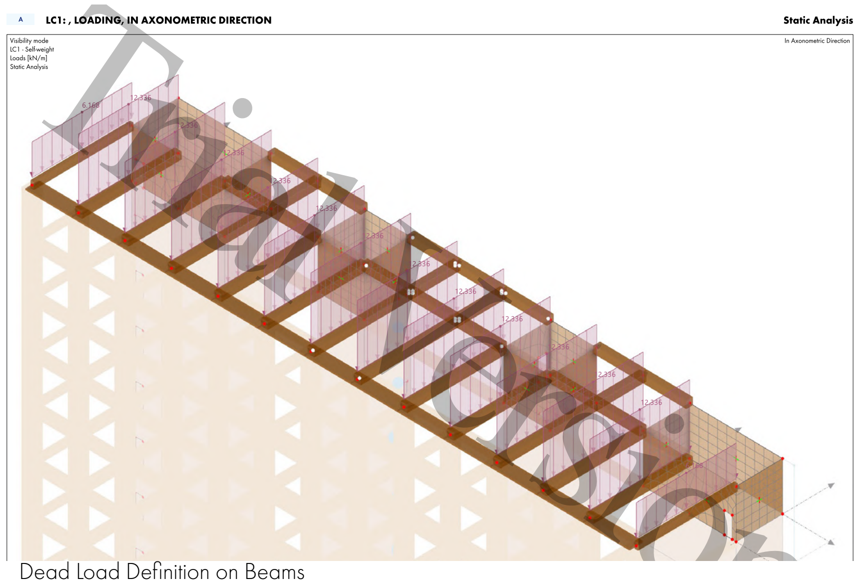

Level 3 with 9.6 meters double height reading area


Level 11 with 9.6 meters double height conference room

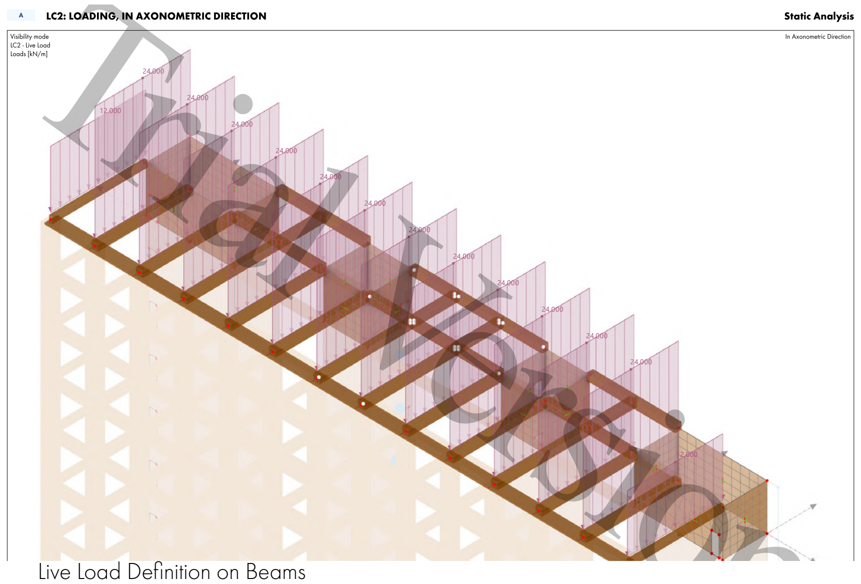

Level 12 with 9.6 meters double height conference room


Level 14 with 9.6 meters research lab

Load Definitions



Dead Load Definition on Beams



Live Load Definition on Beams

In Tena, because of climate conditions, there is not snow load to be considered for the structural analysis. The other lateral load is wind load to apply on the structure, although the wind speed is really low in the city of Tena.

The wind load is calculated by using the data of wind speed from wind intensity rose diagram

$F_w = p_d A$

$= 1/2\, \rho\, v^2 A$

where

F_w = wind force (N)

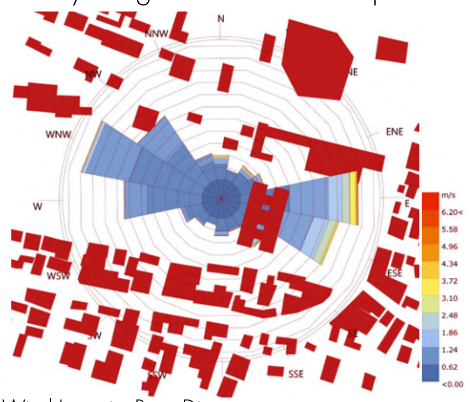
A = surface area (m^2)

p_d = dynamic pressure (Pa)

ρ = density of air (kg/m^3)

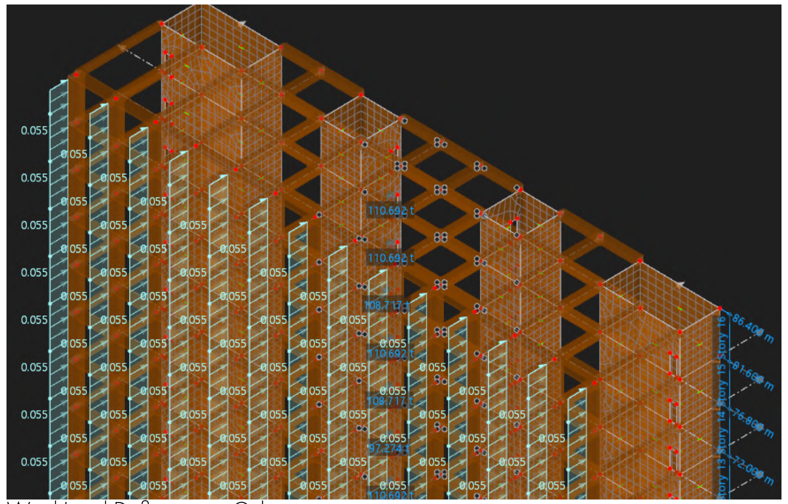
v = wind speed (m/s)

The Formula of Wind load


Wind Intensity Rose Diagram

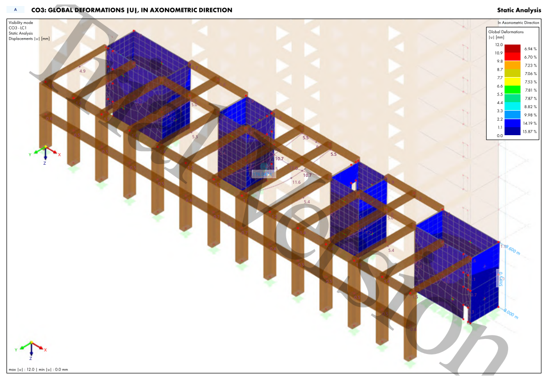
p=1.2 kg/m^3
v= 2m/s
A= 4.8 m x 4.8 m = 23.04 m^2

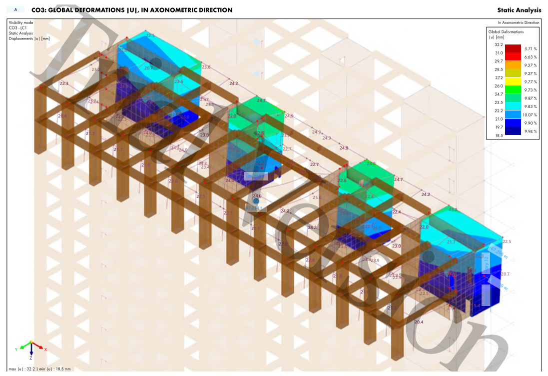
Fw= 55.2 N (55.2 kg.m / s^2)
Fw= 0.0552 kN

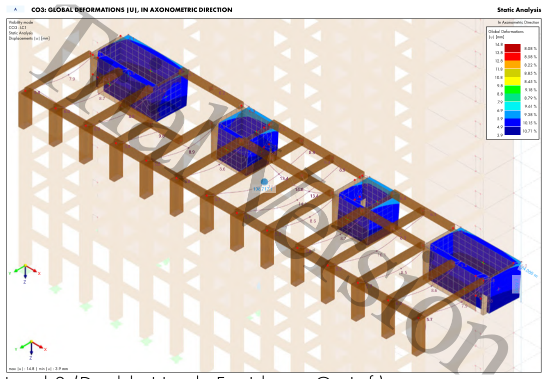


Wind Load Definition on Columns

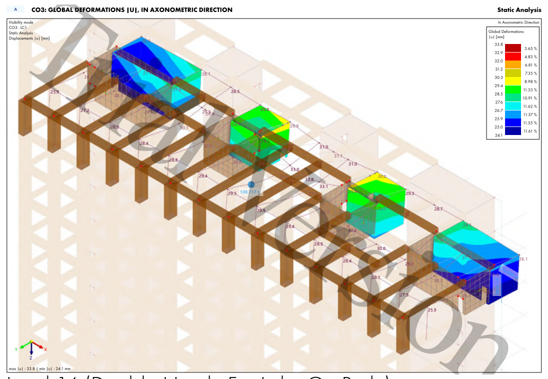
Displacement on Special Spaces at SLS Case 01: Dead Load





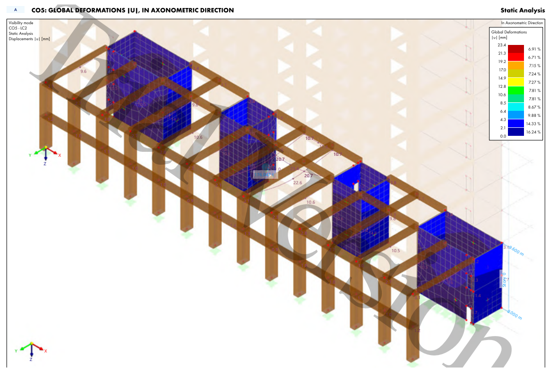


Level 3 (Double Height For Library On Left)

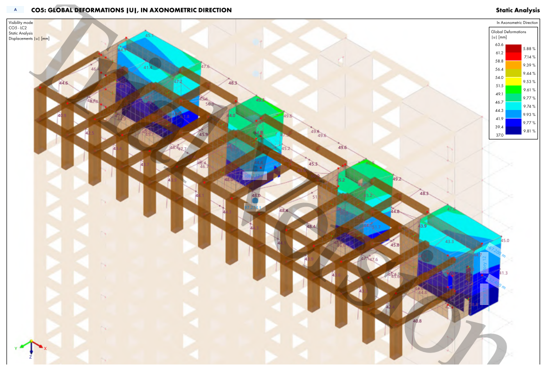


Level 14 (Double Height For Labs On Right)

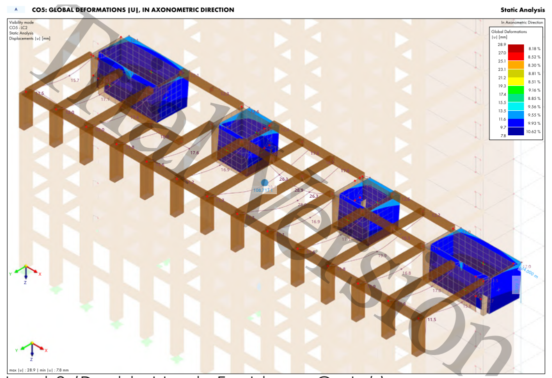
Displacement on Special Spaces at SLS Case 02: Llive Load



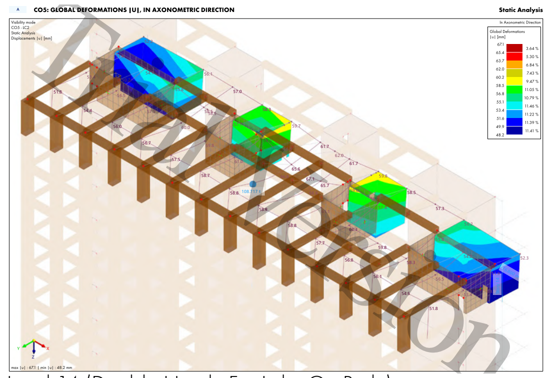
Level 0 (Double Height 9.6m)



Level 11 & 12 (Double Height For Conference Room)

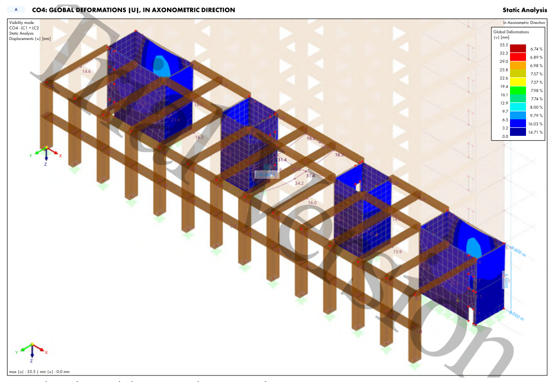


Level 3 (Double Height For Library On Left)

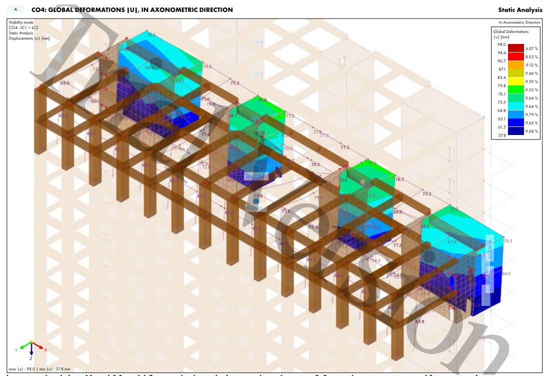


Level 14 (Double Height For Labs On Right)

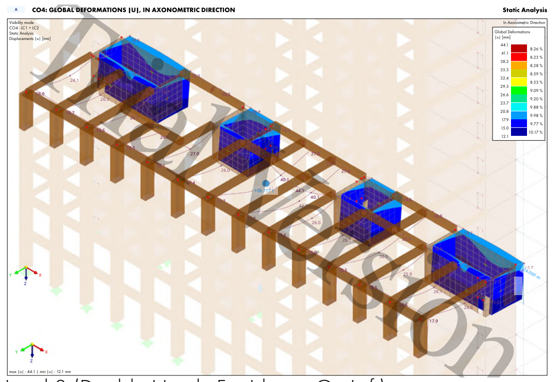
Displacement on Special Spaces at SLS Case 03: Dead Load + Live Load



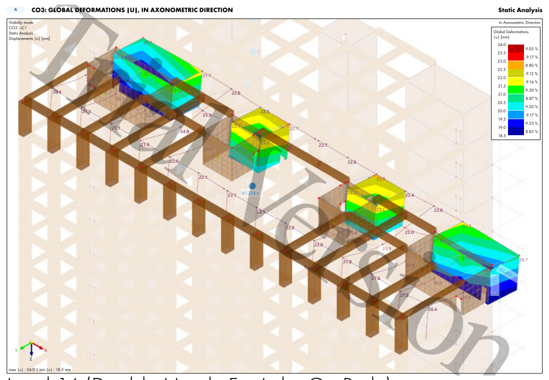
Level 0 (Double Height 9.6m)



Level 11 & 12 (Double Height For Conference Room)



Level 3 (Double Height For Library On Left)

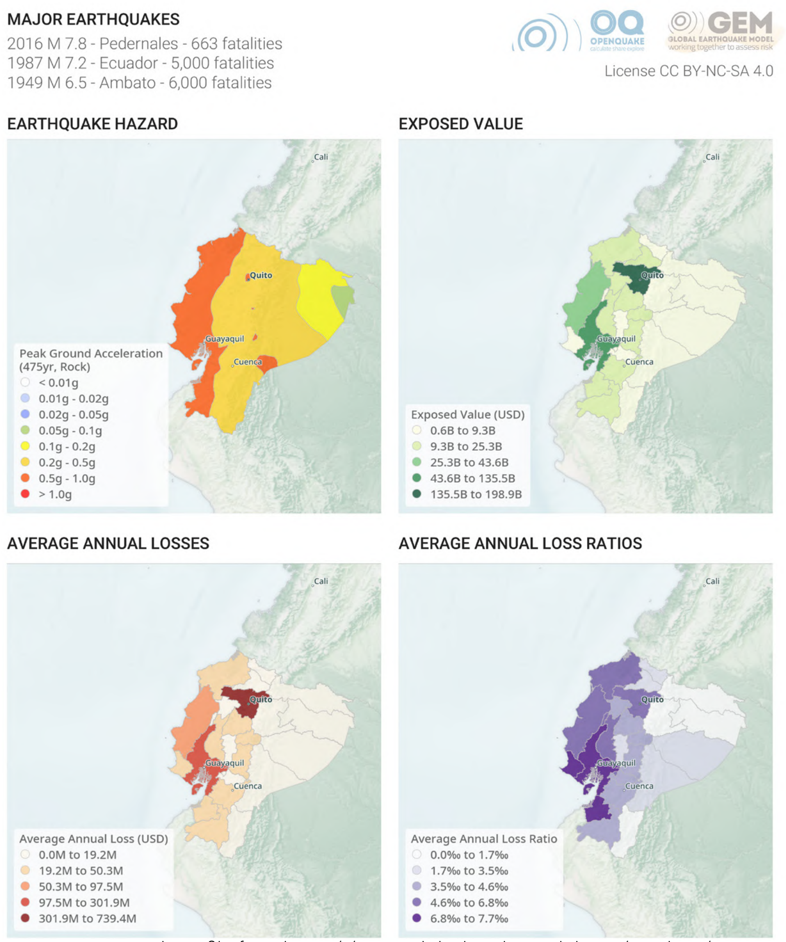


Level 14 (Double Height For Labs On Right)

Earthquake Analysis

Ecuador is located in a seismically active region, particularly along the boundary of the Nazca and South American tectonic plates. The country is prone to earthquakes, and seismic activity is a significant concern. The subduction zone off the coast of Ecuador can generate powerful earthquakes and tsunamis.

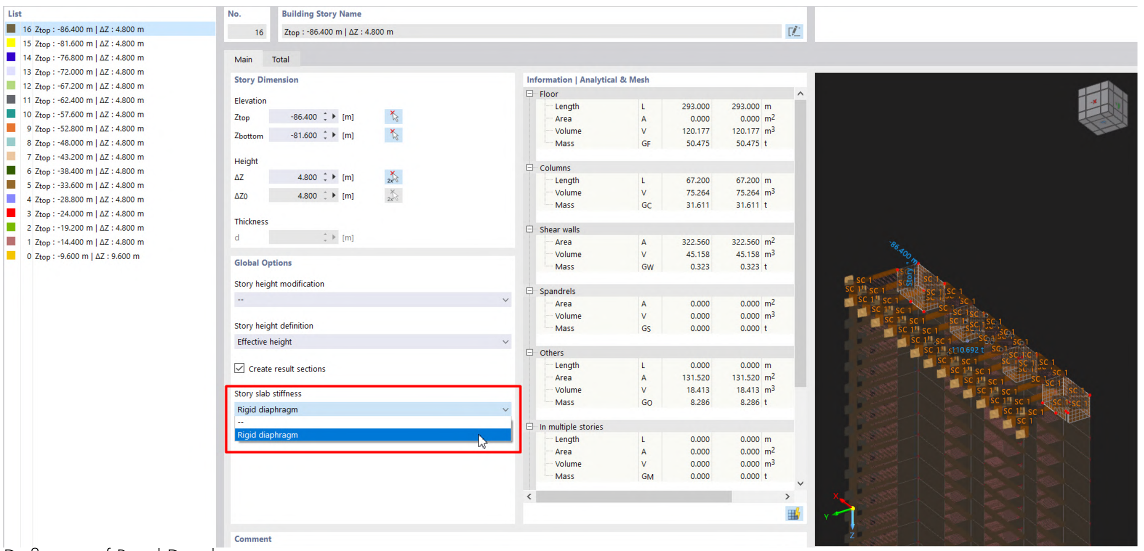
Several historical earthquakes have affected Ecuador, and the region is considered seismically vulnerable. As a result, seismic risk mitigation and earthquake-resistant building practices are essential considerations in the design and construction of structures in Ecuador to enhance resilience to potential seismic events. It's important for residents and authorities to be prepared for seismic activity and to implement measures to reduce the potential impact of earthquakes on both infrastructure and communities.

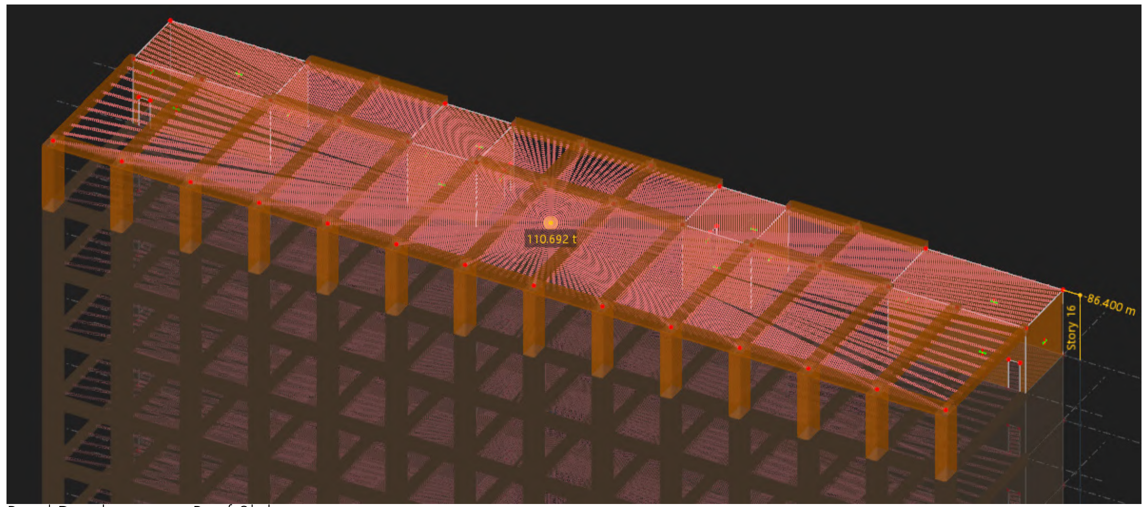


Country-territory seismic risk profile from https://www.globalquakemodel.org/product/seismic-risk-profiles

To analyse earthquake and test the structure, rigid diaphragm is defined first for each storey slabs in order to simplify the assumption where seismic loads are evenly distributed and immediately transmitted through the entire floor and roof. This assumption streamlines analysis by treating the structure as a rigid element, facilitating a simpler design process for the tall building with sufficient stiffness.both infrastructure and communities.

Rigid diaphragm is defined with the help of Building Model add-on which is used to model multi-storey building by defining the height of levels.


Definition of Rigid Diaphragm


Rigid Diaphragm on Roof Slab

In order to calculate the lateral load caused by earthquake, these steps are followed:

1.Calculation of floor areas for
Typical floors
Special floors
Roof
2. Definition of total dead load
3.Calculation of total weight and weight for each floor
4. Calculation of total base shear

All calculations are done based on the Ecuadorian Seismic Law NEC Peligro Sísmico, 2014.

Calculation of Floor Areas

Typical slabs
15.10m x 62.4m - 2(4.8m x 4.8m) -2(9.6m x 4.8m) = 804 m²

Special slabs
Slab 4, Slab 15: 804 m² - (9.6m x 9.6m) = 711.84 m²
Slab 12: 804 m² - (14.4m x 15.1m) = 586.56 m²

Roof
Slab 17: 15.10m x 62.4m = 942.24 m²

Definition of Total Dead Load

1. 804 m² x 2.57kN/m² = 2066.28 kN
2. 711.84 m² x 2.57 kN/ m² = 1829.43 kN
3. 586.56 m² x 2.57 kN/ m² = 1507.46 kN
4. 942.24 m² x 2.57 kN/ m² = 2421.56 kN

13 x 2066.28 kN + 2 x 1829.43 kN + 1507.46 kN + 2421.56 kN = 34449.52 kN

Calculation of Total Weight and Floor Weights

W= Total dead load x 0.85
Wtotal = 34449.52 kN x 0.85 = 29282.1 kN

W_1, W_2, W_3, W_5, W_6, W_7, W_8, W_9, W_{10}, W_{11}, W_{13}, W_{14}, W_{16} (Typical floors)=
2066.28 kN x 0.85 = 1756.338 kN

W_4, W_{15} =
1829.43 kN x 0.85 = 1555.02 kN

W_{12}=
1507.46 kN x 0.85 = 1281.34 kN

W_{17} (Roof) =
2421.56 kN x 0.85 = 2058.326 kN

LEVEL	hi	Hi	Wi	Hi(k=1.60)	$Wi(Hi)^k$(k=1.60)	αi	Fi
1	9.6	9.6	1756.34	37.29	65500.19	0.0041	23.56
2	4.8	14.4	1756.34	71.35	125310.82	0.0078	45.07
3	4.8	19.2	1756.34	113.05	198559.45	0.0123	71.41
4	4.8	24	1555.02	161.56	251231.43	0.0156	90.35
5	4.8	28.8	1756.34	216.29	379871.38	0.0235	136.62
6	4.8	33.6	1756.34	276.79	486128.90	0.0301	174.83
7	4.8	38.4	1756.34	342.71	601919.69	0.0373	216.47
8	4.8	43.2	1756.34	413.78	726745.89	0.0451	261.37
9	4.8	48	1756.34	489.76	860190.36	0.0533	309.36
10	4.8	52.8	1756.34	570.45	1001896.52	0.0621	360.32
11	4.8	57.6	1756.34	655.66	1151554.68	0.0714	414.14
12	4.8	62.4	1281.34	745.24	954904.03	0.0592	343.42
13	4.8	67.2	1756.34	839.06	1473667.24	0.0914	529.99
14	4.8	72	1756.34	936.98	1645661.79	0.1020	591.84
15	4.8	76.8	1555.02	1038.91	1615525.92	0.1001	581.01
16	4.8	81.6	1756.34	1144.73	2010540.59	0.1246	723.07
17	4.8	86.4	2058.33	1254.36	2581885.58	0.1601	928.55
					$\sum Wi(Hi)^k$(k=1.6)= 16131094.48	∑αi= 1	
				V total shear base= 5801.37			

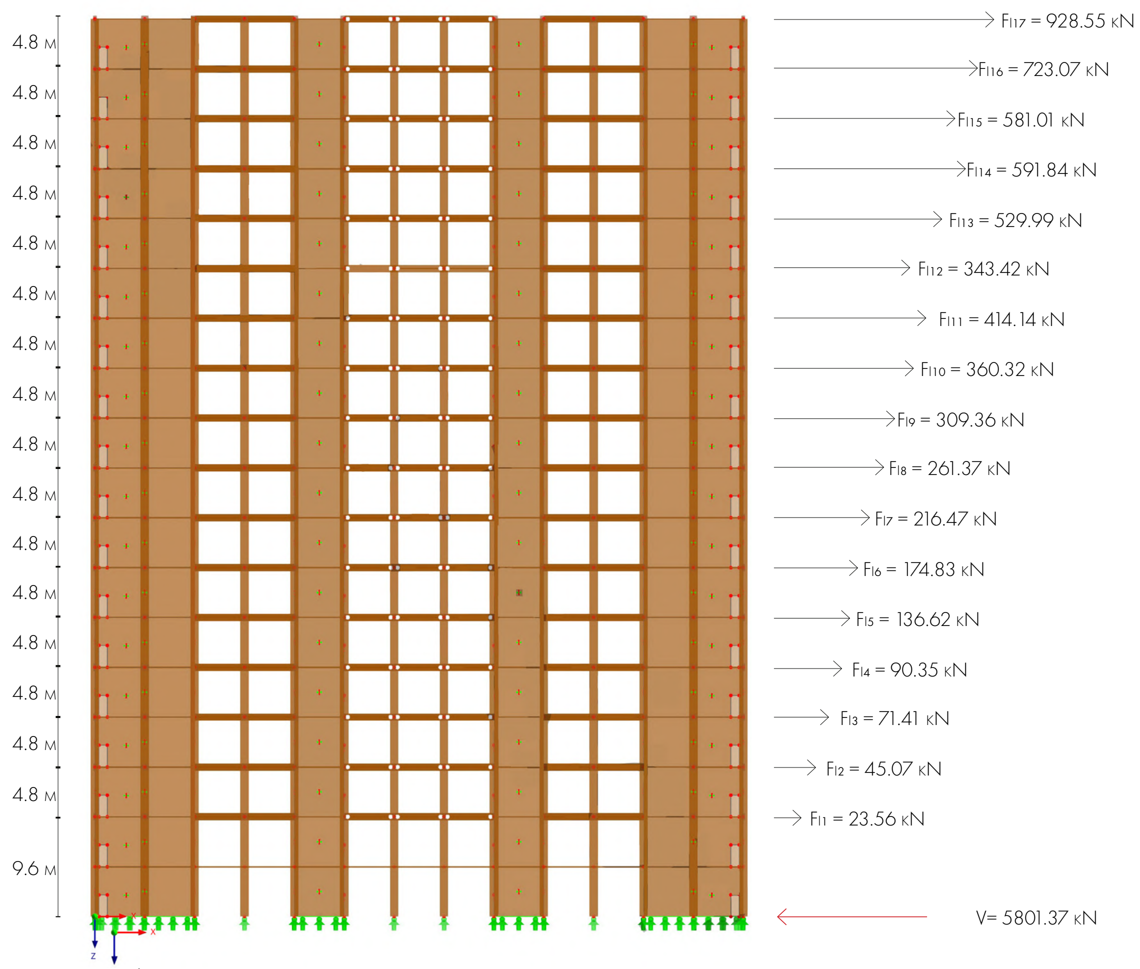
Lateral Forces Calculation for Each Level of Slabs

Calculation of Total Base Shear

V= I x Sa (Ta) x Wtotal / R x ϕp x ϕe

I = 1.3
Sa(Ta) = 0.381g
Wtotal = 29282.1 kN
R = 2.5
ϕp = 1.0
ϕe = 1.0

V= 5801.37 kN



Equivalent Static Force on Structure

Check on Drift

The displacement under the lateral forces is analysed to check the drift.

