LUMINOUS MINDS:
ENHANCING COGNITIVE PERFORMANCE AND KNOWLEDGE ACQUISITION IN FUTURE LIBRARIES THROUGH THE LIGHTING LANDSCAPE



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RESEARCH REPORT

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ABSTRACT

This research explores how lighting landscapes can be strategically designed in future library environments to stimulate user-driven knowledge acquisition and cognitive performance, with a specific focus on the Royal Library in The Hague (KB) as a case study. Throughout history, libraries have evolved from static, exclusive book repositories into dynamic, public learning environments. Central to this transformation is the role of light, which is not just a source of illumination, but also a spatial and neurological stimulant influencing cognition, engagement and user experience.

Despite growing interest in lighting's psychological effects, its integration as a cognitive tool in library design remains underexplored, particularly in heritage settings such as the KB. This thesis addresses that gap by asking: *How can the lighting landscape be designed to stimulate user-driven knowledge acquisition and cognitive performance in the 'Future Library'?*

The study adopts a hybrid theoretical framework informed by neuroscience, architecture, and lighting design. It explores how light affects cogntive performance and knowledge acquisition and how spatial lighting conditions can shape user experience. A mixed-method approach was used, including literature review, empirical research, and design-oriented research.

Findings show that both natural and artificial lighting strongly influence circadian rhythms and cognitive states. Stable light and dark cycles, access to layered views, and lighting systems combining ambient, task, and accent lighting were found to enhance cognitive performance. Other key themes include glare reduction, spatial zoning, and the value of user-controlled lighting.

The outcome of this study is an evidence-based library lighting framework that offers research-informed strategies for designing cognitively responsive library environments. The framework prioritises orientation, spatial form, building openings, daylight controls, artificial lighting quality, and user autonomy.

This thesis ultimately demonstrates that lighting must be treated not merely as a technical or aesthetic feature but as a foundational design element, one that can actively support knowledge acquisition and cognitive performance in the library of the future.

PREFACE & ACKNOWLEDGEMENTS

This thesis was written as part of the graduation project for the Revitalising Heritage Graduation Studio (AR3AH115), which forms part of the MSc Architecture programme at Delft University of Technology.

Having previously worked exclusively on new-build design projects during earlier master's studio courses, I considered it both relevant and enriching to engage with an adaptive reuse context for my graduation project. It was a natural decision to focus on library architecture. Libraries offer a unique opportunity to align architectural expression with intellectual curiosity, resulting in a public typology that is both symbolically rich and socially meaningful. The Royal Library in The Hague provided an ideal case study for this ambition.

The subject of this graduation project is situated at the intersection of architecture, neuroscience, and lighting design. Rather than treating light as a purely technical requirement, this project positions lighting as a spatial and neurological tool that supports knowledge acquisition and cognitive performance. This aligns with the studio's emphasis on sustainable and future-proof transformations of public heritage buildings.

I would like to express my sincere gratitude to those who supported me throughout this process. I thank my graduation committee: Prof. Dr.-Ing. Uta Pottgiesser (design tutor), Dr. M. (Emeline) Lin (research tutor), and Dr. A.J. (Aart) Oxenaar (research tutor), whose valuable feedback, expertise, and critical insights helped steer this project in the right direction. A special thanks to Uta for her support in establishing valuable connections with external parties, including contacts at Technische Hochschule Ostwestfalen-Lippe in Detmold.

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CHAPTER 1: INTRODUCTION

Throughout history, libraries have played a vital role in preserving and disseminating knowledge. Initially, they served as exclusive repositories for manuscripts and books, accessible only to an elite group of scholars, rulers, and religious figures. Early libraries, such as those in Mesopotamia, Egypt, and Greece, were closely tied to centers of governance and learning, emphasising control over knowledge. As libraries evolved, their role expanded beyond mere storage. During the medieval period, libraries were often integrated into monasteries and cathedrals, where ornate architecture and intricate detailing reflected both religious devotion and intellectual prestige. The grand and monumental libraries of later centuries further reinforced the notion of knowledge as a symbol of power and enlightenment (Lushington et al., 2016; Kececi, 2024).