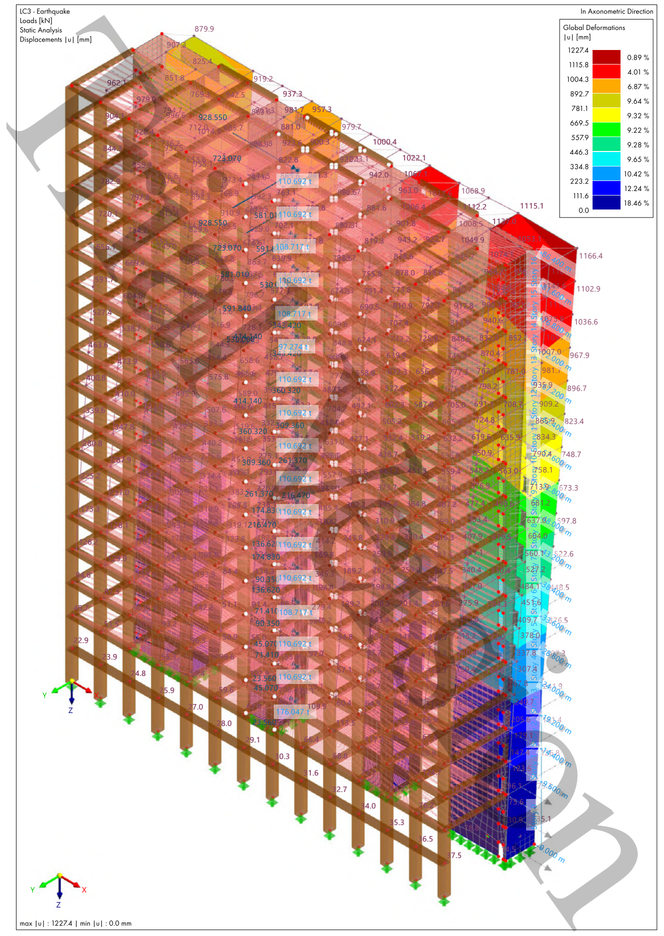
ui < 0.02 x hi
ui = displacement at 'i' floor
hi = height of 'i' floor from ground level

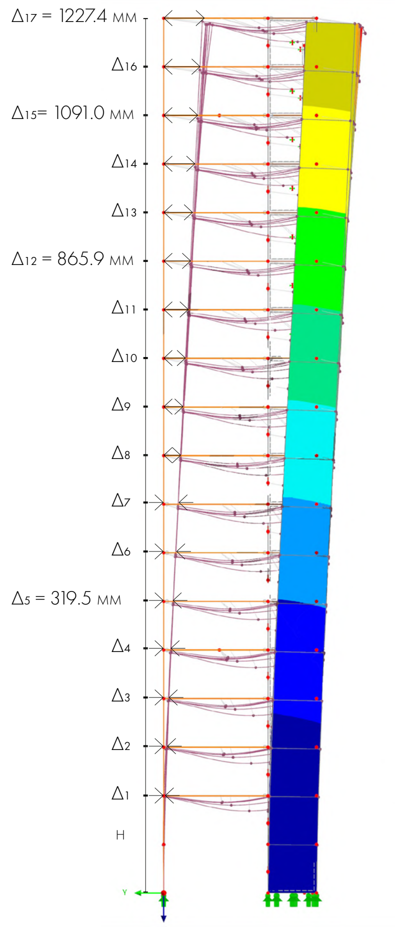
Slab 17 (Roof)
u17 = 1227.4 mm   h= 86400 mm
1227.4 mm < 0.02 x 86400 mm
1227.4 < 1728 mm

Slab 15
u15 = 1091.0 mm   h= 76800 mm
1091.0 mm < 0.02 x 76800 mm
1091.0 mm < 1536 mm

Slab 12
u12 = 865.9 mm   h= 62400 mm
865.9 mm < 0.02 x 62400 mm
865.9 mm < 1248 mm

Slab 5 (Typical Slab)
u5 = 319.5 mm   h= 28800 mm
319.5 mm   < 0.02 x 28800 mm
319.5 mm < 576 mm


Displacement Under The Lateral Forces Of Earthquake



Displacement of Special Floors

Load Combinations

The difference between Ecuadorian and European Code for load combinations:

(NEC Peligro Sísmico, 2014)

$V = \sum_{i=1}^{n} F_i$; $V_x = \sum_{i=x}^{n} F_i$; $F_x = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} V$

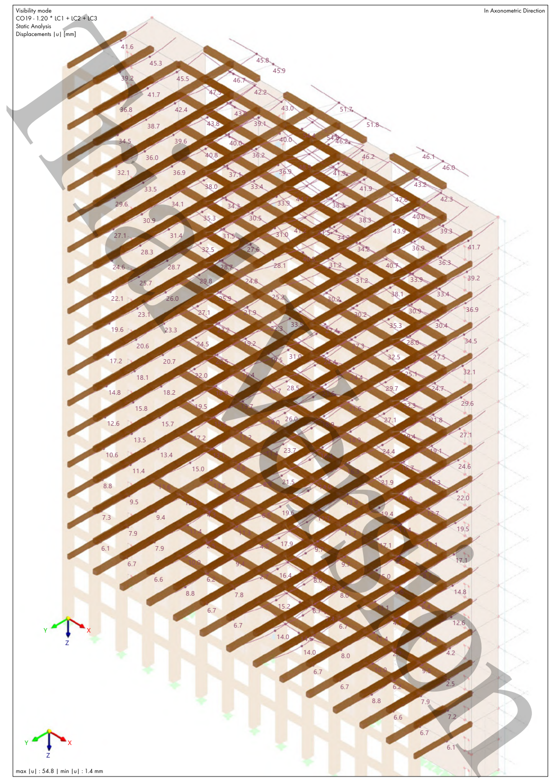
1.2 DL + 1.6 LL + 0.5 Wind
1.2 DL + 1.0 Wind + 1.0 LL

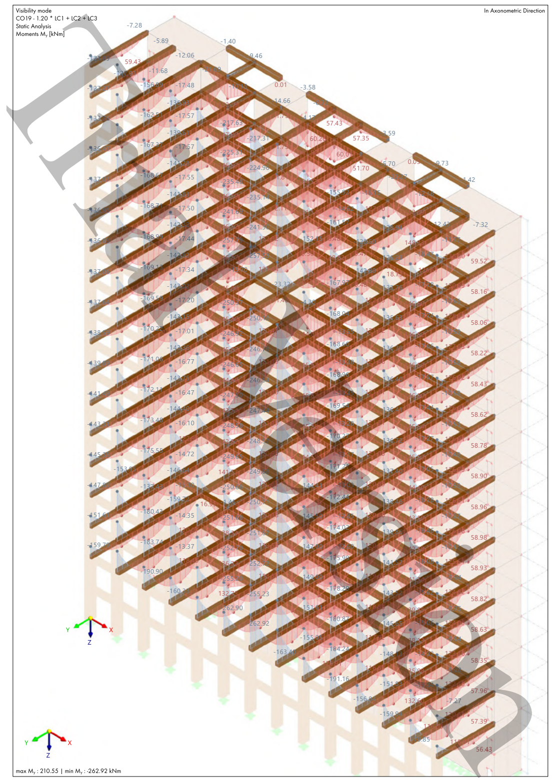
EN 1998-1 :2004 (E)

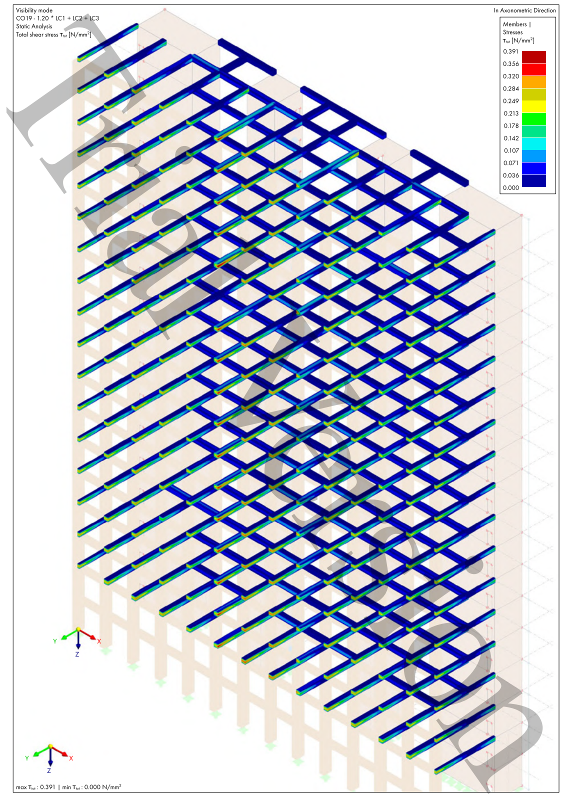
$F_b = S_d(T_1) \cdot m \cdot \lambda$

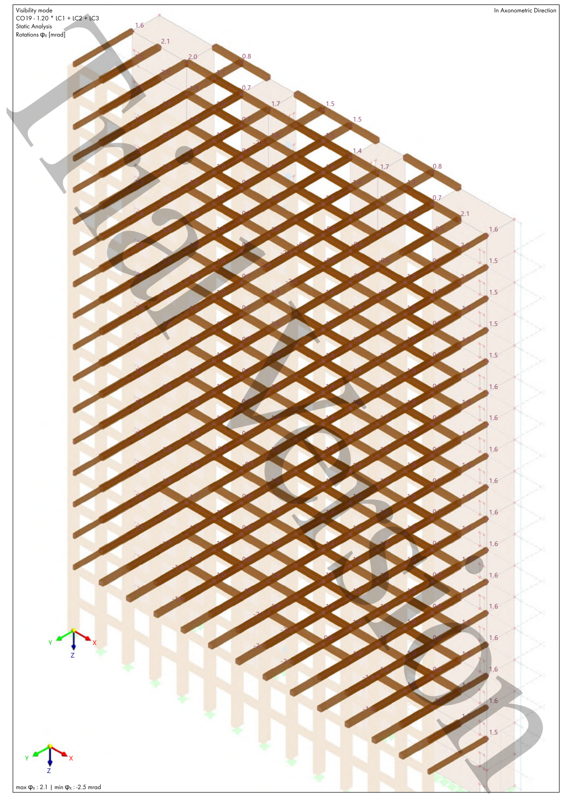
1.35 DL + 1.5 LL
1.35DL + 0 .75 Wind + 1.5 LL

Results of ULS 1.2 DL + 1.0 Wind + 1.0 LL

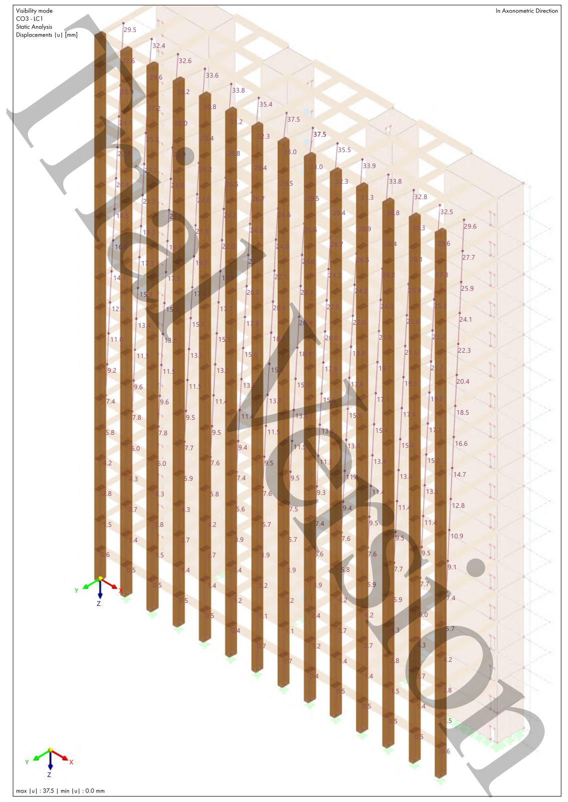

Displacement On Beams


Bending Moment On Beams

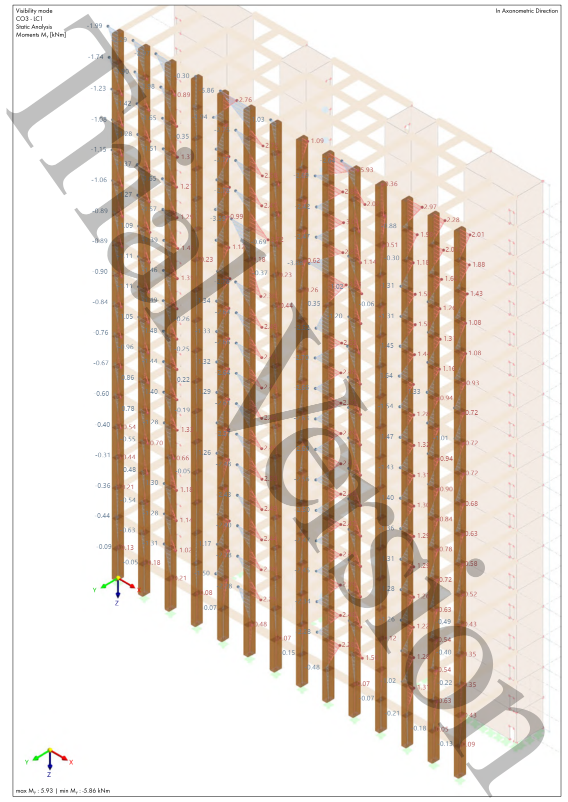

Shear Stress On Beams


Torsion On Beams

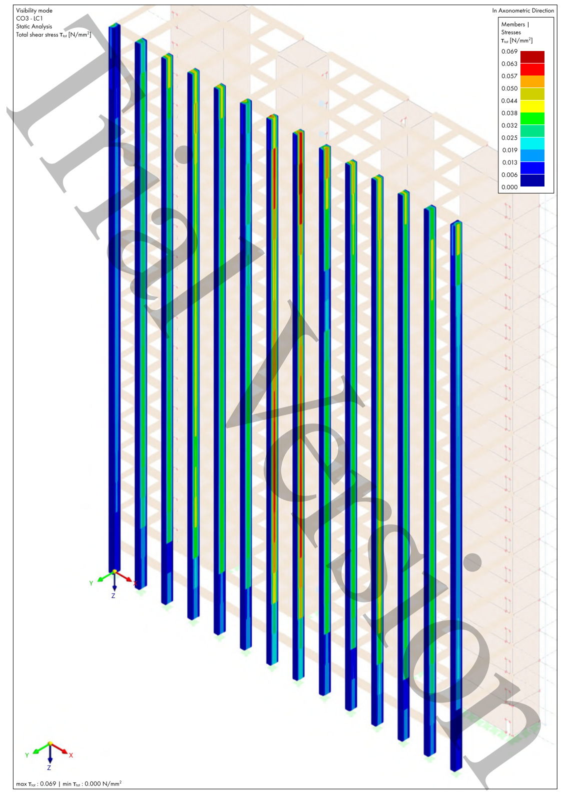
Results of SLS



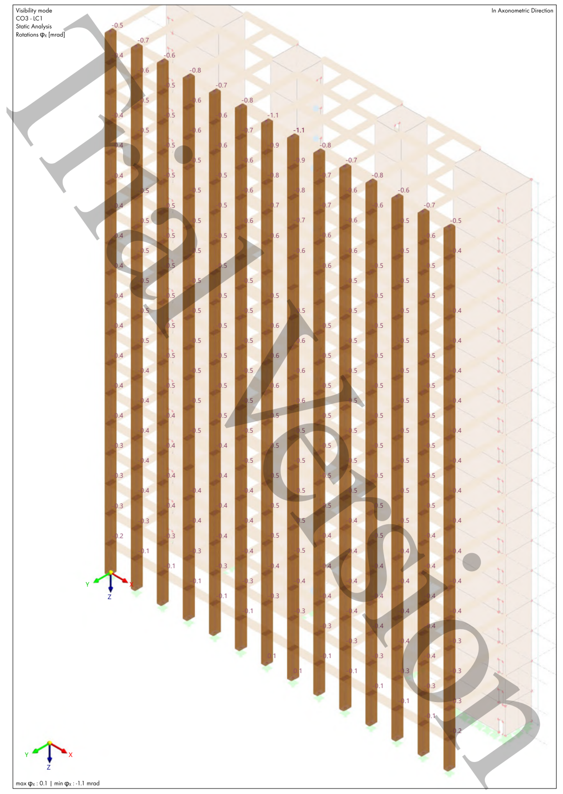
Displacement On Beams



Bending Moment On Beams



Shear Stress On Beams



Torsion On Beams

Automatic Checks

Member	27,30	x: 10.300	DS1	CO2	0.783 ✓
Member	10,48	x: 10.300	DS1	CO2	0.707 ✓
Member	21,36	x: 10.300	DS1	CO3	0.618 ✓
Member	53,55	x: 4.200	DS1	CO2	0.456 ✓
Member	13,45	x: 4.682	DS2	CO8	0.366 ✓
Member	10,48	x: 1.873	DS1	CO2	0.295 ✓
Member	21,36	x: 10.300	DS1	CO1	0.285 ✓
Member	28,31	x: 4.800	DS1	CO2	0.267 ✓
Member	25,34	x: 4.800	DS1	CO2	0.204 ✓
Member	28,31	x: 0.000	DS1	CO1	0.166 ✓
Member	28,31	x: 4.800	DS1	CO1	0.166 ✓
Member	28,31	x: 4.800	DS1	CO2	0.147 ✓
Member	1036,1042	x: 1.800	DS1	CO1	0.121 ✓
Member	24,33	x: 0.000	DS1	CO2	0.112 ✓
Member	1018,1057	x: 2.400	DS1	CO1	0.054 ✓
Member	1017,1055	x: 5.618	DS2	CO6	0.031 ✓
Member	913,922	x: 8.427	DS1	CO1	0.012 ✓
Member	972,981	x: 0.000	DS1	CO1	0.003 ✓
Member	213,272,331,384,39...	x: 0.000	DS1	CO1	0.000 ✓

Conclusion

Finally, all the structural elements used for the design of the building are able to support the different loads and keep the building's stability. The results were obtained after different trials in order to achieve as light structure as possible and to solve the initial architectural concept with an optimal structural system. The calculations allowed us to comprehend if the actions present in the different structural elements are lower than the resistances.

An important consideration was the seismic analysis since the project is located in a dangerous area for seismic hazard. In accordance to the Ecuadorian law, the lateral loads were obtained and the evaluation of the drift shows that the building can stand the possible earthquake forces.

In conclusion, this analysis is absolutely important in order to achieve an equilibrium between architectural, material and structural decisions, using the structural design in such a way that the concepts, ideas and architectonic considerations are kept and emphasized.

06 BUILDING INFORMATION MODELING

GENERAL SCHEME

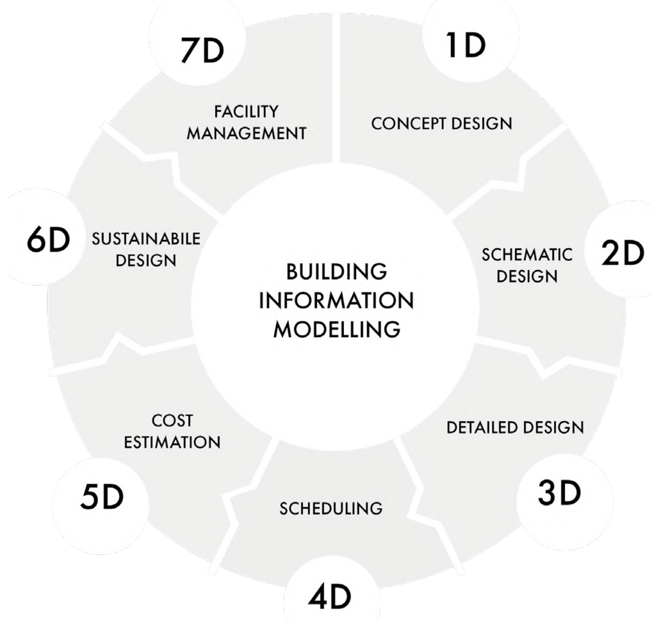
What Is Bim ?

Building Information Modelling (BIM) is a digital working method that uses virtual digital 3D models as the basis for planning, designing, constructing, managing and operating projects. The 3D models contain more than just graphical information, allowing properties to be attached to each building component. In effect, the models become a central element of all relevant project information that can be shared amongst the entire project team.[1] BIM allows for an optimised design process decision making and easier implementation of changes through the process.

Usually the construction process has been fragmented as it involves various parties working on different elements separately. BIM overcomes this flaw by allowing all parties to work together on the project in the same time and everyone can access the most up-to-date information in order to ensure the easy flow of the management and construction.

What Are The Bim Dimensions ?

BIM Level of Development (LOD) is an industry standard which represents how the 3D geometry of a building can achieve different levels of refinement. It shows how much information is modelled in the 3D file and what data is accessible. It is used to communicate to the content and reliability of BIMs at various stages of the design and construction process.