The architectural design of early libraries played a crucial role in shaping the user experience. Limited access to daylight was a defining feature, influenced by both practical and symbolic considerations. As early libraries were primarily designed to preserve rare and valuable collections of books, scrolls, and manuscripts, their enclosed nature helped to protect these collections from physical deterioration and unauthorised access. At the same time, this exclusivity reinforced their perception as institutions reserved for the elite. However, medieval libraries were not entirely dark; they often incorporated controlled natural light that allowed scribes to work effectively. Since artificial lighting did not yet exist, library interiors were often dimly lit, resulting in a somewhat sombre atmosphere (Malman, 2009).

The transition of libraries from exclusive archives to dynamic learning spaces was a gradual process, accelerating with the invention of the printing press in 1439. The mass production of books led to increased accessibility and democratisation of knowledge. This evolution continued into the 18th and 19th centuries, with the establishment of public libraries that prioritised accessibility and enlightenment for all. Modern libraries have continued this trend, shifting from static book repositories into dynamic learning environments, characterised by open, flexible spaces that emphasise user-friendliness, accessibility, engagement, and comfort. A key aspect of this transformation is the growing integration of both natural and artificial light to shape the spatial experience[1] while enhancing cognitive engagement[2] and overall well-being (Lushington et al., 2016).

This shift underscores a pivotal challenge in library design: the creation of environments that simultaneously support cognitive performance[3] and knowledge acquisition[4] while ensuring an optimal spatial experience. Lighting plays a crucial role in achieving this balance. Natural light has been shown to enhance the spatial experience, improve concentration and learning, and support cognitive engagement by regulating circadian rhythms[5] and increasing alertness (Çelik et al., 2024). However, the benefits of natural light must be carefully managed to avoid glare, visual discomfort, and potential distractions. Conversely, artificial lighting provides greater control over environmental conditions; however, if not designed effectively, it can disrupt the ambiance and hinder cognitive performance (Baeza Moyano et al., 2020). The challenge lies in developing an optimal lighting strategy that balances the interaction between light, the built environment, and the neurological processes involved in user-driven knowledge acquisition and cognitive performance.

1 Spatial experience refers to the way individuals perceive and interact with a physical space, influenced by various factors such as layout, lighting, and acoustics. Lighting, in particular, can enhance the spatial experience by creating a comfortable and engaging atmosphere, or it can disrupt it through issues like glare, visual discomfort and potential distractions.

2 Cognitive engagement refers to the mental effort and focus a person applies when processing information, involving activities like concentration, analysis, and problem-solving to enhance learning and knowledge retention.

3 Cognitive performance refers to an individual's ability to process information, retain knowledge, focus attention, and solve problems within a specific environment. In this study, it refers to the user's mental functioning within a library setting.

4 Knowledge acquisition refers to the process of obtaining, understanding, and internalizing information or skills through learning, experience, or instruction.

5 Circadian rhythms are internal processes that regulate the sleep-wake cycle and other physiological functions, typically on a 24-hour cycle. They are influenced by external factors, especially light, which helps synchronize these processes and promote alertness and well-being.

This study will investigate how the lighting landscape in the ‘Future Library’ can be designed to optimise user-driven knowledge acquisition and cognitive performance. By analysing the neurological effects of light on cognitive processes and knowledge acquisition, exploring spatial lighting strategies, and identifying effective lighting solutions for the Royal Library’s existing structure, this research aims to bridge the gap between architectural lighting design and cognitive optimisation. Furthermore, the study will explore how varying lighting conditions influence different learning acquisitions, ensuring that the Future Library, including the Royal Library as a key case study, actively supports diverse modes of learning and cognitive engagement through a well-designed lighting landscape[6].