Lod100 Concept Design
Pre-design stage, the model consists of 2D symbols and the masses to signify an element's existence

Lod200 Schematic Design
The elements are partially defined by outlining their approximate quantity, size, shape, and location

Lod300 Detailed Design
The elements are defined with exact dimensions and their relative positions bolstering precision

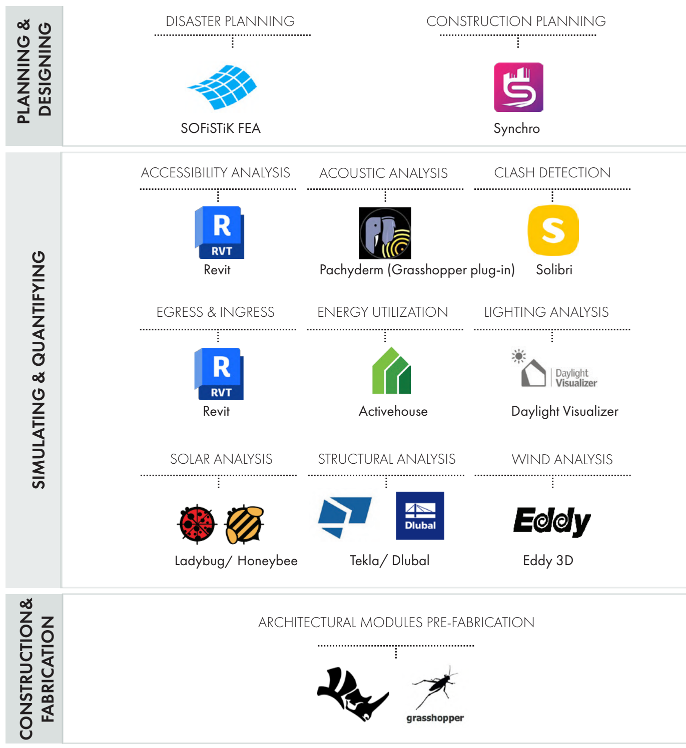
WORKFLOW AND BIM ENVIRONMENT

Lod300 Detailed Design
The elements are defined with exact dimensions and their relative positions bolstering precision

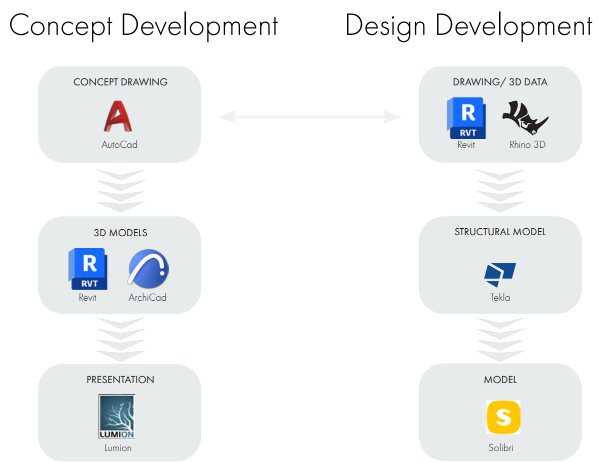
Lod400 Fabrication And Assembly
Model elements are modelled as specific assemblies, with complete fabrication, assembly, and detailing information in addition to precise quantity, size, shape, location and orientation. Non-geometric information to the model elements can also be attached;

Lod500 As-Built
Elements are modelled as constructed assemblies for maintenance and operations. Representation of actual and accurate in size, shape, location, quantity, and orientation, non-geometric information is attached to modelled elements;

Tools



Model Set Up And Workflow

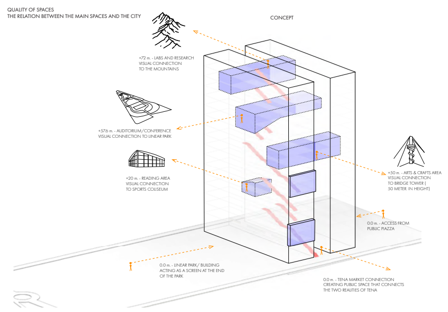


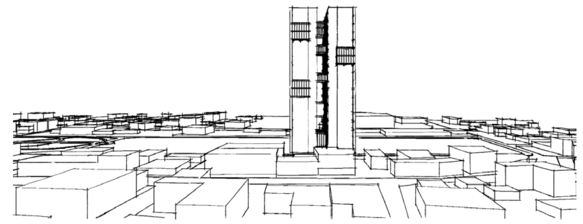
BIM USES DOMAINS		OVERALL BIM MODEL USES APPROPRIATE FOR THE PROJECTS	BIM MODEL USES TO BE EXPLORED
Capturing & Representing BIMe Topic under Operation Competency: Using software tools and specialized equipment to capture and represent physical spaces and environments	Operation Competency	2010 2D Documentation 2020 3D Detailing 2080 Surveying 2090 Visual Documentation	2010 2D Documentation 2020 3D Detailing 2080 Surveying 2090 Visual Documentation
Planning & Designing BIMe Topic under Operation Competency: Using software tools for conceptualization, planning and design	Operation Competency	3010 Conceptualization 3050 Disaster Planning 3060 Lean Process Analysis 3110 Urban Planning 3020 Construction Planning	3010 Conceptualization 3050 Disaster Planning 3110 Urban Planning 3020 Construction Planning
Simulating& Quantifying BIMe Topic under Operation Competency: Using software tools to conduct various types of model-based simulations and estimations	Operation Competency	4010 Accessibility Analysis 4020 Acoustic Analysis 4040 Clash Detection 4080 Egress & Ingress 4070 Cost Estimation 4090 Energy Utilization 4100 Finite Elements Analysis 4120 Lighting Analysis 4140 Reflectivity Analysis 4190 Solar Analysis 4210 Structural Analysis 4229 Sustainability Analysis 4250 Life-Cycle Assessment 4260 Wind Studies	4010 Accessibility Analysis 4020 Acoustic Analysis 4040 Clash Detection 4080 Egress & Ingress 4070 Cost Estimation 4090 Energy Utilization 4100 Finite ELements Analysis 4120 Lighting Analysis 4140 Reflectivity Analysis 4190 Solar Analysis 4210 Structural Analysis 4229 Sustainability Analysis 4250 Life-Cycle Assessment 4260 Wind Studies
Construction & Fabrication BIMe Topic under Operation Competency: Using BIModels for the specific purposes of construction and fabrication	Operation Competency	5020 Architectural Modules Pre-fabrication 5050 Construction Logistics 5055 Construction Waste Management 5080 Site Set-Outs	5020 Architectural Modules Pre-fabrication 5050 Construction Logistics 5055 Construction Waste Management 5080 Site Set-Outs

BIM MODEL USES TO BE EXPLORED IN DETAIL	DEFINITIONS AND KEY PERFORMANCE` INDICATORS
3050 Disaster Planning	3050 -A Model Use where 3D models are used to simulate a building fire, an explosion, an earthquake or similar. The behavior of building systems, individuals and crowds are included within this term. ***KPI - the resistance of the structure and building in case of en exogenous activities such as earthquakes since Ecuador is a seismic active country and therefore the structure and building should be tested for earthquakes.***
3020 Construction Planning	3020 - BIModel is used to plan, organise or test construction activities against constraints (e.g. time, human resources and materials). The scheduling of the construction process shall ensure the efficiency and cost-effectiveness during construction.
4010 Accessibility Analysis	4010 - 3D models are used to assess whether a Facility allows direct (unassisted) or indirect access for people with disabilities, or special needs such as vision, hearing and mobility impairment. ***KPI - Ensuring the barrier free accessibility of the tower and the auditorium;***
4020 Acoustic Analysis	4020 - 3D models are used to conduct sound studies, test the placement of sound equipment, simulate sound insulation/attenuation, and inform the choice of materials used within a space. ***KPI - ensuring the acoustic quality of the auditorium and the conference room.***
4040 Clash Detection	4040 - Use of 3D Models to coordinate different disciplines and to identify/resolve possible clashes between virtual elements prior to actual construction or fabrication. ***KPI - Checking the 3D model for clashes with the HVAC systems and plumbing.***
4080 Egress & Ingress	4080 - 3D models are used to simulate individual/crowd behaviour within a Facility, either during normal operations or during emergency situations. ***KPI - Improve circulation and access to spaces within the tower.***
4090 Energy Utilization	4090 - A metric measuring how and how-much a Facility consumes energy. ***KPI - ensuring a high-performance building based on material choices and system atomization.***
4120 Lighting Analysis	4120 - 3D models are used to simulate natural and artificial lighting levels. This Model Use is a form of Building Performance analysis. ***KPI - ensuring a high-performance building, optimizing day lighting and lighting conditions in the library and co-working spaces.***
4140 Reflectivity Analysis	4140 - 3D models are used to simulate the impact (angle and intensity) of sunlight reflected of building surfaces. ***KPI - reduced reflectivity and light comfort.***
4190 Solar Analysis	4190 - 3D models are used to conduct shadow studies, simulate solar radiance on building envelops, and analyses the effect of building location/shape on solar heat loads. ***KPI - ensuring a high-performance building, optimizing day lighting, available solar radiation and facade design.***
4210 Structural Analysis	4210 - 3D models are used to analyses the behaviour of the structural system. Structural analysis typically includes the study of the effects of static/dynamic loads on buildings. ***KPI - building design can be subsequently optimized.***
4220 Sustainability Analysis	4220 - 3D models are used to calculate the environmental impact of a new construction project or an existing Facility. These calculations may include Carbon Footprint, Life Cycle Assessment, Embodied Energy and other sustainability metrics. ***KPI - Improving the building performance.***
4260 Wind Studies	4260 - 3D models are used to simulate the effects of wind on structures. The simulation is intended to inform the design process by identifying optimal orientations and shapes. ***KPI- optimizing building shape and identifying wind corridors which effect could be reduced with the design of vegetations and building shape.***

Process And Tools Identification

RESEARCH AND DATA ANALYSIS



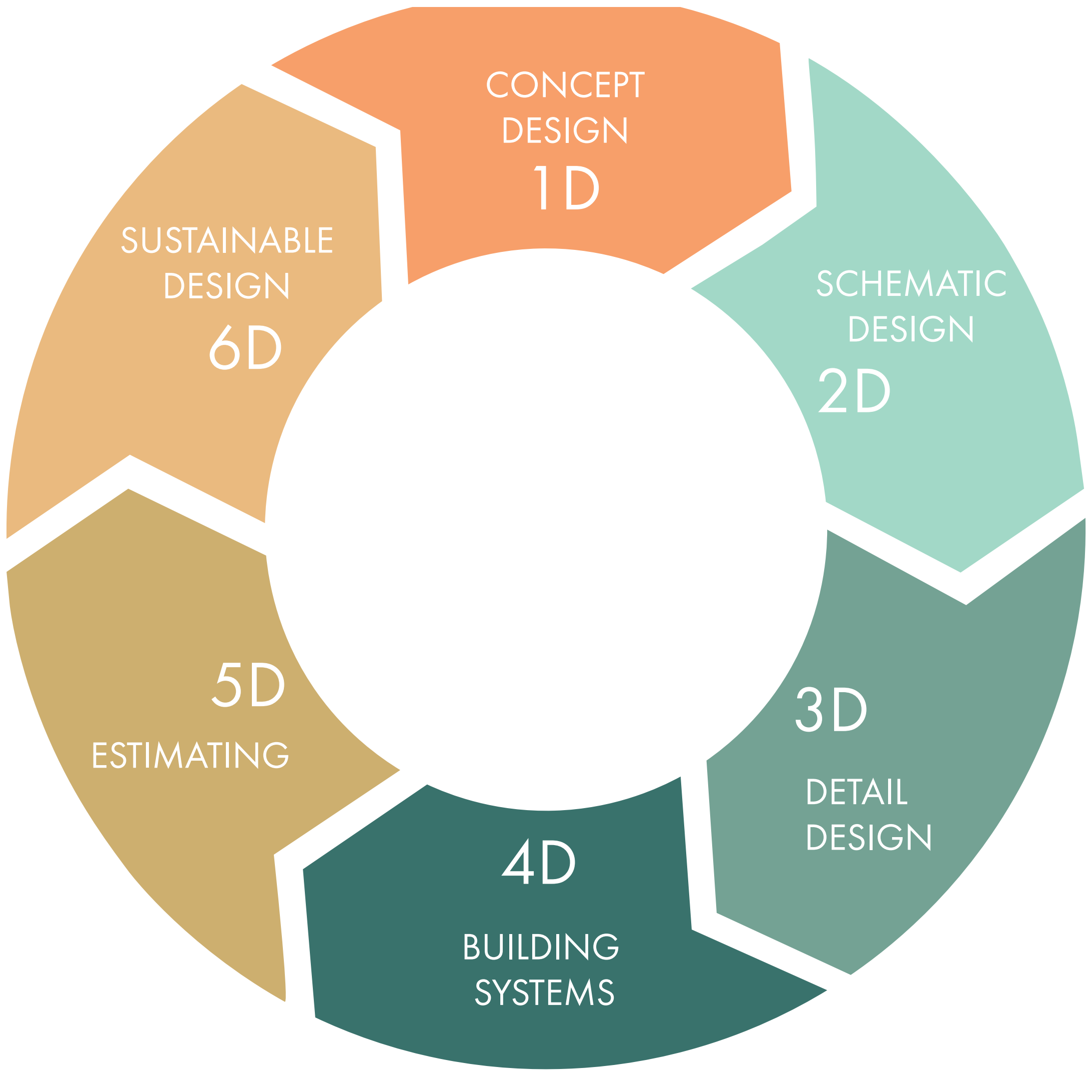


INITIAL DRAWINGS

Ladybug/ Honeybee

Snail (Grasshopper plug-in)

TESTING



Category	Steel	Timber	Benchmark
Cost	£ 14,092,389.60	£ 9,972,440.02	£ 113,000,000.00
Time	408	172	426
Sustainability	2	6	5
Amount of Material	4854.959367	9065.8	2600
MEP Savings	100.00	200.00	300.00

Revit

Excel

COST ESTIMATION

Revit

Daylight Visualizer

grasshopper

DETAILED DESIGN

Tekla/ Dlubal

STRUCTURE DESIGN

Solibri

STRUCTURE + MEP

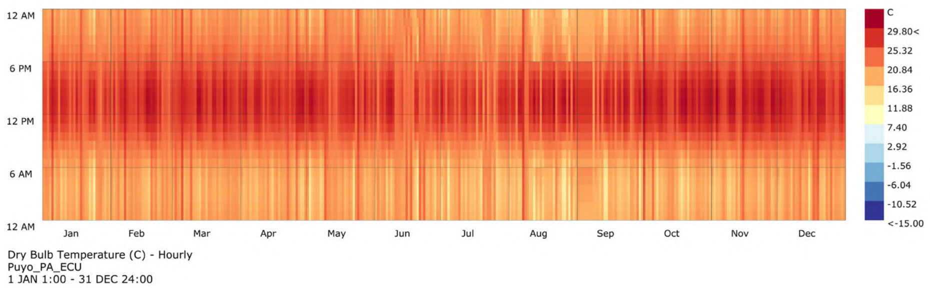
Synchro

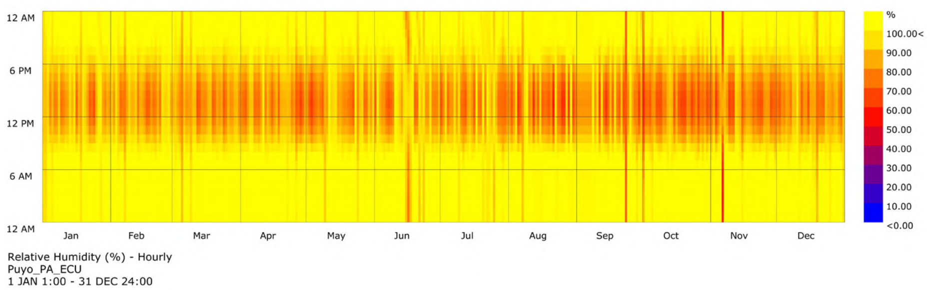
PROJECT MANAGEMENT

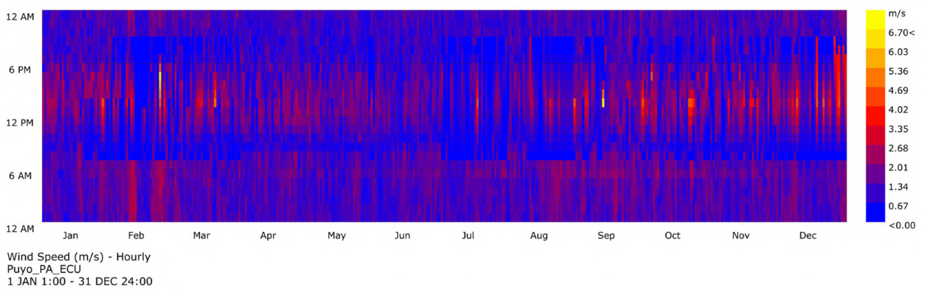
Climate Conditions

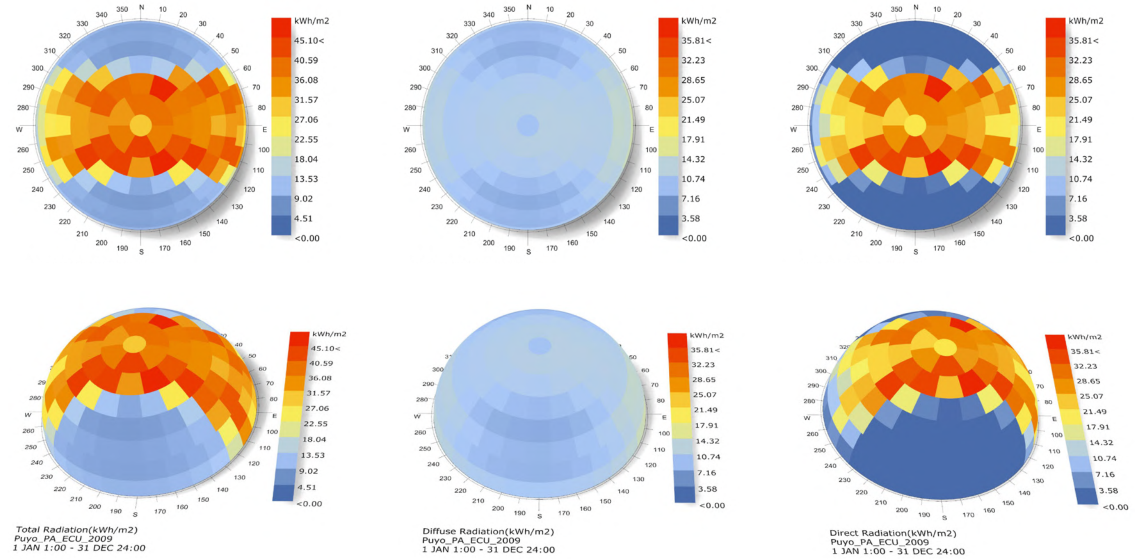
	January	February	March	April	May	June	July	August	September	October	November	December
Average Temperature C°	21.9	22	22	22	21.6	20.9	20.6	21.2	21.8	22.1	22	21.9
Minimum Temperature C°	18.3	18.4	18.5	18.6	18.4	17.6	17.1	16.9	17.3	18.1	18.3	18.3
Maximum Temperature C°	25.4	25.7	25.5	25.4	24.8	20.9	24	25.1	26	25.9	25.5	25.4
Percipitation (mm)	265	298	361	344	390	415	388	277	228	255	308	303
Humidity (%)	83%	83%	84%	84%	85%	85%	84%	81%	80%	82%	85%	85%
Rainy days (days)	18	17	21	20	20	20	20	17	17	19	20	20
Hours of sun (h.)	8.1	8.1	7.9	7.8	7.2	7.0	7.3	8.6	8.9	8.5	7.8	7.6

The Amazon region of Ecuador is usually hot and humid all year round, with temperatures ranging from 26 to 35. The dry season runs from December to March and is usually cooler than the wet season. The Ecuadorian Amazon is located right on the equator, and so while the dry season may be slightly drier than the wet season, with some rivers drying up, the forests actually never completely dry out during this season and rain showers often still occur. As a result, the type of jungle in Ecuador is very specific to the region and consists of almost entirely moist-dependent animals and plant life. The warmer rainy season in Ecuador usually starts in March and finishes in July/August time.





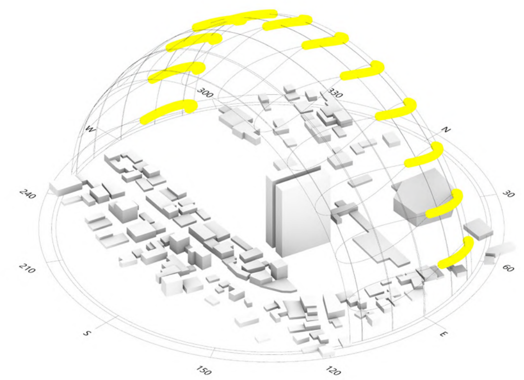




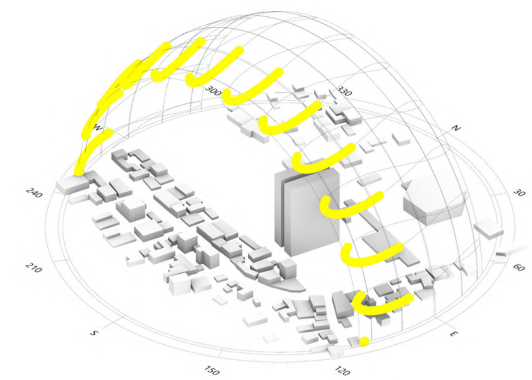
Sky Dome Matrix Of Radiation

Sun Path Analysis

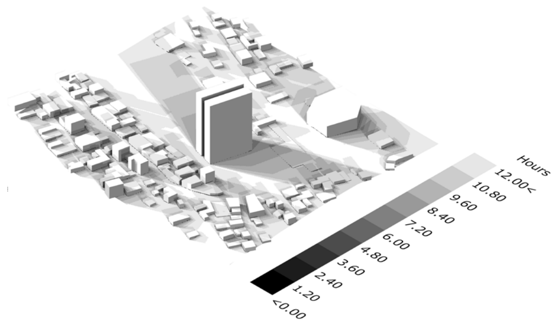
The Amazon region of Ecuador is usually hot and humid all year round, with temperatures ranging from 26 to 35. The dry season runs from December to March and is usually cooler than the wet season. The Ecuadorian Amazon is located right on the equator, and so while the dry season may be slightly drier than the wet season, with some rivers drying up, the forests actually never completely dry out during this season and rain showers often still occur. As a result, the type of jungle in Ecuador is very specific to the region and consists of almost entirely moist-dependent animals and plant life. The warmer rainy season in Ecuador usually starts in March and finishes in July/August time.



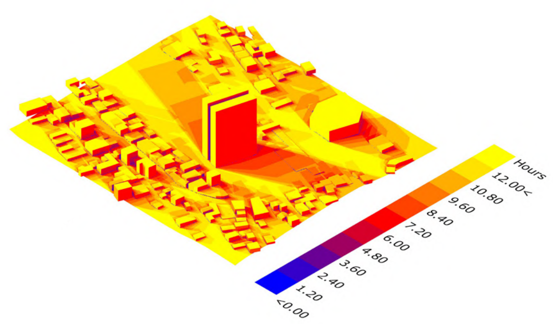
Sunpath Summer Analysis



Sunpath Winter Analysis



Shadow Analysis

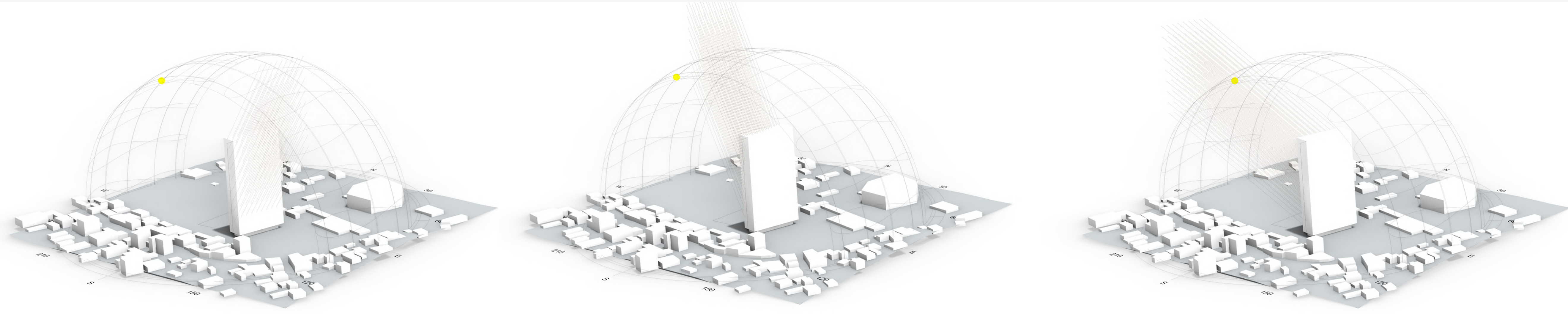


Sunlight Hours Analysis

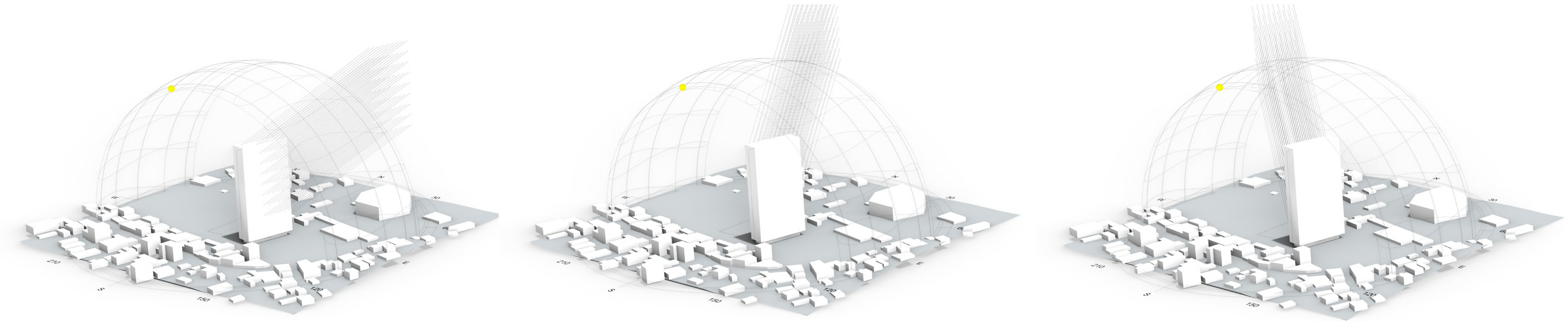
Ray Trace Analysis

15:00

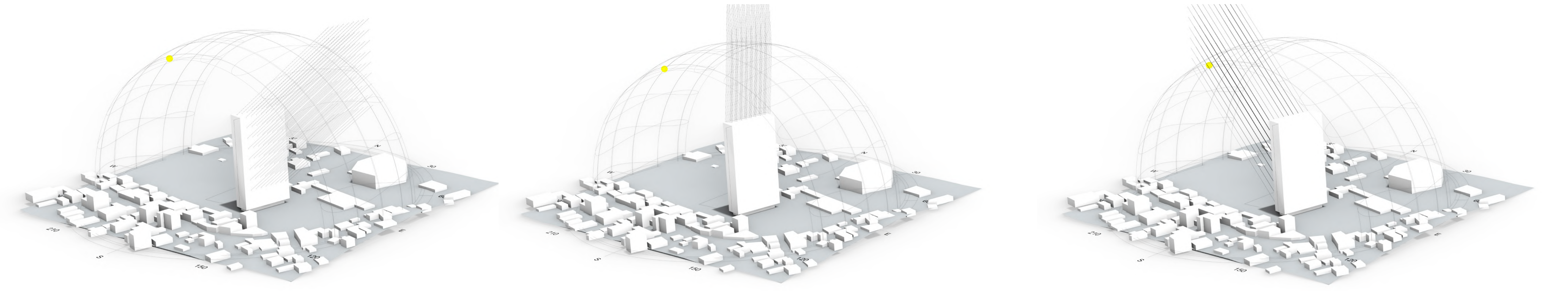
21ST DECEMBER



21ST JUNE

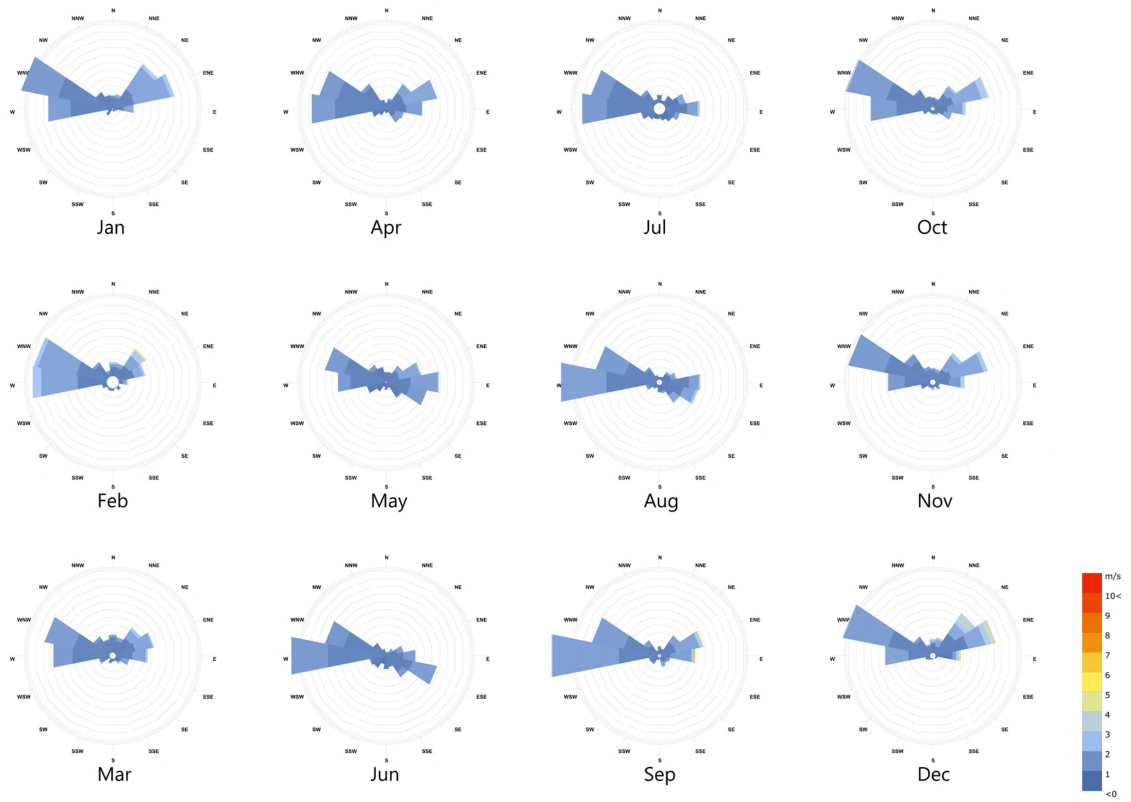


20TH MARCH

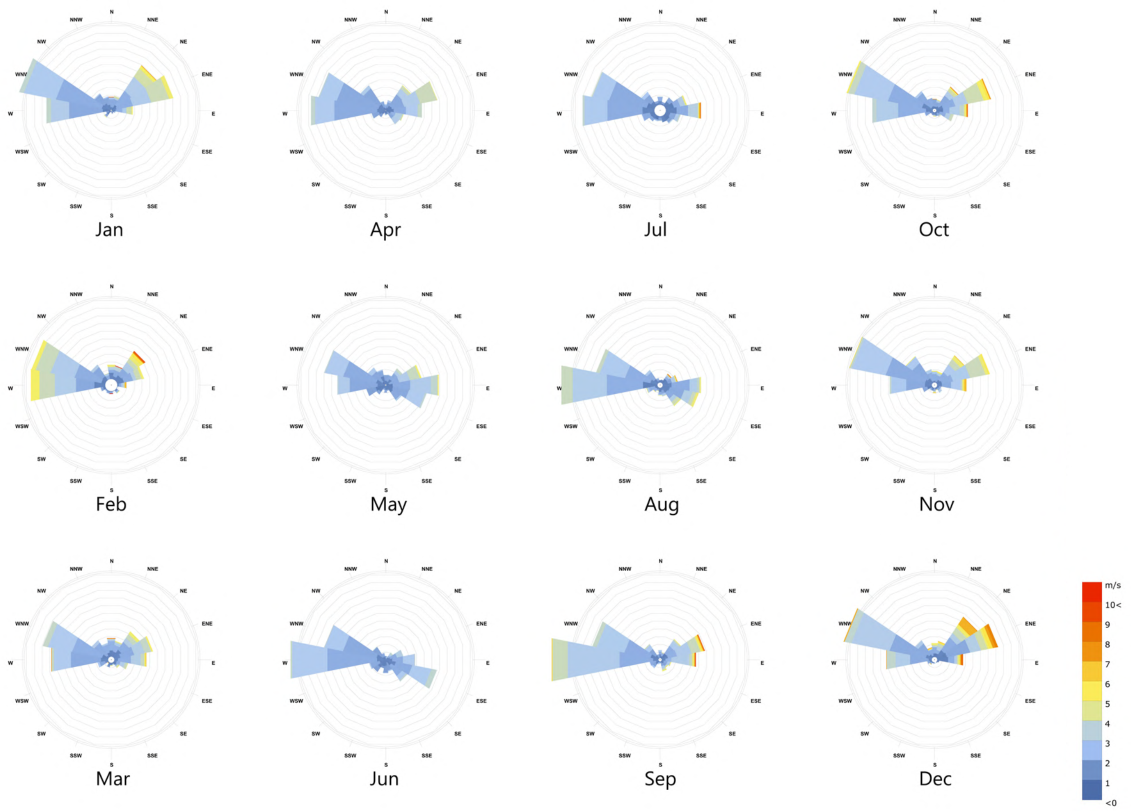


Wind Analysis

4260 Wind Studies GRASSHOPPER/LADYBUG



High Bound Wind Rose

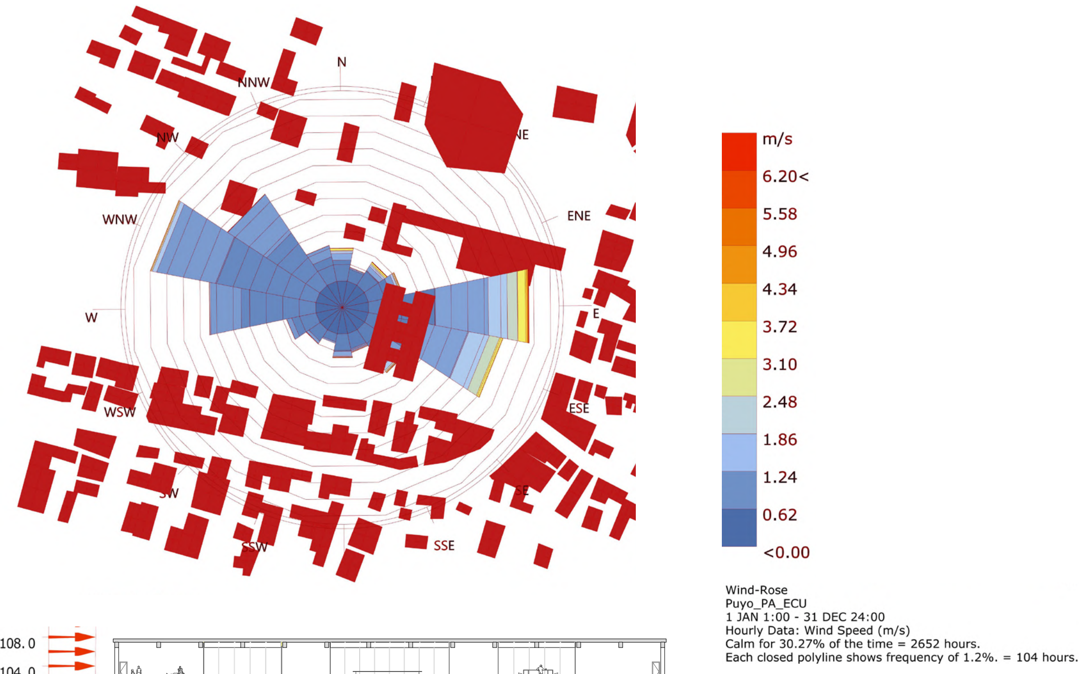


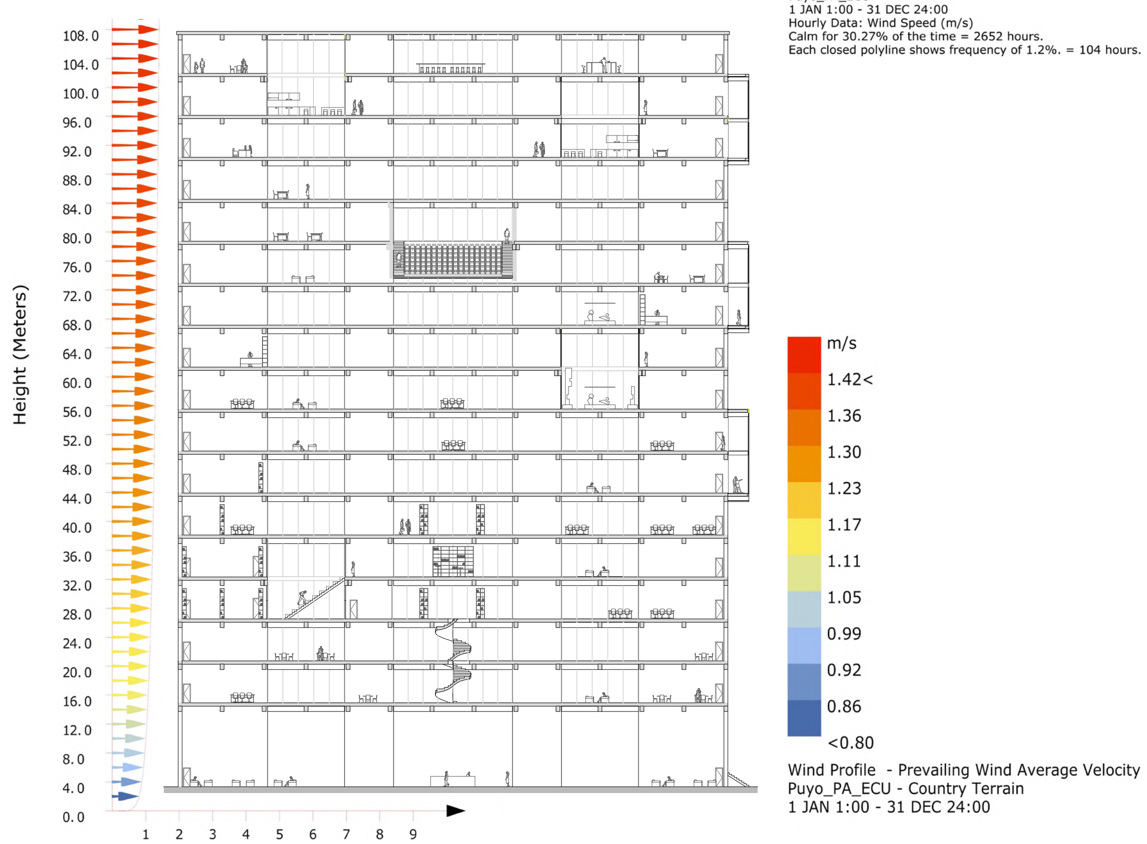
Low Bound Wind Rose

Annual Wind Intensity & Velocity In Height

4260 Wind Studies GRASSHOPPER/LADYBUG

The average hourly wind speed in Tena does not vary significantly over the course of the year, remaining within 0.1 meters per second to1.8 meters per second throughout. Pre-dominant wind direction in Tena is east throughout the whole year. As evident from the climate information, the wind in Tena is not excessively strong and the wind forces would not have a big implication on the positioning of the building. The illustration on the right represents the changing wind velocity in height. Even though, the prevailing winds are coming from the east, we can observe that the stronger winds are coming from the west and therefore the building will act as an obstacle to shelter and slow it down so that the park in fron of the building is less windy.

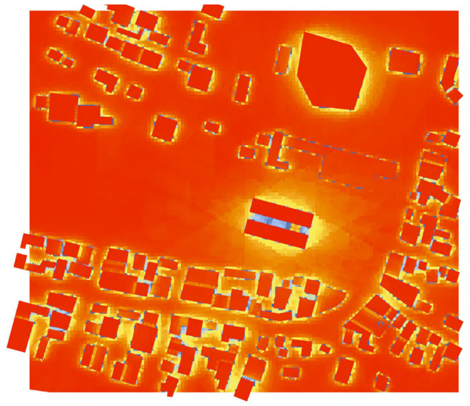




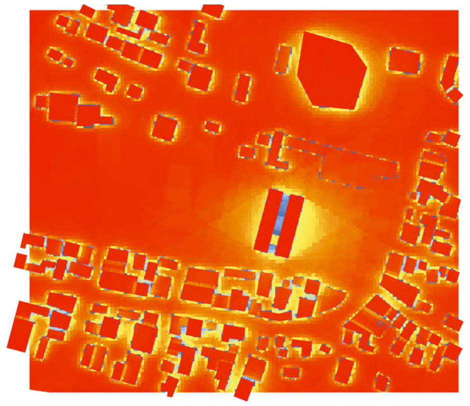
Solar Radiation Analysis

4190 Solar Analysis GRASSHOPPER/LADYBUG

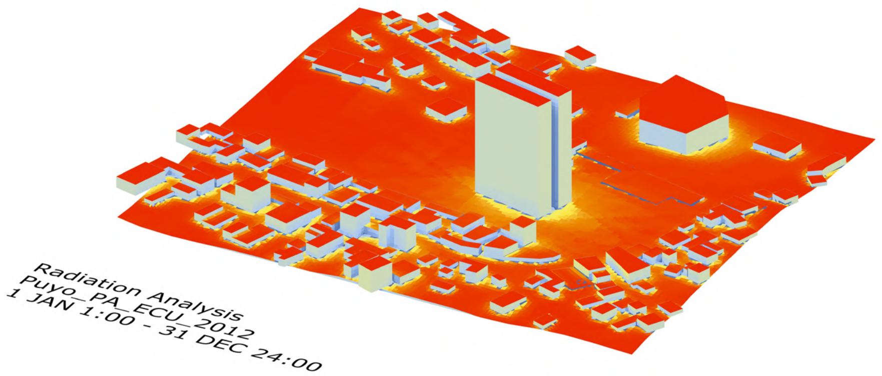
Based on the radiation analysis of the tall building with timber structure, while the solar energy can be used by PV panels in the roof is 1675.01 kWh/m2, the value for steel structure building was 846.54 kWh/m2. It shows that the difference in the geometry affects the solar gain considerably. Therefore, the geometry of building with timber structure is providing more benefit in terms of solar radiation. The higher solar radiation is more favourable for the energy production with pv panels. When pv panels produces more energy for the building, the energy consumption will be less

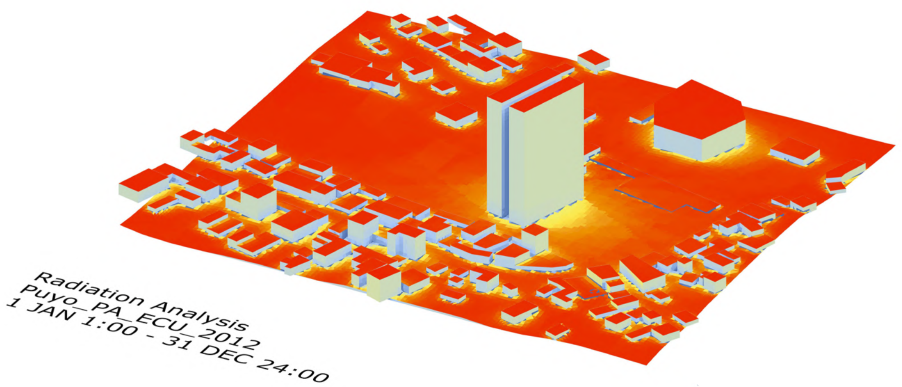


Radiation Analysis
Puyo_PA_ECU_2012
1 JAN 1:00 - 31 DEC 24:00



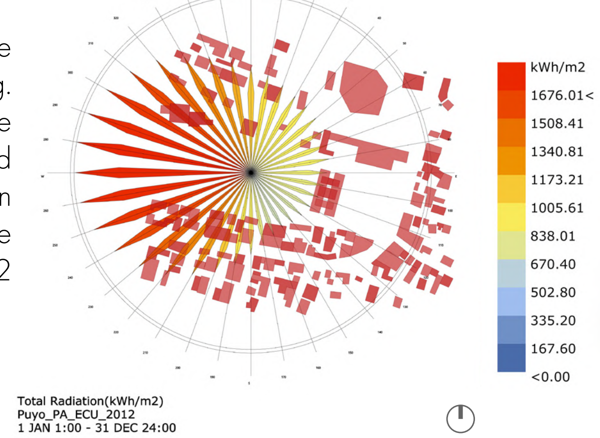
Radiation Analysis
Puyo_PA_ECU_2012
1 JAN 1:00 - 31 DEC 24:00

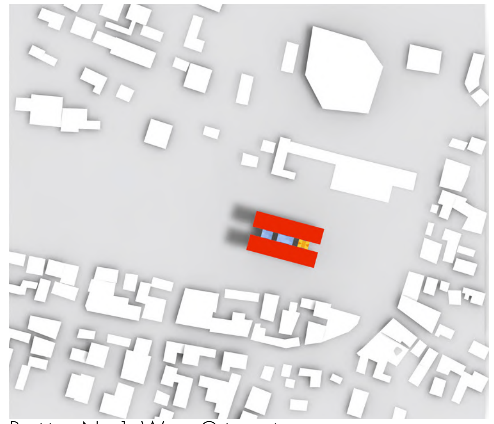




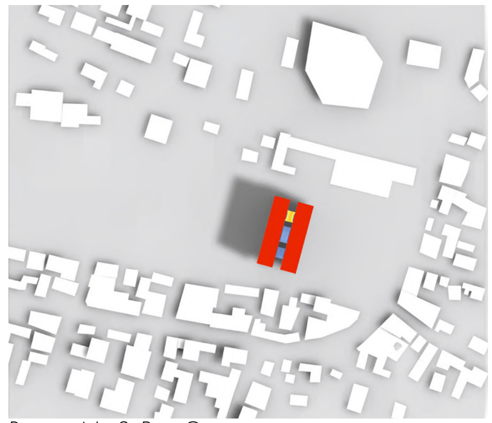
4190 Solar Analysis GRASSHOPPER/LADYBUG

Radiation analysis was used to evaluate the best and worst orientation of the building. By using this analysis from ladybug and the rotation component we were able to find the angles of best and worst orientation according to the solar radiation that the building will receive. Therefore position No. 2 is more desirable than position No.1.

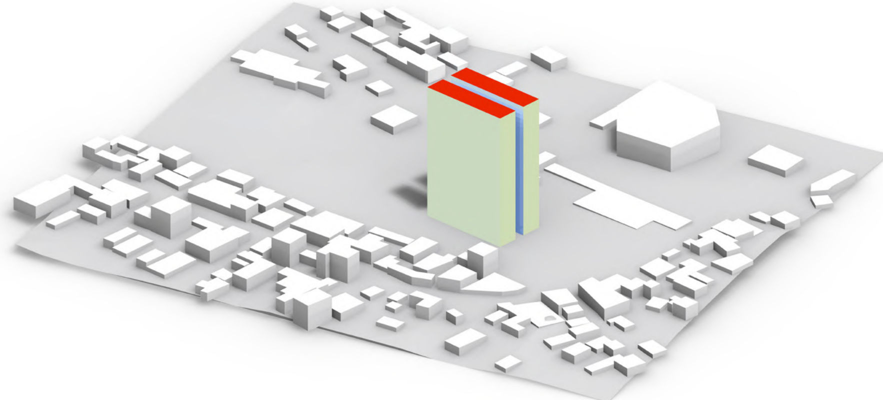




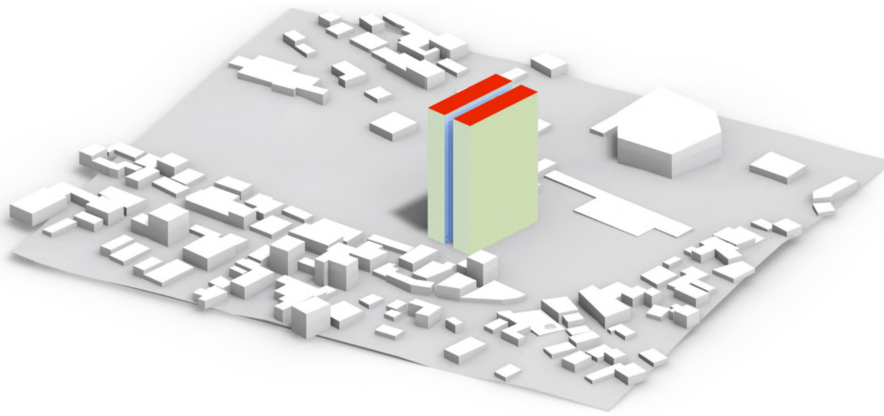
Position No.1: Worst Orientation



Position No.2: Best Orientation



Position No.1: Worst Orientation

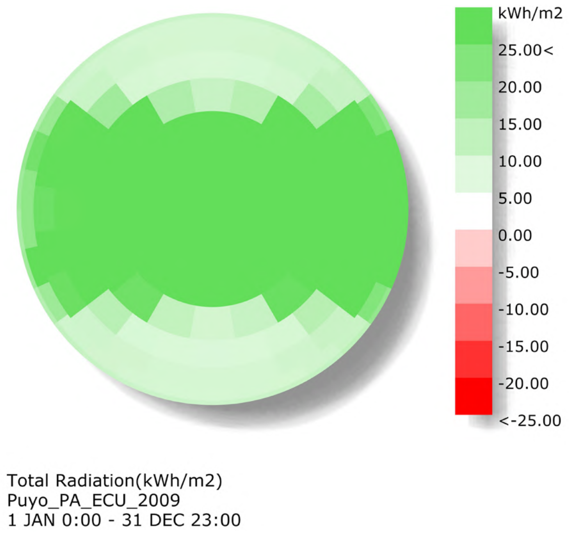


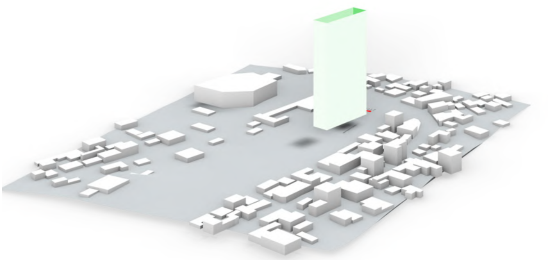
Position No.2: Best Orientation

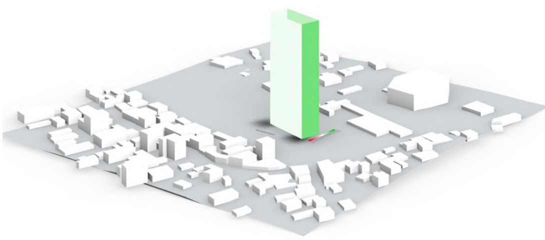
Solar Benefit Analysis

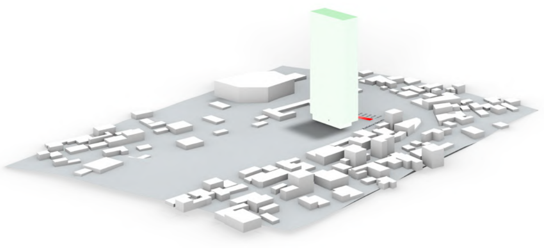
4190 Solar Analysis GRASSHOPPER/LADYBUG

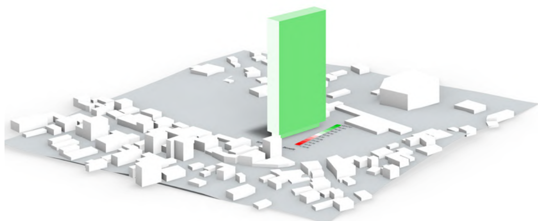
Solar benefit analysis was used to determine which of a set of building massing design options is better oriented. The study compares the total amount of helpful winter solar radiation (green) with the total amount of harmful solar radiation (red) to determine a final "radiation benefit" value. The higher this value (more intense green), the better performing the building massing is. Therefore, the building's best orientation according to the solar benefit

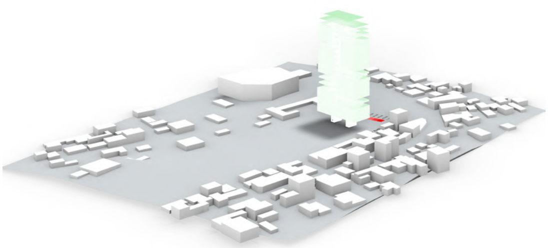


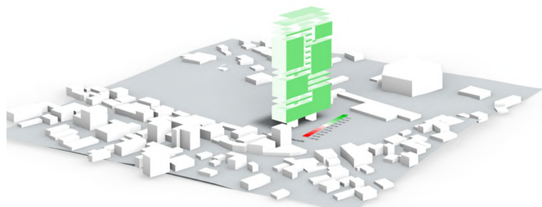

Position No.1: West Facade


Position No.1: East Facade


Position No.2: West Facade

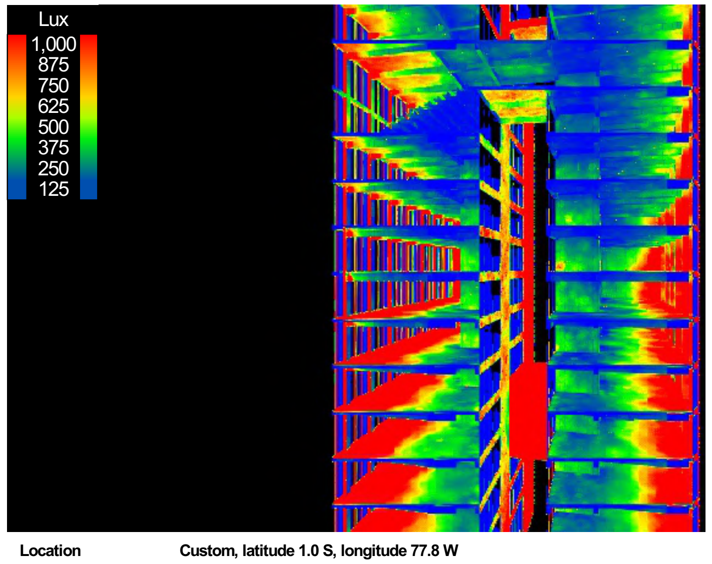

Position No.2: East Facade

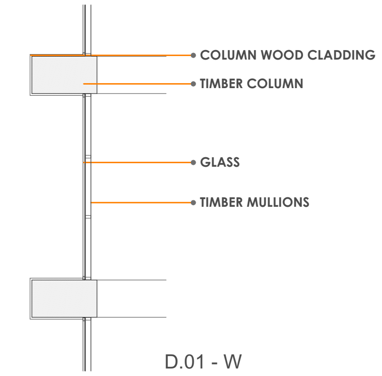

Articulation: West Facade


Articulation: East Facade

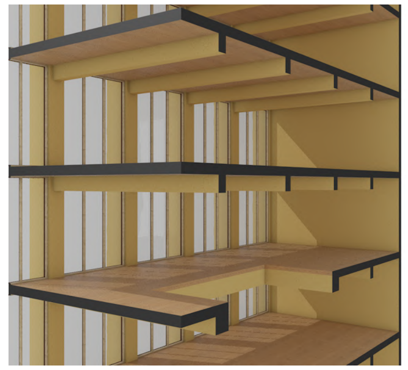
Daylight Analysis

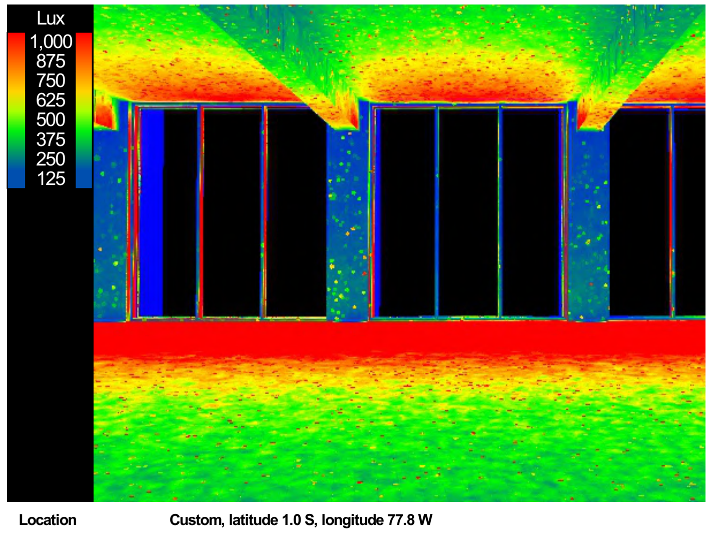
4120 Lighting Analysis VELUXDAYLIGHT SIMULATOR



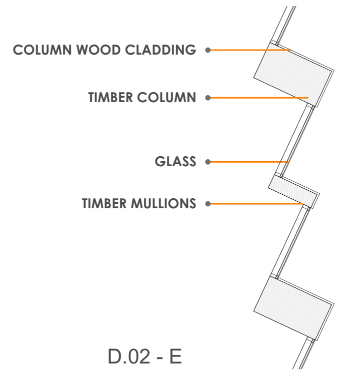


D.01 - W

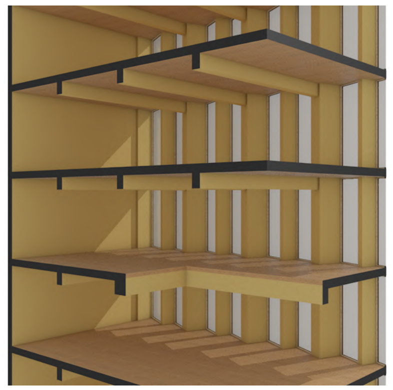


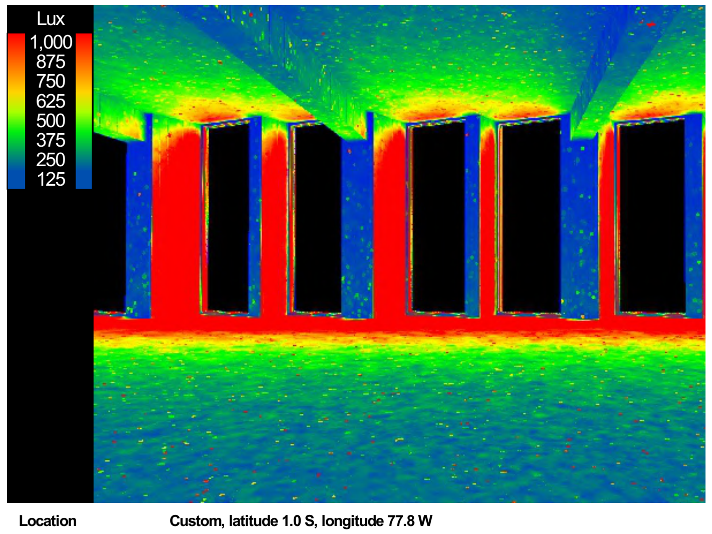


Facade/Sunshading Solution West



D.02 - E





Facade/Sunshading Solution East

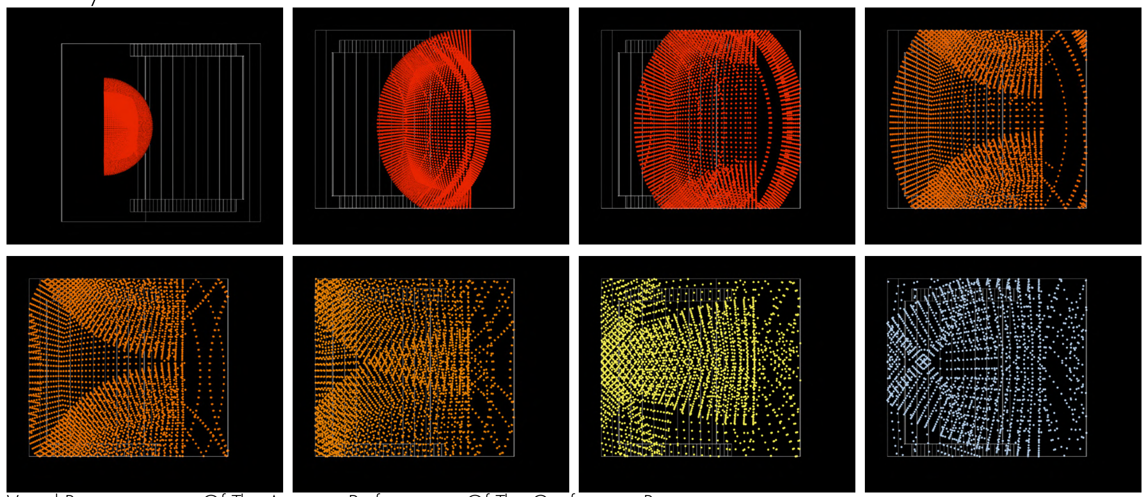
3D DETAILED DESIGN

4020 Acoustic Analysis PACHYDERM

Acoustic Analysis of Conference Room

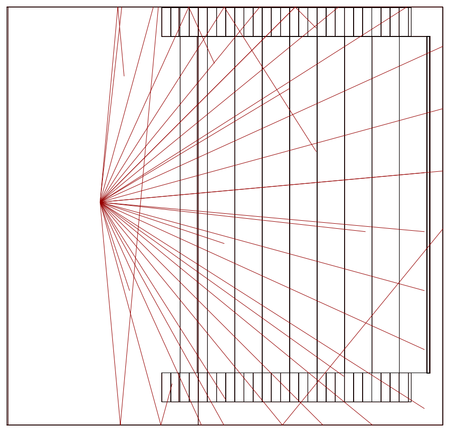
Pachyderm Acoustic Simulation is a collection of acoustics simulation algorithms which can be used to predict noise, visualize sound propagation, and critically listen to designed spaces. By using Pachyderm plug-in for Grasshopper it was possible to simulate the propagation of the sound in the room. Different criterias were taken in order to evaluate the sound,including the materials of the surfaces, the volume of the speaker and the absorbency of the ceiling.

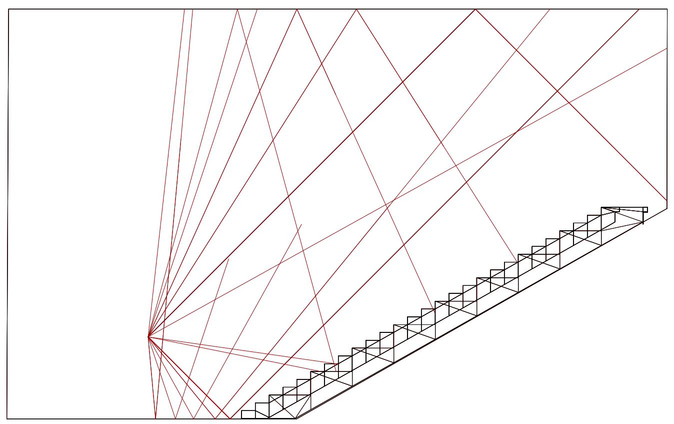
In the initial simulation it can be observed that due to the set properties of the materials as well as the configuration of the room, the noise particaldispertion is even and it can reach to all parts of the conference room in an qual manner. However further analysis had to be conducted in order to varify the reverberation times.



Visual Representation Of The Acoustic Performance Of The Conference Room

The reverberation period assessment has aided us in the more detailed design of the conference space. Here it can be observed that due to the low absorption value of the ceiling and the lack of absorption/reflection panels to control the sound, the ray-trace of the sound is bouncing, creating unnecessary echo and vibration. The initial calculation showe that the reverberation=1.93s.





4D SCHEDULING, FABRICATION AND ASSEMBLY

SOLIBRI MODEL CHECKER TM

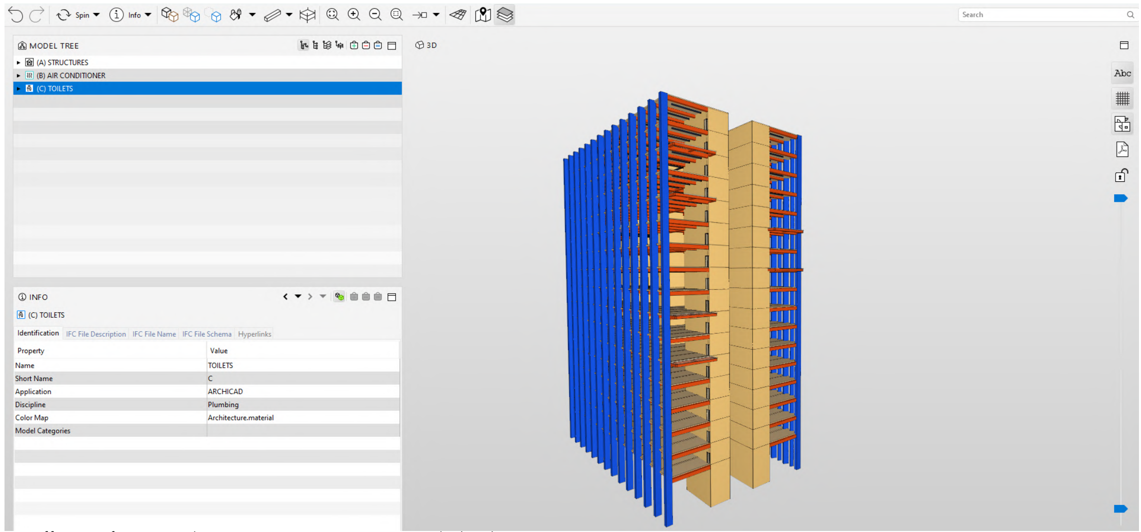
4040 Clash Detection

Solibri Office

Solibri is used in BIM Quality Assurance and Quality Control. Providing tools for BIM validation, compliance control, design process coordination, design review, analysis and code checking. Solibri allows to improve the quality of Building Information Modeling (BIM) and makes the entire design process more productive.

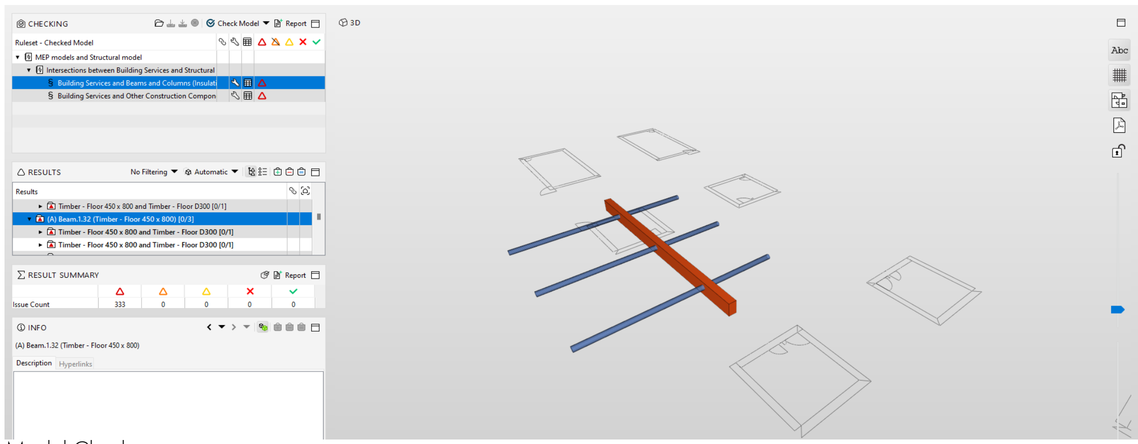
Solibri provides numerous sets of costumizable rules (ruleset), to validate models according to the regulatory and project requirements. Once the quality of the modeling has been verified and ascertained (BIM Validation), it will continue with the interderence checks (clash detection) and the verification of compliance with the chosen standards.

Since KPI is checking the 3D model for clashes with the HVAC systems and plumbing we used Solibri Office to verify the place of clashings and then to proceed with possible solutions.



3 Different Ifc According To Structures, Hvac And Plumbing

Solibri Model CheckerTM is a BIM quality assurance software solution that analyzes BIM and architectural and engineering designs for integrity, quality, and physical safety. Besides, Solibri Model Checker includes functionality for information take-out, analyzing and extracting the information available in BIM models. It targets zero desgin errors, producing cost savings in construction projects, and more effective modeling and quality assurance.



Model Check

4040 Clash Detection SOLIBRI MODEL CHECKER TM

The software was used to detectmistake from the initial stages of the building modellin in ArchiCad. Running the chech it allowed us to understand the clashing problems between structural elements and HVAC or Plumbing systems, then we were able to rethink about the beams design in order to provided the necessary holes to permit the systems to be continous.

Briefly, Solibri Model Checker (SMC) enables you to check a BIM file against a set of rules and to indetify and report potential problems found. This is significantly faster and more reliable than the traditional way of manually checking and analyzing the building documents.

By setting the desired tolerance of the different elements, it was possible to evaluate, check and see were the model does not compky with the set of rules. After this check, a report was created and exported in roder to make the process of verification and fixing more efficient and productive. By using this software, the clashes between the structural elements and the systems are detected beforehand.

Get Started	Acc	Rej	Maj	Nor	Min	Comment
BIM Model Structure Validation	-					
Architectural model must follow the IFC hierarchy	-					
Architectural model must have storeys defined	-					
Architectural model must have listed building elements	-					
Architectural model must have spaces	-					
Architectural model components must have unique GUID	-					
Clearances - Free Area in Front of Components	OK					
Clearance in Front of Doors	OK					
Clearance in Front of Windows	-					

MEP models and Structural model	Acc	Rej	Maj	Nor	Min	Comment
Intersections between Building Services and Structural Components			x			
Building Services and Beams and Columns (Insulations Not Included)			x			
Building Services and Other Construction Components (Insulations Not Included)			x			
Insulations and Beams and Columns	OK					
Insulations and Other Construction Components	OK					
Distance between Components				x		
Distance Between Columns/Beams and MEP components				x		
Distance Between Walls and MEP components				x		
Allowed Intersections In Beams	OK					
Allowed Beam and Ducts/Pipes Intersections	OK					
Allowed Beam and Cable Carrier Intersections	OK					

1. MEP models and Structural model

1.1. Intersections between Building Services and Structural Components

1.1.1. Building Services and Beams and Columns (Insulations Not Included)

Report: Intersection volume report

Table of intersection volumes organized according by construction types.

Component	Type	Total Component Volume	Intersection Volume	Percentage
Beam	Timber - Floor D300	408.85 m3	5.21 m3	1%
Beam	Timber - Floor 450 x 800	2,566.80 m3	5.21 m3	0%

Results

Intersections of Beam

(A) Beam.1.15 (Timber - Floor 450 x 800)

Timber - Floor 450 x 800 and Timber - Floor D300

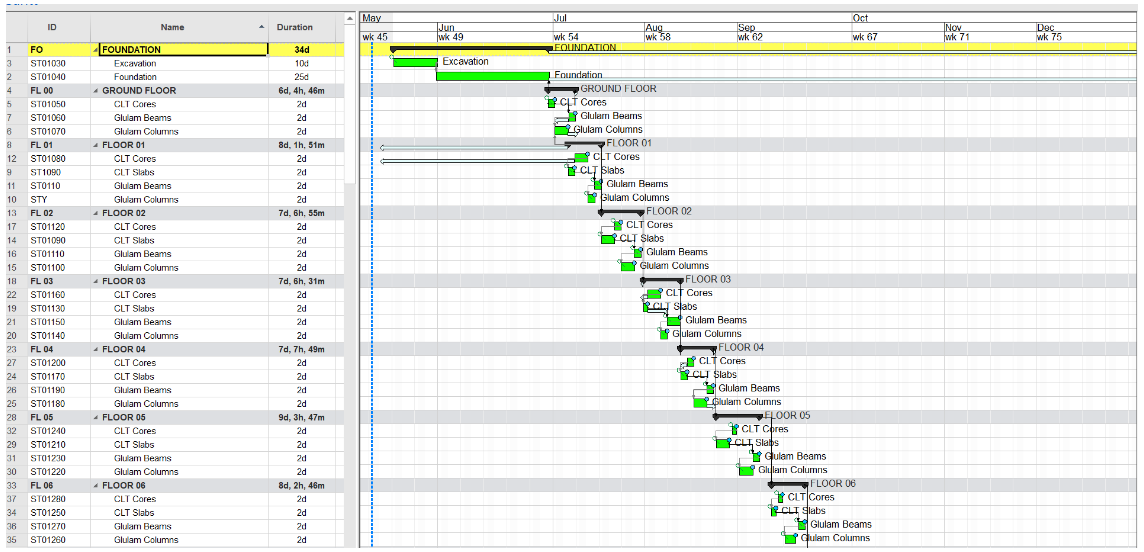
(A) Beam.1.15 (Timber - Floor 450 x 800) and (B) Beam.1.21 (Timber - Floor D300) are intersecting

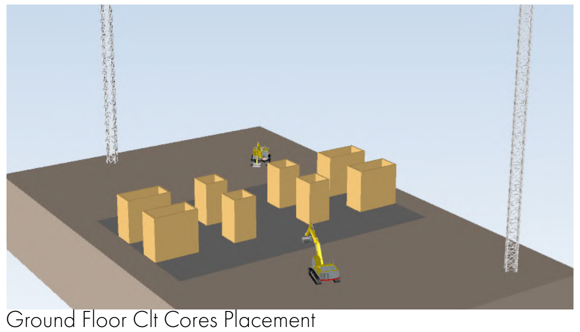
The depth, width, height, and volume of the intersections are:
(B) Beam.1.21, (A) Beam.1.15, 450 mm, 300 mm, 300 mm, 31 l

Report

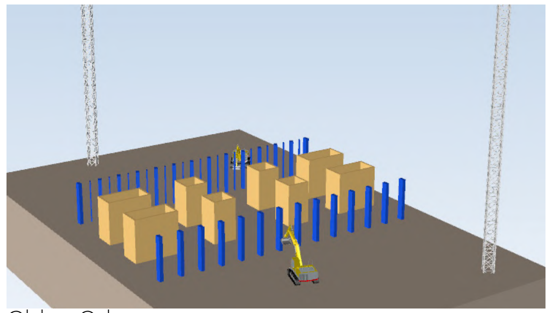
Scheduling of Construction

3020 Construction Planning SYNCHRO 4D PRO

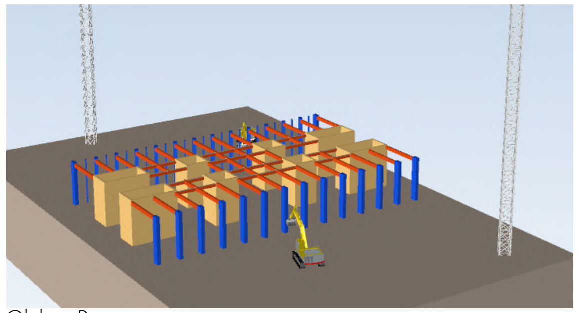




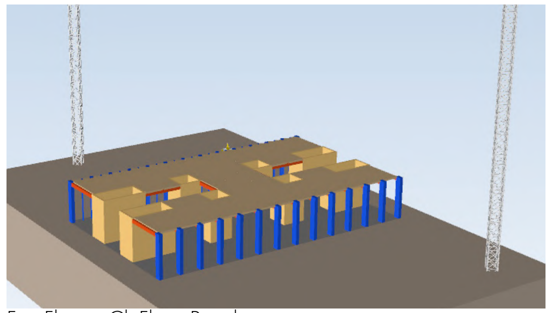
Ground Floor Clt Cores Placement



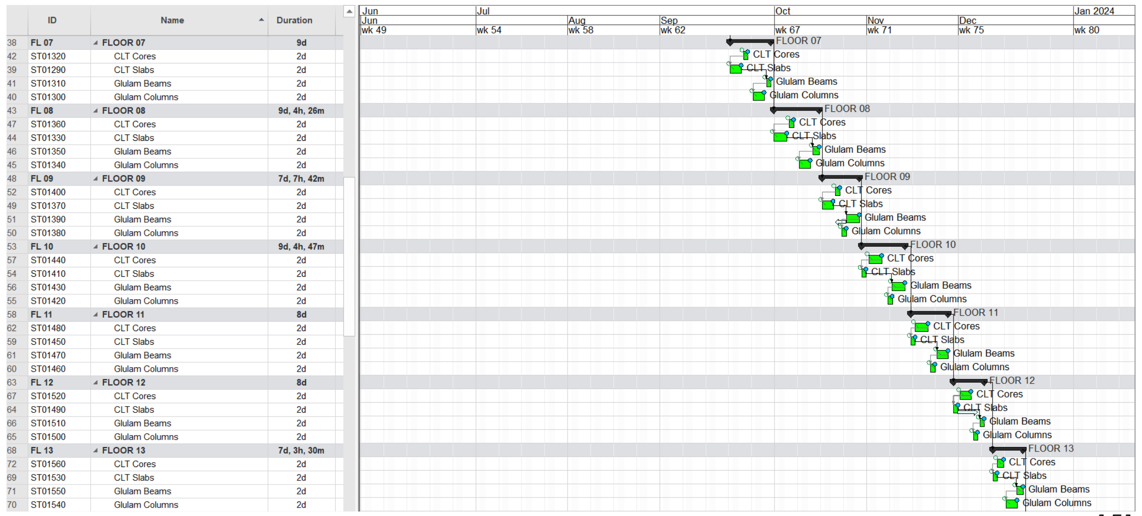
Glulam Columns

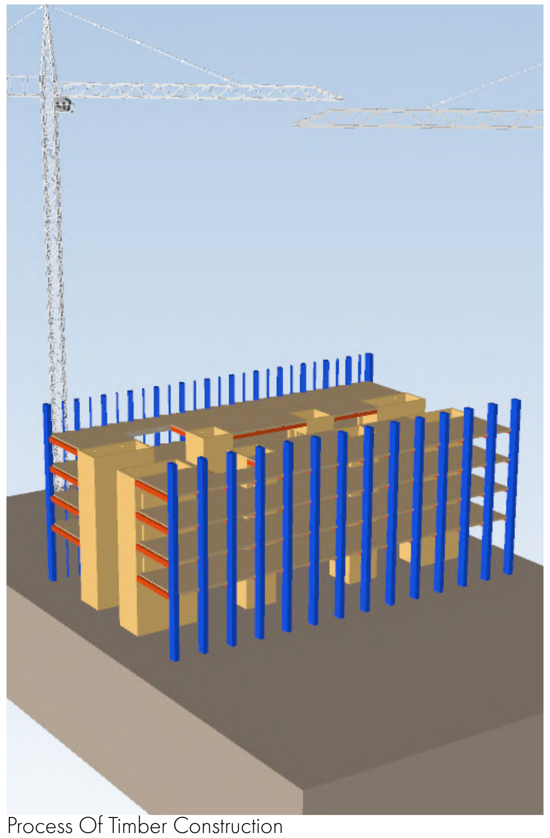


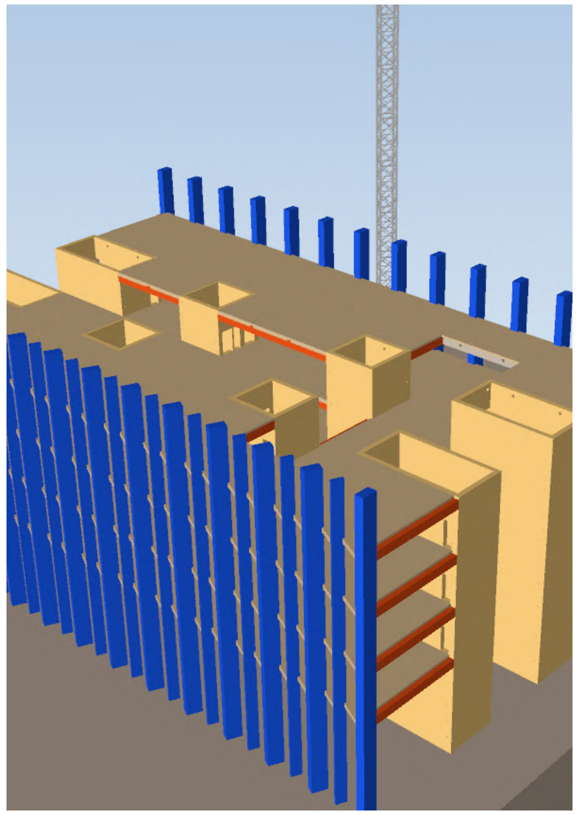
Glulam Beams



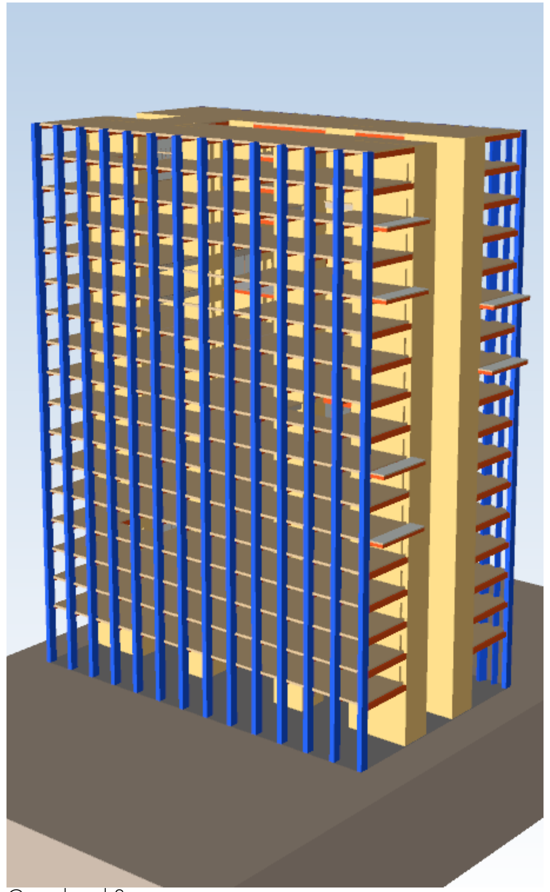
First Floor - Clt Floor Panels

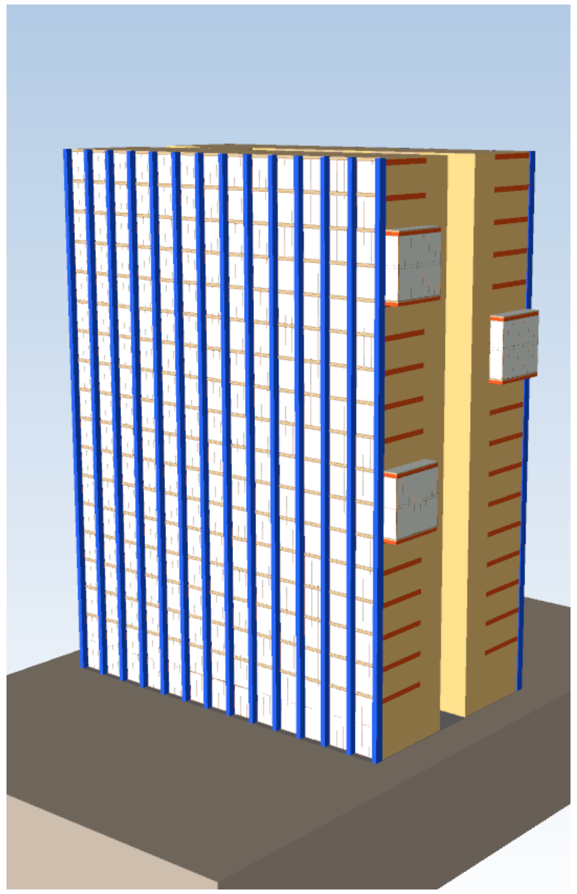






Process Of Timber Construction



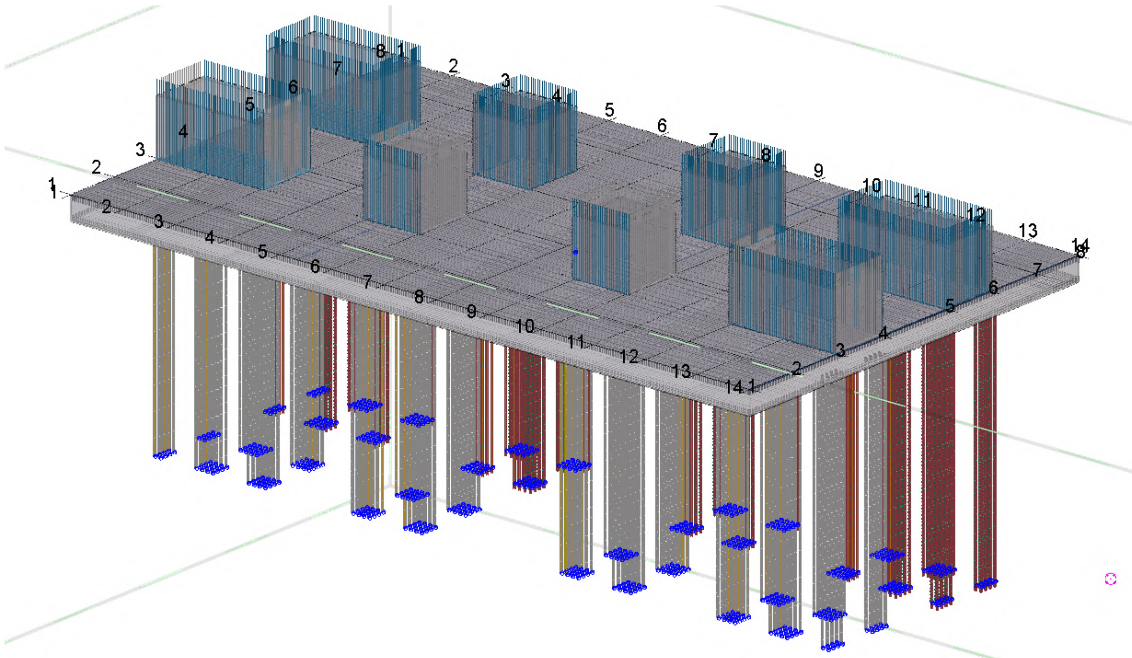


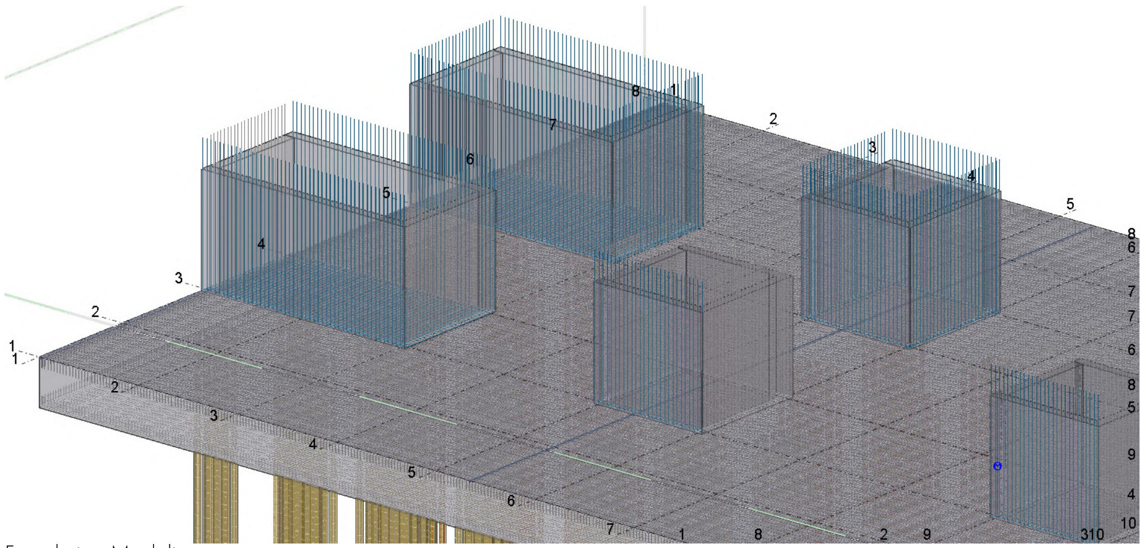
Completed Structure

Tekla Structural Analysis

Tekla Structures is used to create and manage 3D structural models in various materials and guides them through the process from concept to fabrication. It allows the built up of a parametric model which represents the central node of the project activities. From the constantly updated model, it is possible to extract information at different levels always aligned with the progress of the project and construction of the building.
By using Tekla, non-structural elements can be also modeled and analysed even for the complex structural connections. It is possible to have different configurations and localized environments.

For the Amazon Healing Tower, C25/30 concrete is used for the foundation. The foundation model consists of eight concrete cores, two meters deep mat foundation and the piles which have been reinforced. Under the cores, the piles with circular rebars are continuous through 20meters. For all the steps in structural modeling, 4.8mx4.8m structural grid was followed.





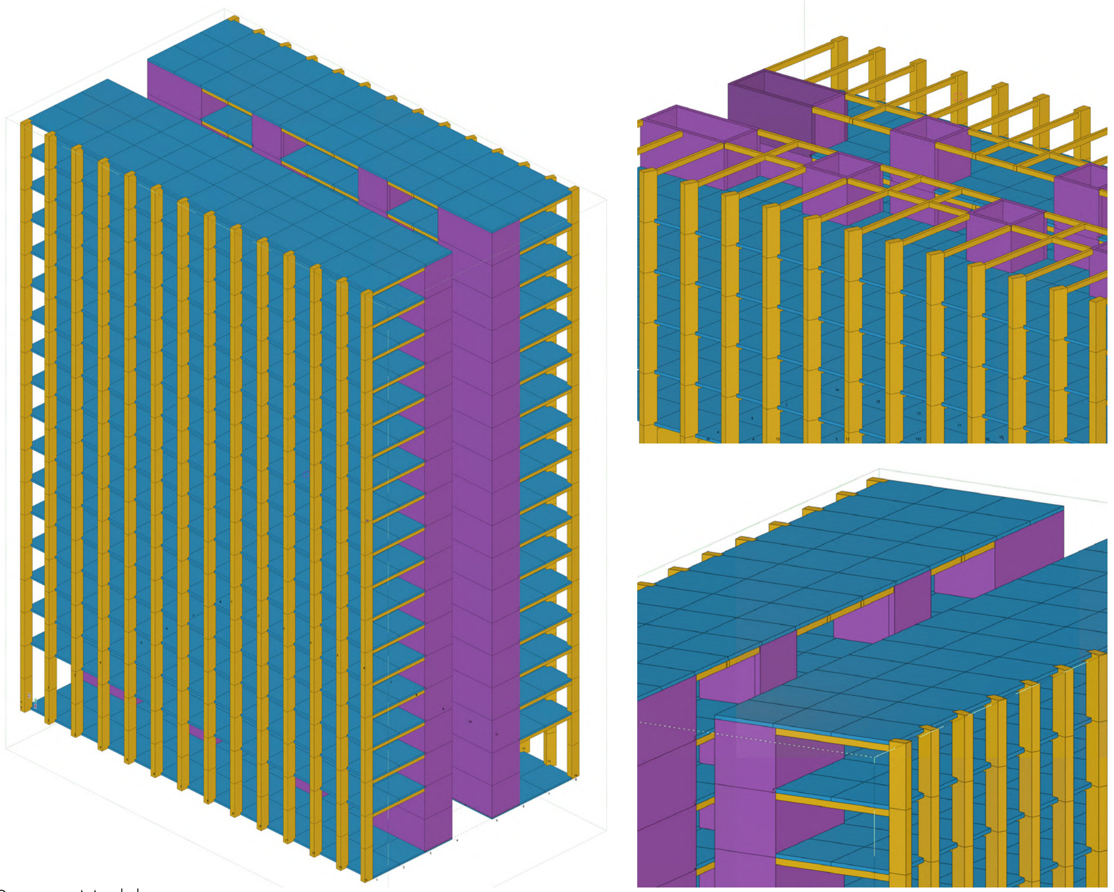
Foundation Modeling

Generic Structure:

4210 Structural Analysis Tekla TEKLA STRUCTURES

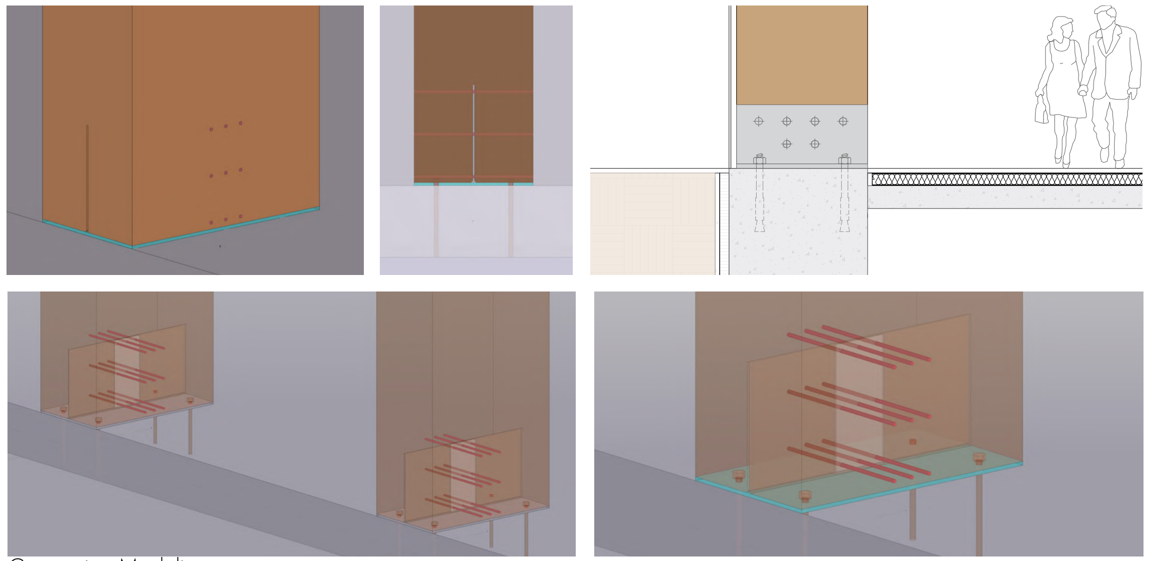
While the main cores are made of CLT panels, the beams and the columns are glulam timbers to build a structure.

The size of the glulam timber columns 0.8m x 1.4m
The size of CLT slab panels 4.80m x 4.80m



Structure Modeling

The connection detail is also modeled in Tekla Structure by using the special plug-in produced for timber structures. lulam columns with the size of 140cm x 80cm are connected to the concrete ground floor slab with steel knife plates and bolts to provide structural stability.



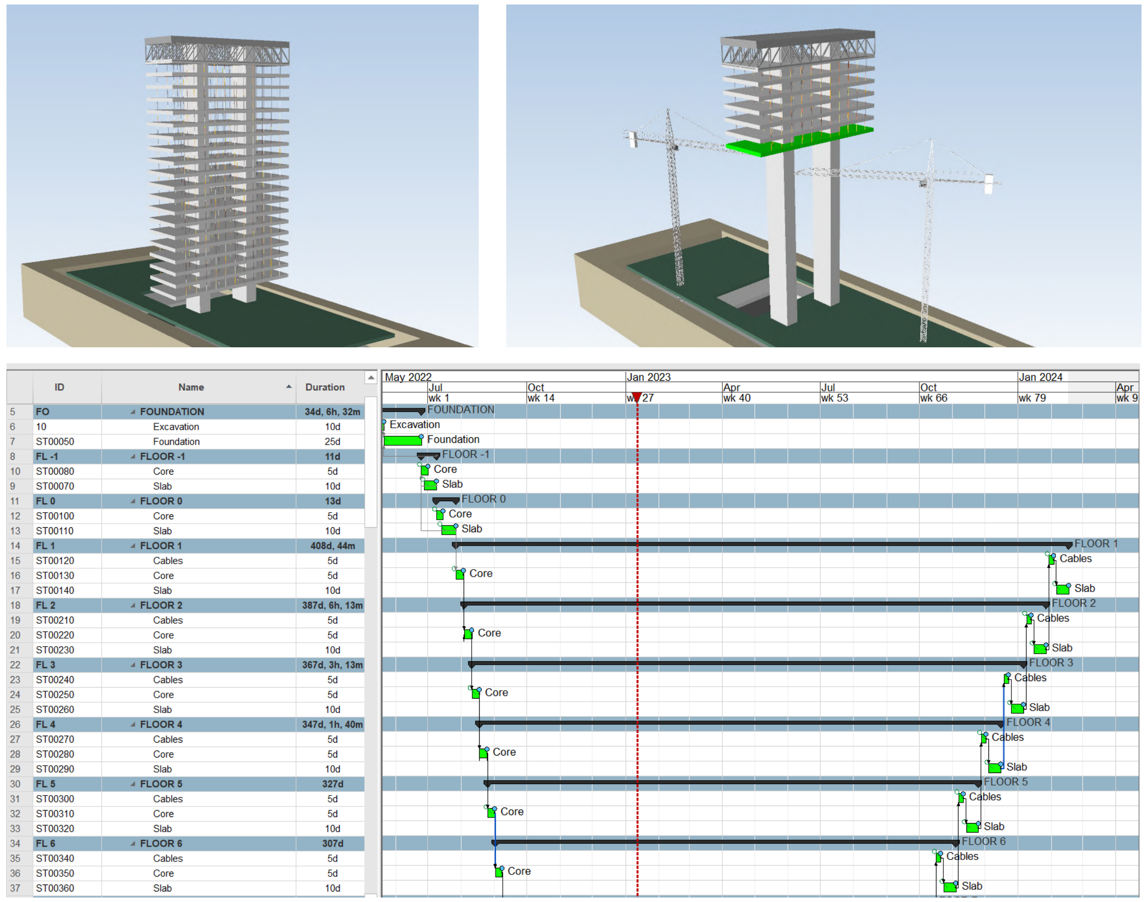
Connection Modeling

Time Management

The construction planning of the tall tower is analyzed by using Synchro for steel structure and timber structure. Based on the schedule, while the steel structure construction takes 408 days to complete, the timber structure is completed in 172 days.

The main reason in that difference on timing is the possibility of faster installation with timber. Unlike steel, concrete and other conventional construction materials CLT panels can be prefabricated at an offsite manufacturing facility and then installed in a shorter time because fewer joints are needed between interior support elements.

Also, installation process for concrete requires formwork, shoring and reinforcement with steel rebar. With CLT, on the other hand, a construction crew can crane the prefabricated panels into place, set connectors and then tie the components together. Therefore, the total construction time for timber is almost three times less than steel structure tall tower according to the scheduling in Synchro 4D Pro.



Steel Structure

5D COST ESTIMATION

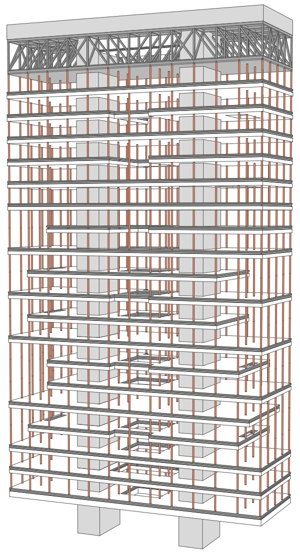
The steel/concrete structure tower is 1.40 times more expensive than the timber structure tower. Its important to mention that for the timber building the number of floors was reduced so the height of the building is 86.40 m while the steel one is 115 m.

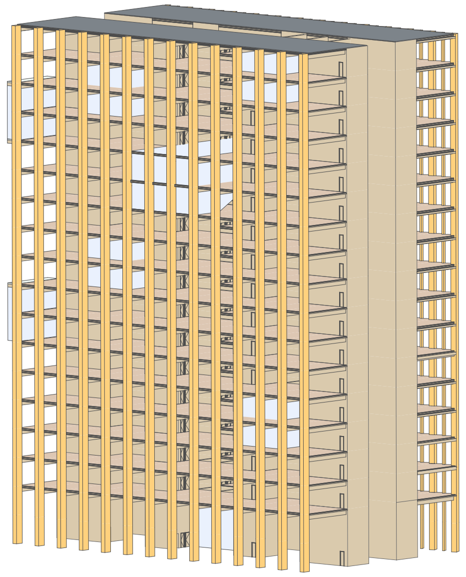
STEEL STRUCTURE TOWER

MATERIAL	AMOUNT	COST/UNIT	TOTAL COST
Steel	3793115.03 kg	3.60 €/kg	13655214.10 €
Concrete	4371.76 m3	100.00 €/m3	437175.50 €
		Total	14092389.60 €

TIMBER STRUCTURE TOWER

MATERIAL	AMOUNT	COST/UNIT	TOTAL COST
Timber	9065.85 m3	1100.00 €/m3	9972440.02 €



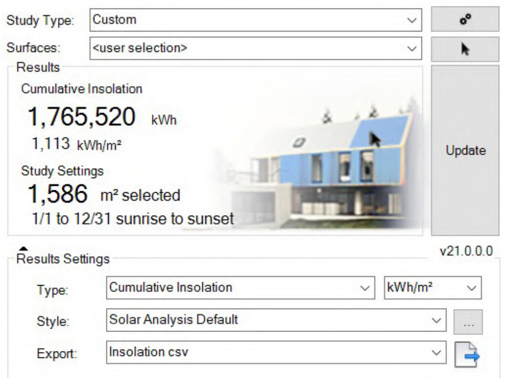


6D SUSTAINABLE DESIGN

Energy Consumption

Total radiation between the period of January 1st - December 31st is analysed. The building with timber structure has 1766kWh/m2 solar radiation for the 1586 m2 selected areas.

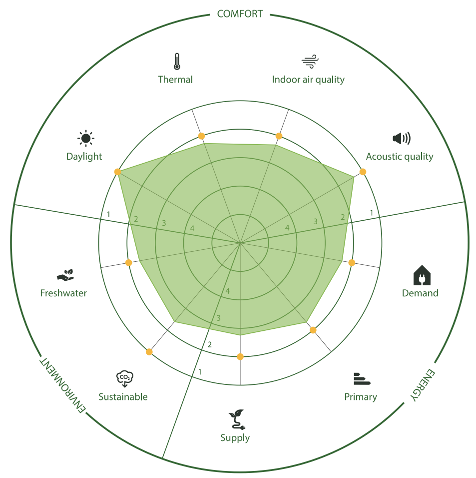
As the solar radiation affects the power, it also affects the outcome efficiency of the PV panels on the roof of the building. The increase in solar radiation intensity is followed by an increase in the panel temperature which eliminates the produced current and then reduces the power (the energy consumption) and at the end affects the efficiency and reduces it.

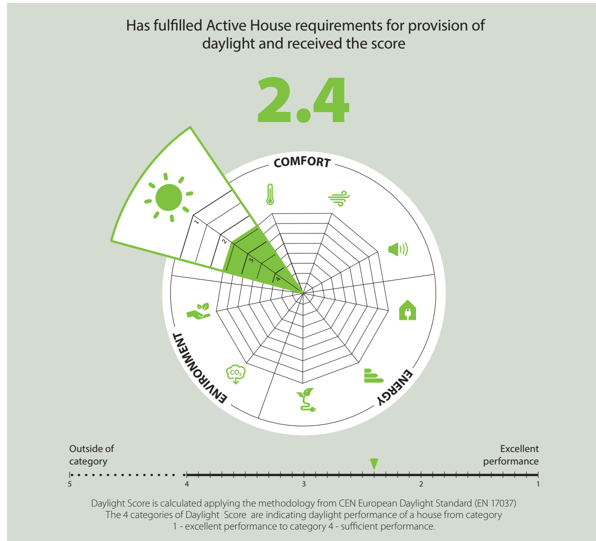


Comfort & Energy Analysis

After the application of the special elements in the architectural design, we carried out the evaluation of the building again.
The graph of the evaluation of the active house radar with the changes made to the facade, roof, and lighting type is presented below.
In general, there was an improvement in the energy and sustainability sections.

Regarding the building means, in the comfort section, thermal balance was achieved by using the ventilation strategy according to the users. In the energy section, energy demand has been improved due to the added applications over energy-efficient technologies. Regarding the environment section, due to the materials used in terms of construction, the building contributes to the levels of sustainability and low CO2 emissions.



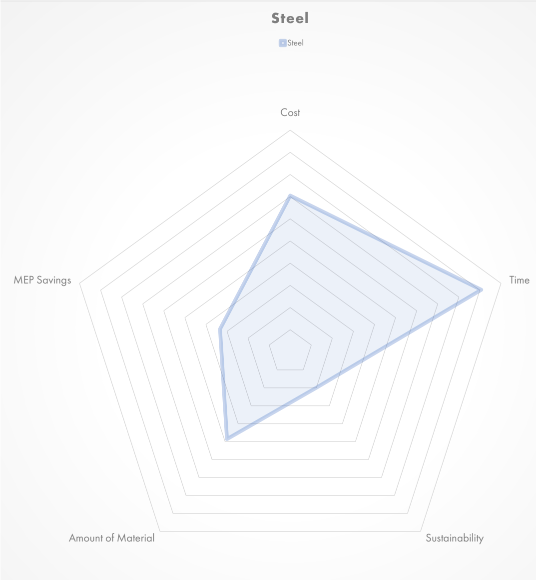


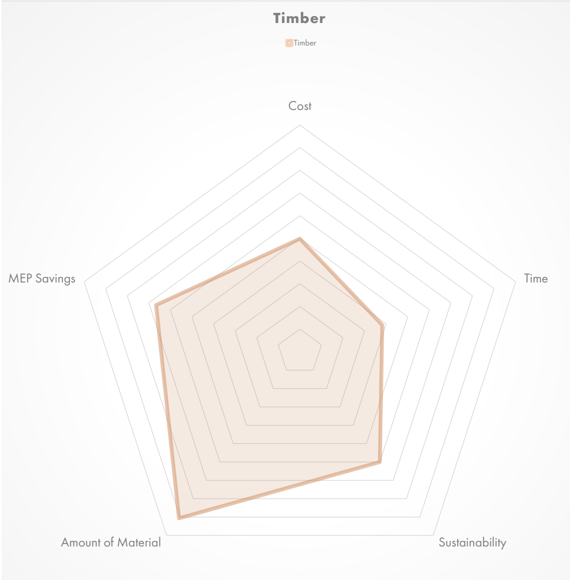
Multi-Criteria Analysis Radar

Resulting from the analysis undertaken in the report and the evaluation of both alternatives for the building, the summary below shows the comparison between the different alternatives according to various criteria. Five categories were chosen which are different and detrimental for the projects as cost, time of construction, amount of materials used, MEP Savings.

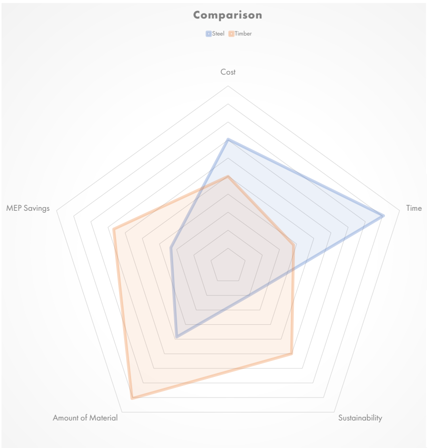
The cost has given us a snapshot of the feasibility of the project for the town of Tena. The time is important factor taking into consideration the precious location and the will to minimise the impact of the construction area on the town and the people. Sustainability was evaluated base on the Active House Radar and MEP savings were considered as the amount of Solar energy power available for the building.

By overlapping the two outcomes of the steel and timber material, it is visible that the time for the construction of the steel building is almost five times more that the construction of the timber tower. This is a result of the benefit of the pre-fabrication that the timber parts allow to be made off-site. However, the amount of timber used compared to steel/concrete is 2.25 times more . Although the value seems very high, the sustainability category shows that the timber building is much more sustainable than the steel one.





Spider Charts Showing The Difference Between Different Material Choice



Category	Steel	Timber	Benchmark
Cost	£ 14,092,389.60	£ 9,972,440.02	£ 113,000,000.00
Time	408	172	426
Sustainability	2	6	5
Amount of Material	4854.959367	9065.8	2600
MEP Savings	100.00	200.00	300.00

Category	Steel	Timber
Cost	7.05	4.99
Time	9.07	3.82
Sustainability	2.00	6.00
Amount of Material	4.85	9.07
MEP Savings	3.33	6.67

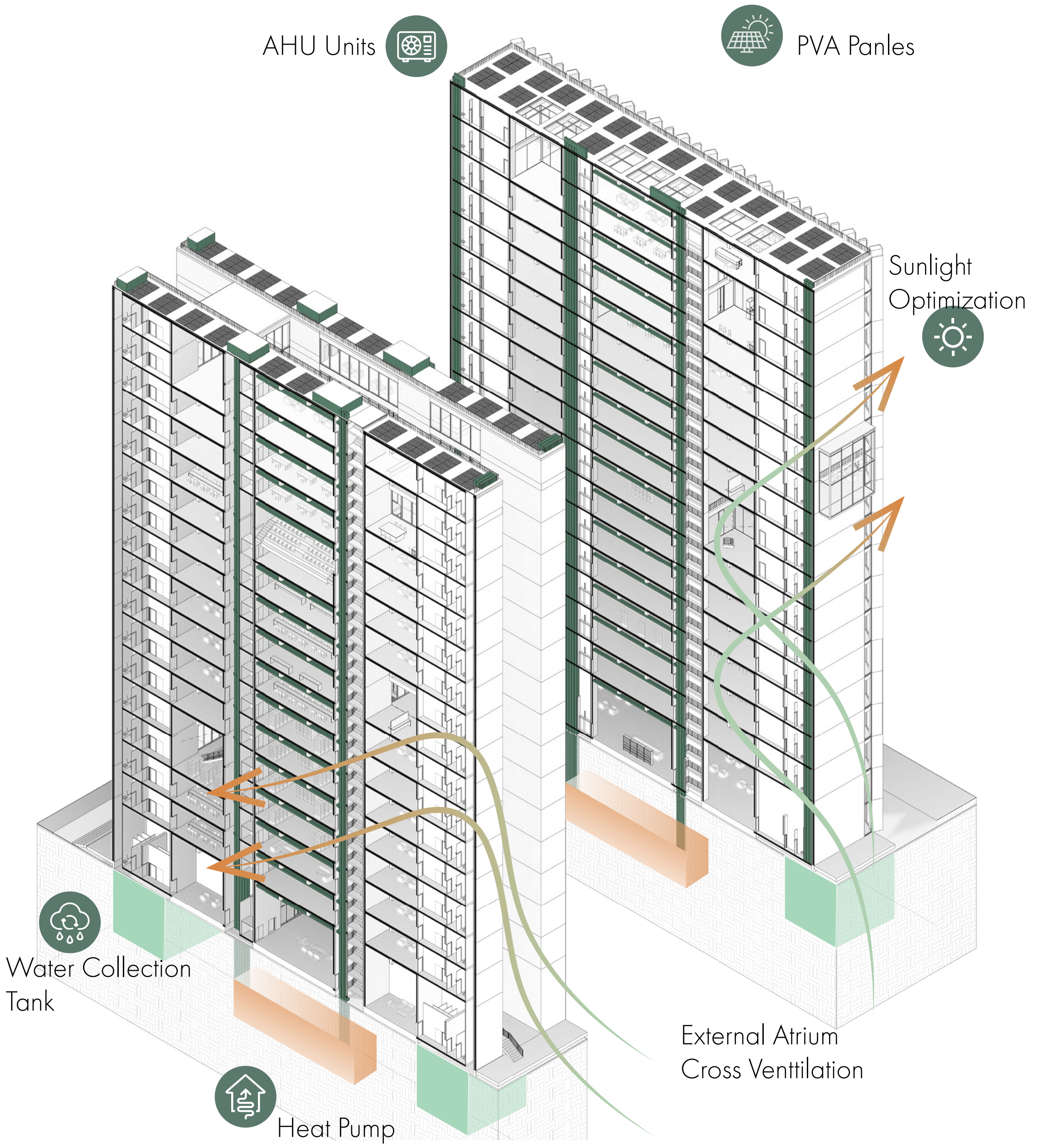
Project Comparison and Evaluation

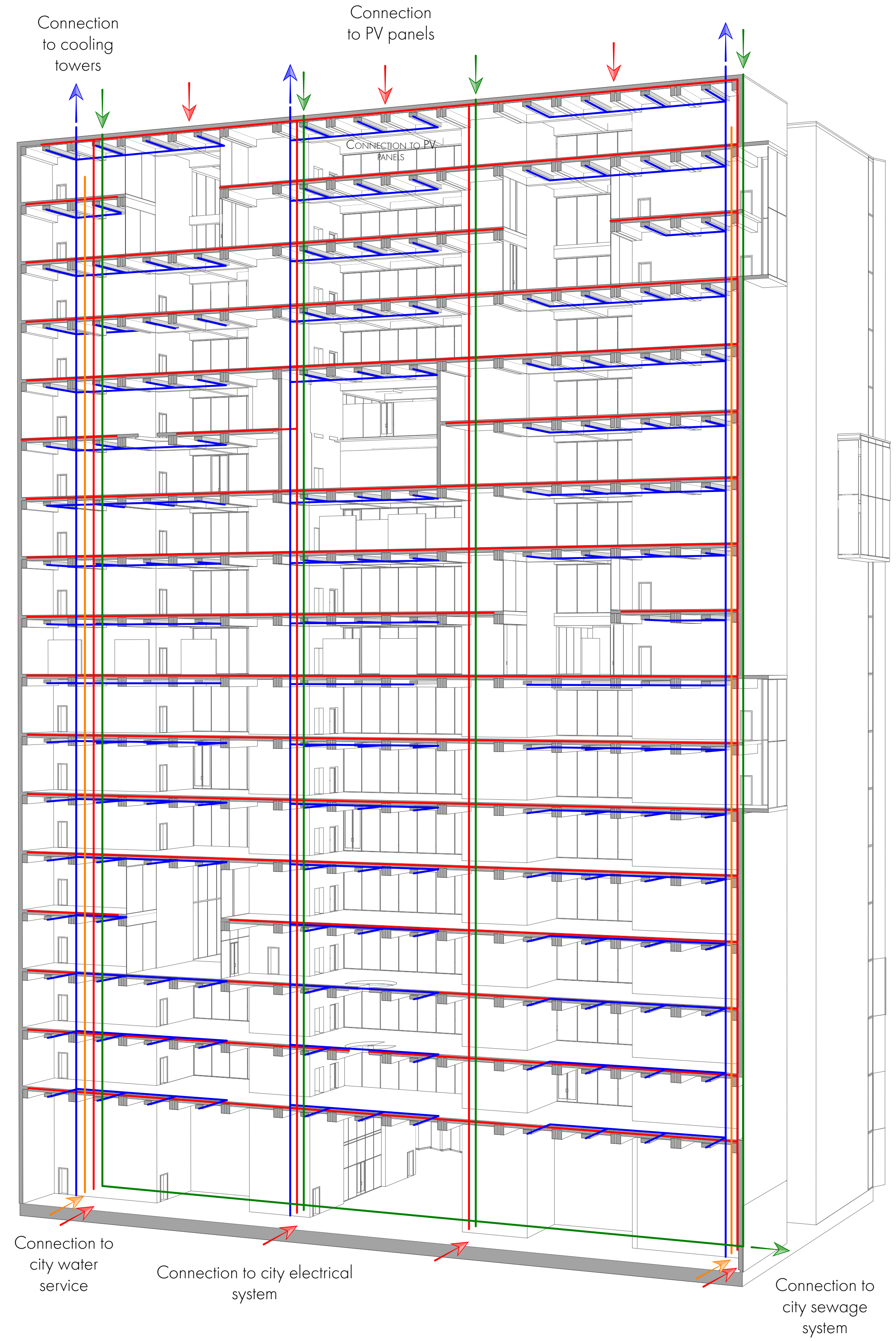
07 BUILDING SERVICES

GENERAL SCHEME

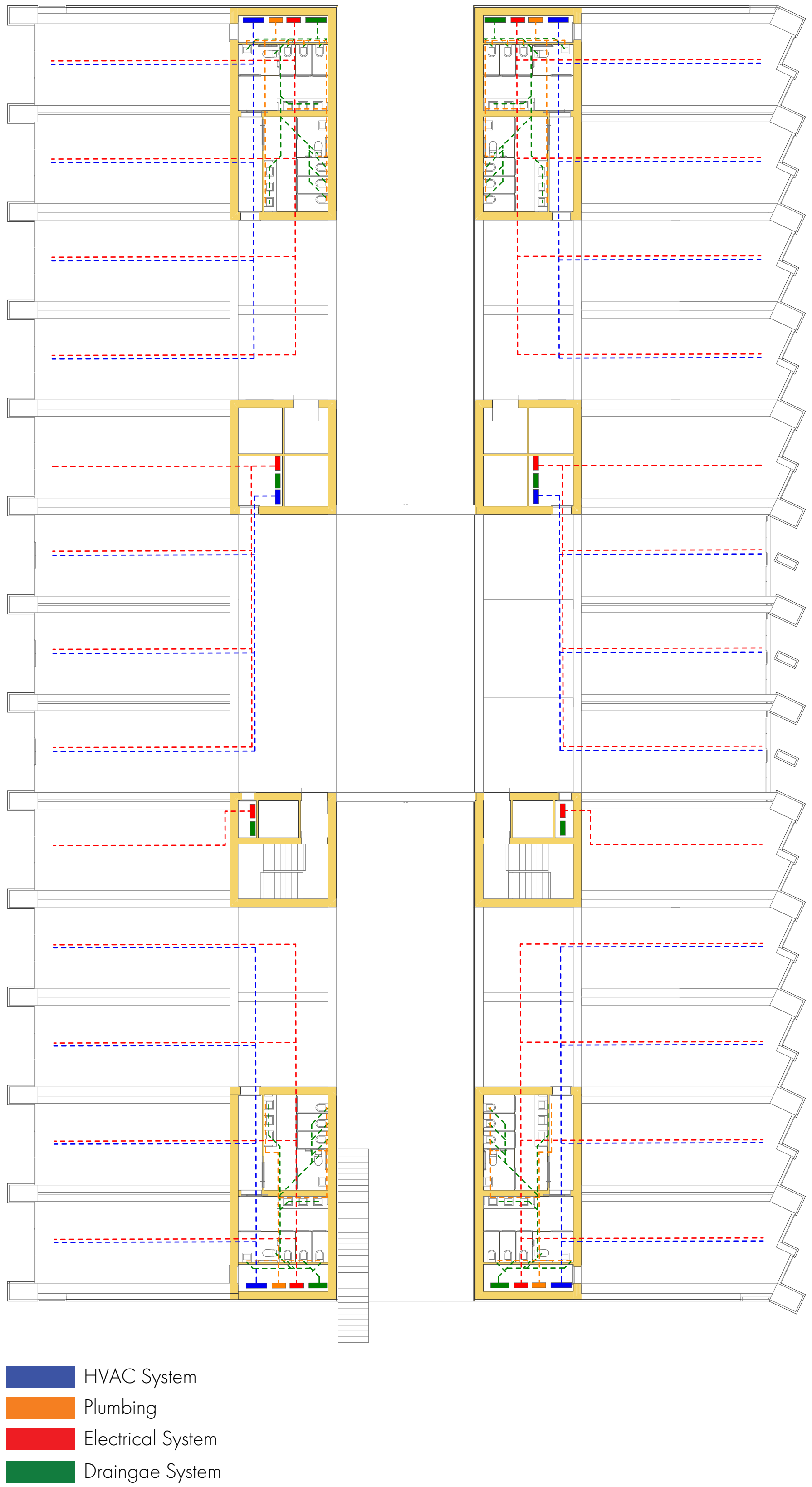
Climate in Tena

Tena, situated in the Amazon rain-forest region of Ecuador, experiences a tropical rain-forest climate characterized by consistently high temperatures and significant rainfall throughout the year. The average temperature in Tena ranges between 24°C to 30°C (75°F to 86°F), providing a warm and humid environment. The city is subject to two distinct seasons: a wet season from October to April and a drier season from May to September. During the wet season, Tena receives heavy rainfall, contributing to the lush greenery of the surrounding rainforest. The humidity remains high, fostering a rich biodiversity and vibrant ecosystems. The drier months bring slightly cooler temperatures and a reduction in precipitation. Therefore a heating unit is not required bu providing ventilation to tackle the humid environment is implemented. Furthermore, heavy rainfalls provide an opportunity for water collection. Heat pump in the underground will heat up the cold water with the help of the hot exhaust air from the AHU Units.





Systems Integration Scheme



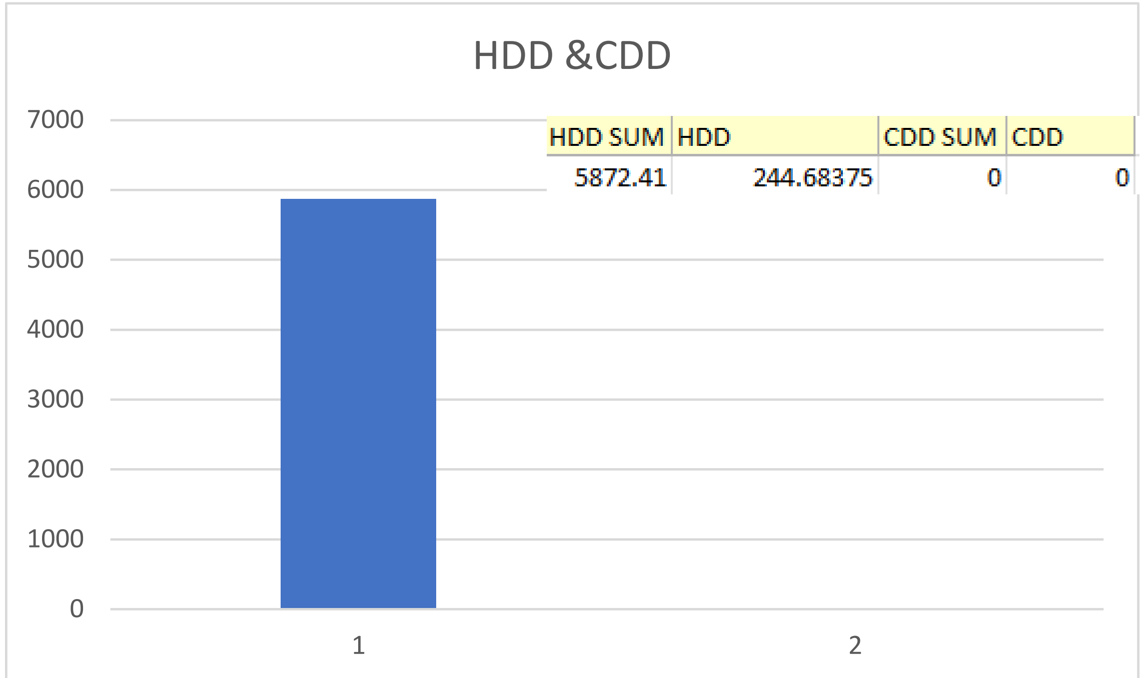
Systems Integration Scheme in PLan

Degree Days and Climate in Tena

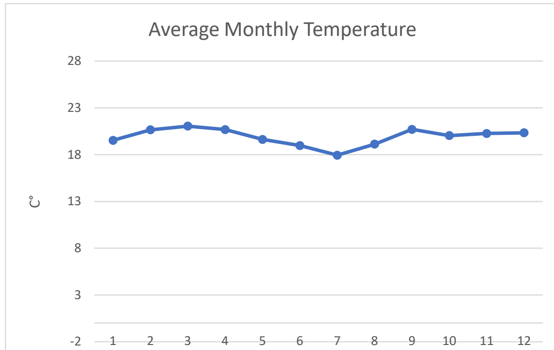
The initial stage in determining heat loss involves utilizing weather data for Tena, Ecuador. Heating Degree Days (HDD) are calculated by establishing a base temperature of 19 degrees Celsius and assessing the period from October 22nd to April 3rd. During this timeframe, the goal is to identify the number of degrees by which the daily average temperature falls below the base temperature. This information is then aggregated for the entire period, providing a measure of the demand for heating during the colder months.

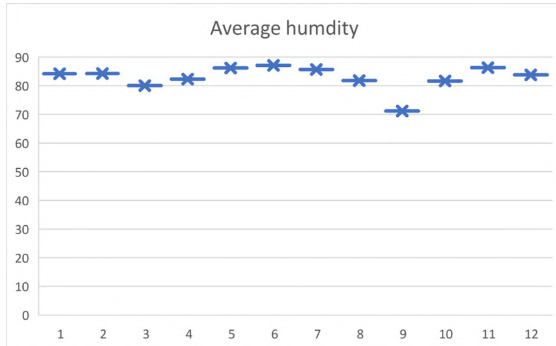
Conversely, Cooling Degree Days (CDD) are computed using a base temperature of 27 degrees Celsius, and the analysis encompasses the remaining months of the year. In this case, the objective is to determine the number of degrees by which the daily average temperature exceeds the base temperature, indicating the demand for cooling. The cumulative value over the entire year reflects the cooling requirements for the given location.

In the context of the provided data for Tena, the calculation yields 5872 Heating Degree Days, representing the cumulative demand for heating, and 0 Cooling Degree Days, indicating no cooling requirements over the course of one year. These metrics are essential for understanding and estimating the energy needs for heating and cooling systems in a specific climate, aiding in efficient energy management and building design.



HDD and CDD diagram





time(UTC)	T2m	RH	G(h)	Gb(n)	Gd(h)	IR(h)	WS10m	WD10m	SP
20060101:	19.33	85.08	0	0	0	359.95	0.84	320	95148
20060101:	19.01	85.65	0	0	0	357.68	0.86	269	95242
20060101:	18.69	86.21	0	0	0	355.42	0.88	289	95317
20060101:	18.36	86.78	0	0	0	353.15	0.9	288	95383
20060101:	18.04	87.35	0	0	0	350.89	0.92	288	95401
20060101:	17.72	87.91	0	0	0	348.62	0.94	302	95373
20060101:	17.4	88.48	0	0	0	346.36	0.96	297	95307
20060101:	17.07	89.05	0	0	0	344.09	0.98	293	95213
20060101:	16.87	83.8	0	0	0	330.8	1.17	290	95157
20060101:	17.02	80.85	0	0	0	328.2	1.17	296	95195
20060101:	16.9	79.9	0	0	0	331.2	1.24	296	95232
20060101:	17.16	79.7	0	0	0	362.8	1.1	292	95317
20060101:	17.3	80.2	14	0	14	338.8	1.03	292	95392
20060101:	18.6	87.85	32	0	32	352.4	0.34	278	95505
20060101:	20.25	83.25	146	6.51	142	346.2	0.83	129	95543
20060101:	21.48	81.25	616	262.72	413	336.6	1.24	132	95524
20060101:	22.29	80.5	672	201.45	495	345.4	1.86	128	95496
20060101:	23.23	81.7	981	900.38	148	348.8	1.72	116	95439
20060101:	22.19	80.6	960	894.29	147	353	1.66	123	95345
20060101:	22.04	83.45	863	867.06	142	361.4	0.97	101	95251
20060101:	22.5	81.8	701	815.44	132	380.8	1.17	103	95195
20060101:	22.38	79.1	487	719.64	115	364.8	1.1	87	95138
20060101:	20.74	81	10	0	10	364	0.76	72	95148
20060101:	20.4	81.75	0	0	0	371.6	0.28	27	95138
20060102:	19.73	88.05	0	0	0	348	0.41	1	95157
20060102:	19.79	83.3	0	0	0	332.85	0.41	15	95279

month	year	Average Temperature	Average Humidity	Average Wind Speed	Average Surface	Average Global Irradiance
1	2006	19.52864474	84.14751316	0.910881579	95410.68947	357.7424868
2	2015	20.65	84.21	1.01	95462.5	368.87
3	2006	21.045	80.05	0.9	95335.5	361.755
4	2010	20.685	82.275	0.91	95415.5	362.595
5	2007	19.63	86.185	0.72	95486.5	361.2
6	2006	18.97	87.085	0.51	95618	366.29
7	2007	17.945	85.65	1.115	95594.5	355.165
8	2012	19.125	81.745	0.755	95505	357.195
9	2014	20.7	71.19	1.245	95523.5	339.45
10	2005	20.035	81.635	1.12	95486.5	357.315
11	2009	20.26	86.295	0.895	94964	363.46
12	2014	20.33	83.795	0.81	95387	361.715

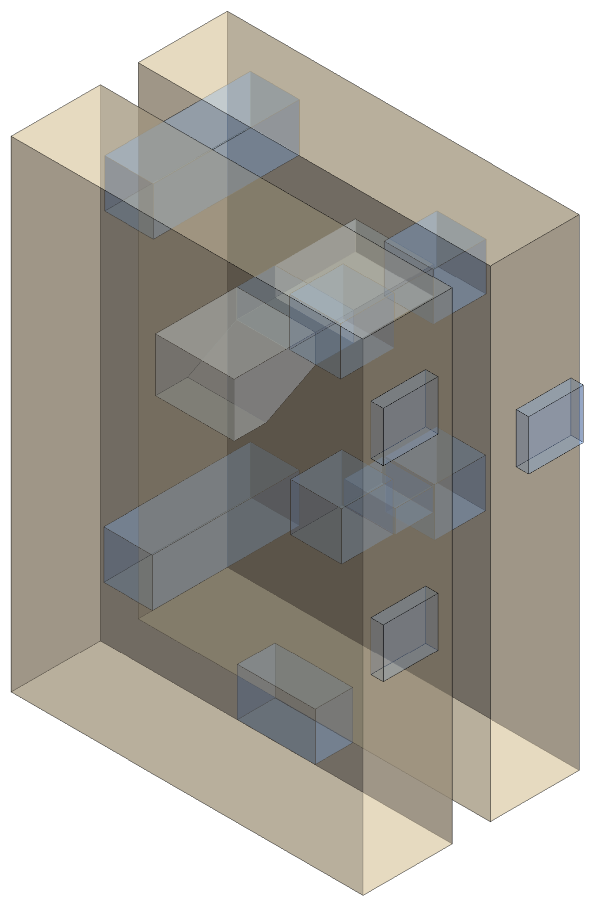
BASE W	RESULTS	POSITIVE RESULTS	BASE S		POSITIVE RESULTS	HDD SUM	HDD	CDD SUM	CDD
19	-0.33	0	27	-7.67	0	5872.41	244.68375	0	0
19	-0.01	0	27	-7.99	0				
19	0.31	0.31	27	-8.31	0				
19	0.64	0.64	27	-8.64	0				
19	0.96	0.96	27	-8.96	0				
19	1.28	1.28	27	-9.28	0				
19	1.6	1.6	27	-9.6	0				
19	1.93	1.93	27	-9.93	0				
19	2.13	2.13	27	-10.13	0				
19	1.98	1.98	27	-9.98	0				
19	2.1	2.1	27	-10.1	0				
19	1.84	1.84	27	-9.84	0				
19	1.7	1.7	27	-9.7	0				
19	0.4	0.4	27	-8.4	0				
19	-1.25	0	27	-6.75	0				
19	-2.48	0	27	-5.52	0				
19	-3.29	0	27	-4.71	0				
19	-4.23	0	27	-3.77	0				

U-value calculation of the envelope

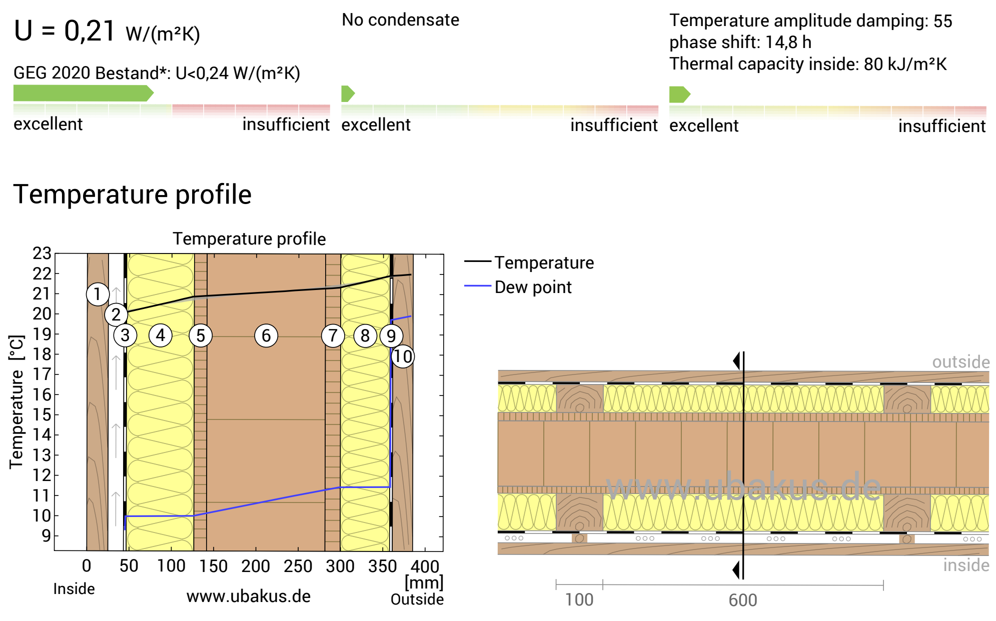
U-value, also known as thermal transmittance, is a crucial parameter in building construction and energy efficiency. It represents the rate at which heat is conducted through a structure, such as a wall, roof, or window. The U-value is expressed in watts per square meter kelvin (W/m^2K) and indicates the thermal conductivity of a material or an assembly of materials.

A lower U-value signifies better insulation and, consequently, reduced heat loss. It is a key factor in determining a building's overall energy performance and its ability to maintain a comfortable indoor temperature while minimizing the need for excessive heating or cooling. We used the U-value calculations to make informed decisions about the selection of building materials and components, aiming to achieve optimal thermal efficiency and meet energy conservation standards. In summary, a lower U-value indicates better insulation properties and improved energy efficiency in a building.

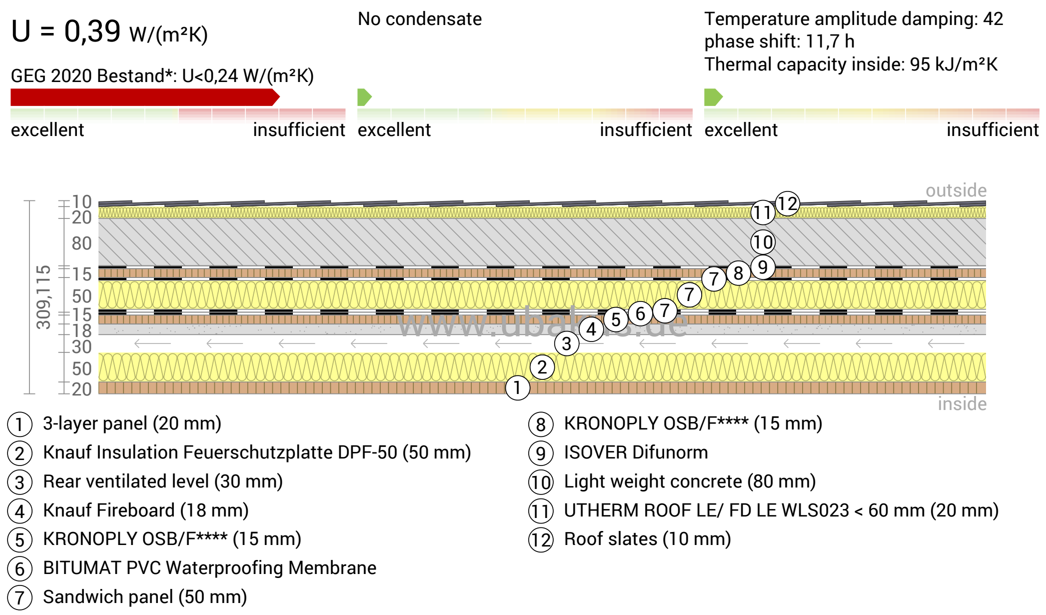
The U-value takes into account the thermal conductivity of materials, as well as their thickness and arrangement in a building assembly. Windows, walls, roofs, and doors all contribute to a structure's overall U-value. In the tower design we tried to balance the design consideration with the material selection.



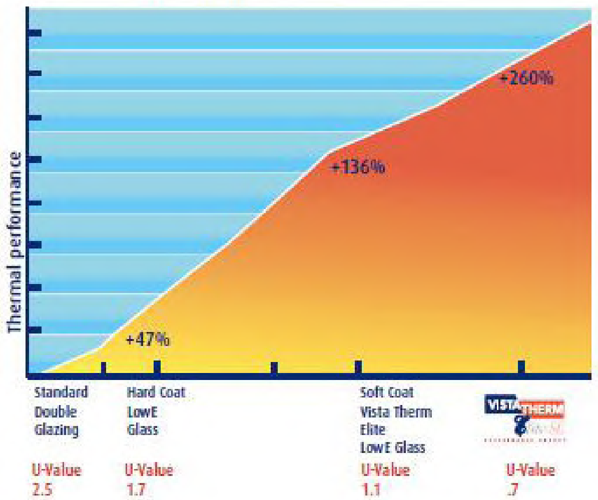
Buildinh Envelope Summary



Wall Layers and U-value



Roof Layers and U-value



Glass U-Value

U-value calculation of the envelope

Utilizing the previously determined heating degree days and the U-value specific to each envelope type, we employ a comprehensive methodology to compute heat loss and consequent energy dissipation through each facade of the building. This involves applying the formula U x A x ΔT x HDD (hours), with a designated indoor temperature target of 19 degrees Celsius during the winter season.

In this formula, "U" represents the U-value characterizing the thermal conductance of the building's envelope, "A" denotes the surface area of the facade under consideration, "ΔT" signifies the temperature difference between the interior and exterior environments, and "HDD" reflects the heating degree days. By incorporating these variables into the calculation, we gain insights into the intricate dynamics of heat transfer and energy loss across various building facades.

	U-Value (W/(m²K)	sqm	ΔT	Heat Loss (W)	Heat Loss (kW)	HDD (hrs)	Annual Energy Loss (kWh)
Opaque Wall	0.18	10,080 sqm	16	29,030.4	29.03	5,872	170,404
Roof	0.39	1,600 sqm	16	9,984	9.9	5,872	58,132
Curtain Wall	1.10	11,815 sqm	16	12,996.5	13	5,872	76,336
Spandrel Panels	0.21	59 sqm	16	198.24	0.21	5,872	1,233
			16				306,105

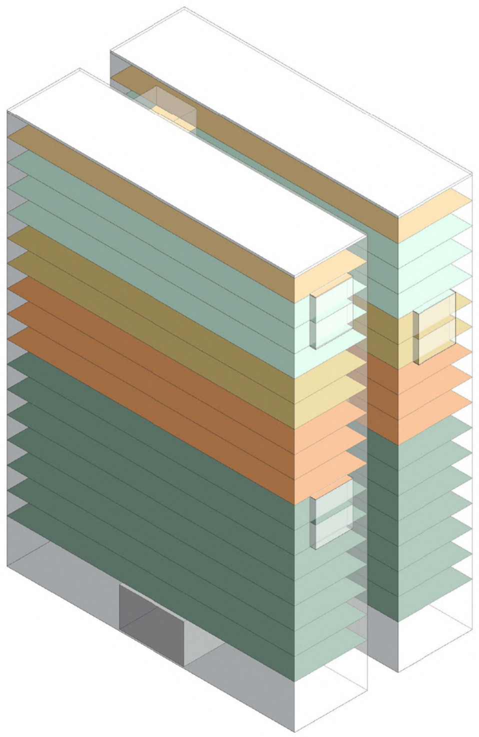
This approach extends beyond mere numerical computations; it involves a nuanced understanding of the building's thermal characteristics and the environmental conditions it encounters. The utilization of a specific indoor temperature target adds a practical dimension to the analysis, aligning the calculations with real-world conditions. Through this method, we not only quantify heat loss but also establish a foundation for informed decision-making regarding energy-efficient measures and thermal performance enhancements in the building envelope.

Formula - U x A x ΔT x HDD (hours) using a target indoor temperature of 19C in the winter.

LIGHTING ENERGY DEMAND

After calculating the energy required for heating, we shift our focus to determining the amount of energy needed to illuminate the building and its energy demand. To do this, we first establish a desired level of illumination, known as target illuminance, and then determine the number of hours of lighting needed based on the building's program and daylighting conditions. Based on the programme there are 5 distinctive zones with different working hours and hence different daylight requirements. Next, we calculate the power required to achieve the target illuminance level, and from that, we can determine the annual energy demand caused by lighting.

- Zone 1(I.01 to I.07) - Library & Co-working - Opening 09:00/ Closing 21:00 / 12h
- Zone 2 (I.08 to I.10) - Arts & Crafts - Opening 09:00/ Closing 17:00 /8h
- Zone 3 (I.11 to I.12) - Conference - Opening 09:00/ Closing 15:00 / 6h / when needed
- Zone 4 (I.13 to I.15) - Offices and Labs - Opening 08:30/ Closing 18:30 / 10h
- Zone 5 (I.16) - Cafe - Opening 08:30/ Closing 16:30 / 8h

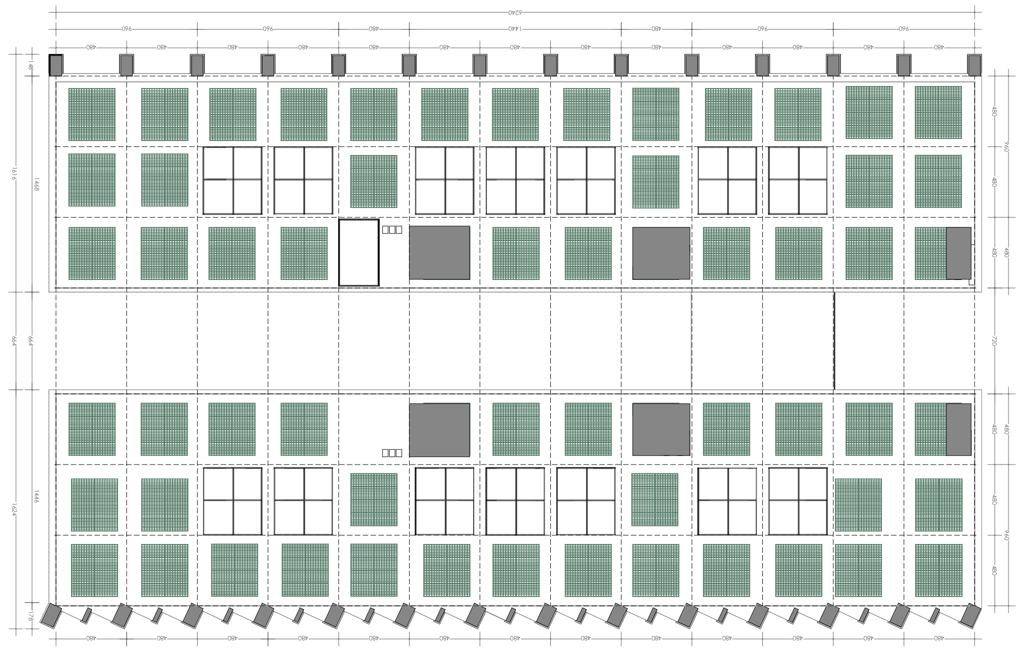

Working Hours Scheme

ENERGY CONSUMPTION DUE TO LIGHTING USING FLUORESCENT LAMPS		
Average Target Illuminance Level		100 lux
Zone 1: Period Of Illumination	12	h/day
Zone 1: Total Floor Area	10,780	sqm
Zone 2: Period Of Illumination	8	h/day
Zone 2: Total Floor Area	4.656	sqm
Zone 3: Period Of Illumination	6	h/day
Zone 3: Total Floor Area	4,943	sqm
Zone 4: Period Of Illumination	10	h/day
Zone 4: Total Floor Area	3116	sqm
Zone 5: Period Of Illumination	8	h/day
Zone 5: Total Floor Area	1588	sqm
W/M² Required To Reach 150 Lux	5.5	W/m2
Daily Energy Demand For Zone 5	69.87	kWh
Daily Energy Demand For Zone 4	171.38	kWh
Daily Energy Demand For Zone 3	163.12	kWh
Daily Energy Demand For Zone 2	204.86	kWh
Daily Energy Demand For Zone 1	711.48	kWh
Total Daily Lighting Demand	1320.72	kWh
Total Yearly Lighting Demand	**482,060.98**	kWh

SOLAR ENERGY SUPPLY

Solar panels, also known as photovoltaic (PV) panels, are devices designed to convert sunlight into electricity. They are composed of multiple solar cells, typically made from semiconductor materials like silicon. These cells absorb photons from sunlight, which in turn generates an electric current through the photovoltaic effect. Solar panels are the building blocks of solar power systems and are widely used to harness renewable energy from the sun.

In a solar panel system, these panels are arranged on rooftops or open spaces to capture sunlight effectively. The total power output of the system depends on factors such as the number of panels, their efficiency, and the amount of sunlight the location receives. The electrical output from each panel is direct current (DC), and it is then converted into alternating current (AC) using inverters to make it compatible with standard electrical systems.


PV Panels Roof Plan

To determine the power generated by the solar panels, we multiply the output of a single panel by the total number of panels installed on the roof. Additionally, we factor in the average daily sunlight hours for the city of Tena. The resulting calculation yields a total annual output of 1,681,920 kilowatt-hours (kWh).

This amount is a lot more than the combined energy demand for heating and lighting, which is estimated at 482,060 kWh + 306,105 kWh = 788,165per year. This indicates that the solar panel system is capable of meeting the energy requirements for both heating and lighting in the specified location, highlighting the efficiency and sustainability of the solar power solution.

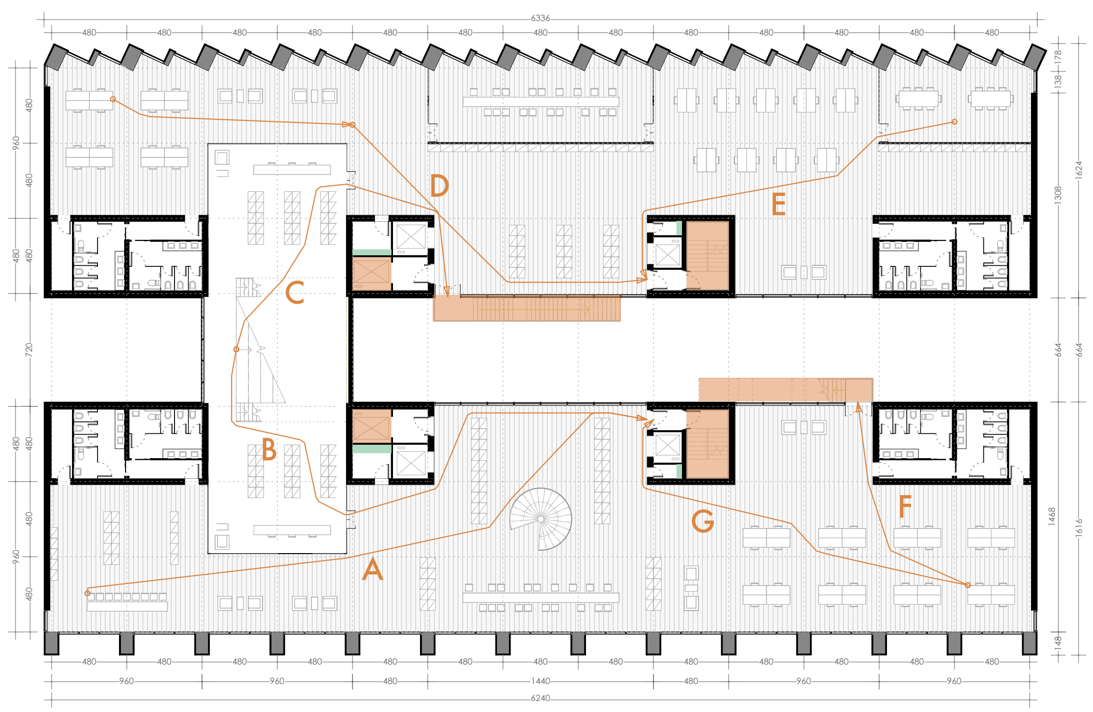
The solar panels can be also used by the city grid for a sustainable energy accumulation.

SOLAR PANEL OUTPUT		
Solar Panel Size (90X150Cm)	1.35	sqm
Ideal Tilt For Panels In Tens	0	degrees
Effective Usable Roof Area	1152	sqm
Roof Area Used For 1 Panel	1.35	sqm
Number Of Panels On The Roof	**400**	
Output Of 1 Solar Panel (W)	450	w
Average Direct Sun Hours	6	hours/day
Daily Energy Output Per Panel	**1.92**	kWh/day
Total Daily Energy Output	**4,608.00**	kWh/day
Total Annual Energy Output	**1,681,920.00**	**kWh/year**

FIRE PROTECTION

In timber buildings, fire protection is a crucial consideration to ensure the safety of occupants and minimize the risk of fire-related damage. In Ecuador, adherence to local fire codes is imperative to establish standards for fire safety. Fire protection measures in timber structures typically involve the use of fire-resistant materials, such as treated timber or fire-retardant coatings, to enhance the building's resistance to ignition and slow the spread of flames. Additionally, the design and implementation of exit fire routes are fundamental in ensuring swift and secure evacuation during emergencies. According to Ecuadorian fire codes, the distance of exit routes must comply with specified regulations to guarantee that occupants can evacuate the building safely and efficiently. These regulations may include guidelines on the width of exit routes, the placement of emergency exits, and the incorporation of fire-resistant doors and barriers.

Fire escape routes
Smoke shafts

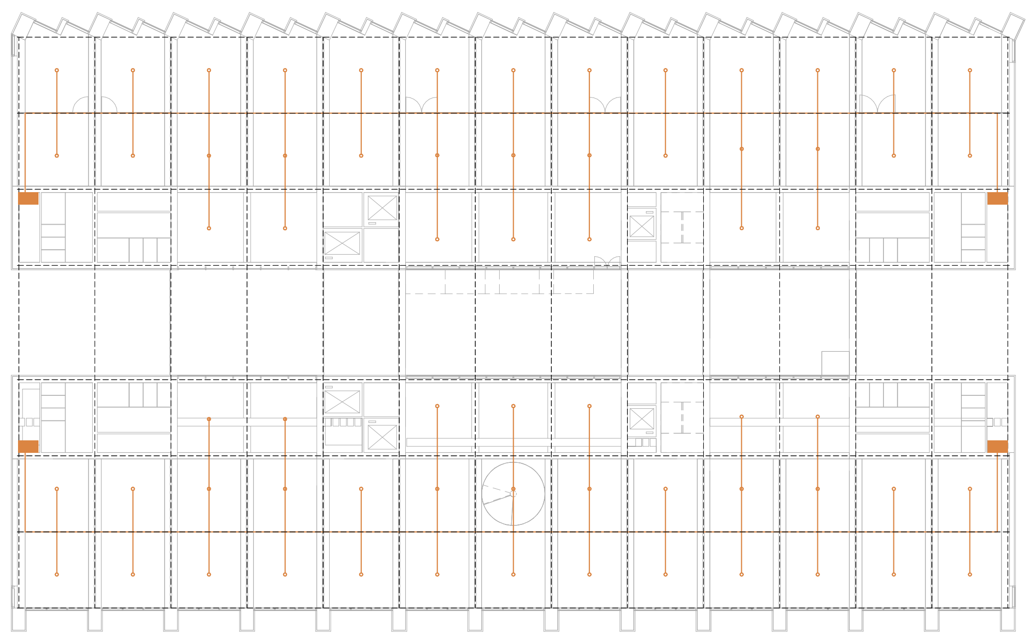


Fire Exit Route Plan Level 02

	Lenght	Time	Speed
Path A	35m	25.7s	4.828 km/h
Path B	37m	28.3s	4.828 km/h
Path C	25m	18.7s	4.828 km/h
Path D	38m	28.1s	4.828 km/h
Path E	26m	19.4 s	4.828 km/h
Path F	15m	11.5 s	4.828 km/h
Path G	26m	19.8 s	4.828 km/h

Integrating sprinkler systems for fire protection within a wooden floor system cavity represents a crucial advancement in modern fire safety engineering. This innovative approach combines the structural elements of a building with life-saving fire suppression technology. Typically concealed within the floor cavity, these sprinkler systems are designed to activate rapidly in the event of a fire, effectively controlling and extinguishing flames before they escalate. The integration of sprinklers into wooden floor systems enhances both aesthetic and functional aspects of a space, as the system remains hidden from view while providing robust fire protection. This proactive approach not only safeguards the structural integrity of the wooden elements but also minimizes potential damage caused by traditional overhead sprinkler systems.

Sprinkler shaft
Sprinklers



Reflected Ceiling Plan with Sprinklers Level 02

WATER CONSUMPTION

To determine the building's water usage, our initial step involves approximating the daily number of visitors by analyzing data from analogous libraries situated in cities of comparable size. This comparative approach allows us to extrapolate visitor statistics that align with the building's scale and urban context. Subsequently, we proceed to assess plumbing water consumption, encompassing facilities such as toilets and sinks. This evaluation is based on statistical information regarding the average water usage patterns observed in public buildings.

Moving beyond the general assessment, our analysis extends to specific areas such as the cafe within the building. Here, we gauge water consumption by referencing the average usage observed in restaurants, adjusting it proportionally to the cafe's floor area. This targeted approach ensures a nuanced understanding of water needs in a distinct functional space, catering to the unique requirements of the building's diverse areas.

	Estimating Daily users of tower		
	sqm	yearly users	daily users
Tena Tower	27,000	547500	1500
Sara Cultural Centre Skellefteå	30,000	857750	2350

Plumbing water consumption		
average daily users	1500	people
avg time spent / visit	3	hours
avg water use / person / hour	3.5	litres
avg daily water condumpsion	**15,750.00**	**L/day**

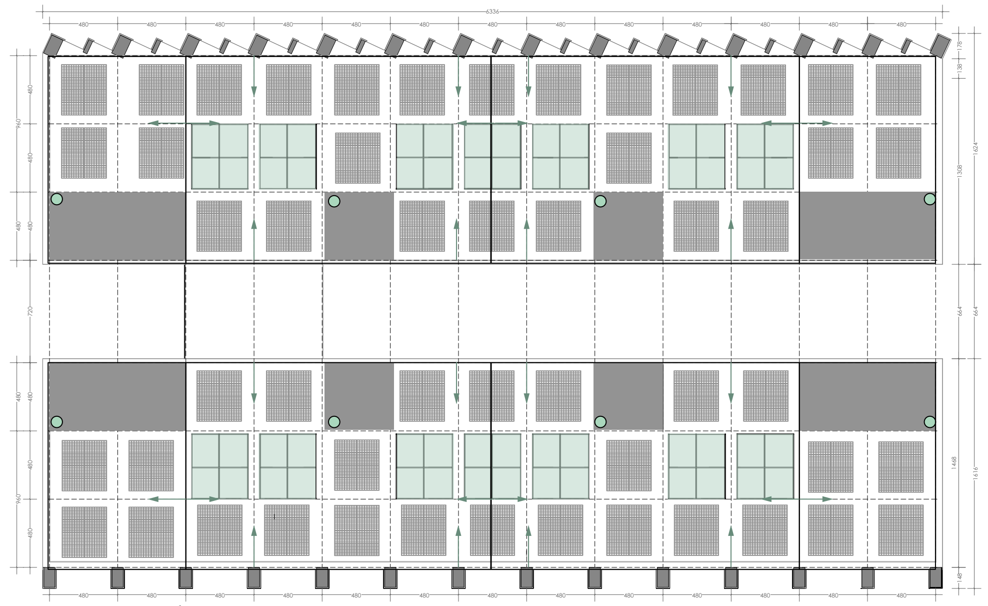
Cafe Water Consumption		
average consumption per sqm	21	litres/sqm
café LFA	1200	sqm
total café water consumption	**25,200.00**	**L/day**

Water Collection		
For every sqm 1mm of rainfall = 1L of water		
Tena avg yearly precipitation	4,359.91	mm
Total roof surface area	1,600	sqm
Total water collected per year	6,975,856.00	L/year
Total water collected per day	**19,111.93**	**L/day**

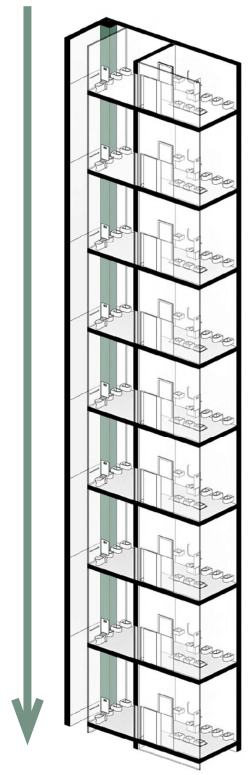
Total daily water consumption	**40,950.00**	**L/day**
Total daily water collection	**19,111.93**	**L/day**
Total Daily water deficit	**21,838.07**	**Litres**

This comprehensive methodology ensures a thorough examination of water utilization throughout the building, considering both common areas and specialized spaces. By incorporating statistical insights and industry benchmarks, we aim to provide an accurate depiction of water consumption patterns that is tailored to the building's characteristics and functionalities.

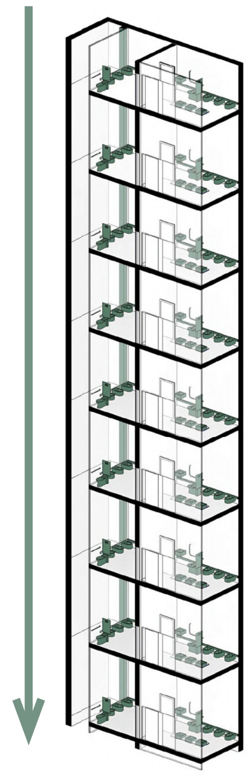
The plan shows the plan of the water drainage systems integrated in the roof with a slope ot 7 %. The drains connect vertically in the cores of the buildings to lead the rainwater into the tank at the basement level so that the water can be reused in the toilets as greywater or for irrigation purposes.



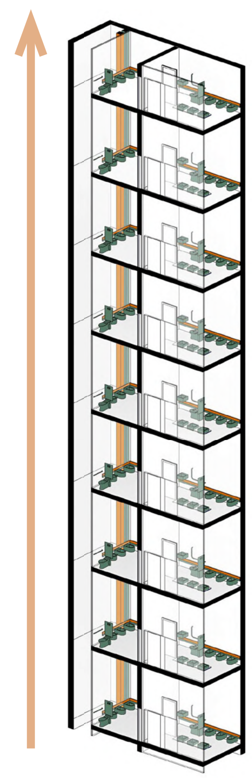
Drainage Plan Roof



Draingae Scheme



Toilet Grey Water Discharge



Toilet Fresh Water Supply

08 CONCLUSION

This project was developed under an integral approach of architectural, structural, and technological components. The theoretical tools and city analysis allowed us to propose a tall building that belongs to the site and has a well-defined relation with the context. The chosen materiality corresponds to the sustainable criteria and the location. Furthermore, the structural analysis shows that the timber building stands over different actions, especially the lateral forces in a seismic zone.

We took the challenge to experiment, learn, and propose a timber building in a precious nature-characterized context, we searched for a design that belongs to the site and that makes use of the qualities of the place and emphasizes the local wealth with its cultural and research program.

Regularity in the exterior and complexity in the interior, connecting the different functions by vertical circulations and generating articulated spaces with the external stairs and bridges.

Throughout the development of the study, the objectives set have been met and as the final project of the Master of Science in Building Architecture the "Amazon Healing" is a tower that represents the necessary collision between different areas of the design of an executive project, urban analysis, architectural design, the feasibility of using BIM tools, knowledge of material properties, the response to bioclimatic aspects and the essential understanding of structural behavior.

1:200 Physical Model

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