6 Lighting landscape refers to the integrated system of natural and artificial lighting within a spatial environment, designed to support cognitive, emotional, and spatial experiences. It includes dynamic modulation, seasonal variability, and interaction with architectural elements.

1.2 PROBLEM STATEMENT

Libraries have evolved from being exclusive book repositories to becoming interactive and dynamic learning spaces, with a focus on accessibility, engagement, and adaptability. However, the challenge of creating an environment that optimises cognitive performance and knowledge acquisition remains underexplored in contemporary library design. A key factor in creating such an environment is lighting. The role of lighting extends beyond mere illumination; it is a crucial factor in cognitive performance, user-driven knowledge acquisition, and overall well-being (Çelik et al., 2024).

The static and monotonous nature of current library environments often fails to support the diverse cognitive needs of users. As Matthijs van der Meulen (intermediary at the Royal Library (KB) of the Netherlands) notes about the current KB building: "Every day is the same here" and "One doesn't notice the seasons here", highlighting the lack of adaptive and dynamic lighting approaches in existing library environments.

Although extensive research has been conducted on the impact of lighting on cognition in workplaces and educational settings, and numerous guidelines exist for energy-efficient and functional lighting in buildings, its application within libraries, particularly heritage buildings such as the Royal Library in The Hague, remains underexplored. In this context, the Royal Library serves as an ideal case study for exploring how lighting strategies can be integrated into an existing heritage building, with the aim of optimising both the cognitive and spatial needs of users while respecting its historical significance.

A clear research gap exists in linking the neurological effects of the overall lighting landscape to its spatial role in library design and its impact on user-driven knowledge acquisition and cognitive performance. This research aims to address this gap by exploring how lighting strategies can be optimised to enhance cognitive performance and support user-driven knowledge acquisition in future libraries. Drawing on insights from neuroscience[7] and lighting design, the goal of this study is to develop an evidence-based spatial lighting framework for libraries that positions (day)light as a neurological stimulant[8]. The outcome will contribute to the discourse on neuroarchitecture and guide future library design in aligning spatial lighting with cognitive needs.

7 Neuroarchitecture is the field that explores the relationship between the brain and the built environment, focusing on how architectural elements like light, space, and design influence cognitive processes, emotional well-being, and behavior. It aims to design environments that support neurological functions, enhancing mental health, productivity, and overall human performance.

8 Neurological stimulant refers to an environmental factor that influences brain functions such as attention, memory, alertness, and emotional regulation. In this study, light is considered a neurological stimulant, particularly through the interaction of natural and artificial lighting, because of its impact on circadian rhythms and hormonal processes. This interaction enhances cognitive performance and supports knowledge acquisition in libraries.

1.3 RESEARCH QUESTIONS AND THEORETICAL FRAMEWORK

Building on the problem of underexplored lighting strategies, this research examines how lighting can enhance cognitive performance and knowledge acquisition in the 'Future Library.' The main question focuses on designing an effective lighting landscape, with sub-questions addressing its neurological effects, spatial strategies, and integration in the Royal Library.

MAIN QUESTION

How can the lighting landscape be designed to stimulate user-driven knowledge acquisition and cognitive performance in the 'Future Library'?

SUB-QUESTIONS

What is the role of the lighting landscape in influencing the neurological processes that drive knowledge acquisition and cognitive performance in a library environment?

What spatial lighting strategies enhance user-driven knowledge acquisition and cognitive performance within libraries?

What are effective lighting strategies to integrate into the existing structure of the Royal Library to optimise knowledge acquisition and cognitive performance?

THEORETICAL FRAMEWORK

This research adopts a hybrid theoretical approach, combining insights from neuroscience, architecture and lighting design principles. The central hypothesis underpinning the project is that an integrated lighting landscape, specifically one that leverages both natural and artificial light, can function as both a spatial and neurological stimulant. This, in turn, will enhance cognitive performance and user-driven knowledge acquisition in future library environments.

At the core of the theoretical foundation lies the understanding that light directly influences the brain's cognitive functioning, including attention, memory, emotional regulation and alertness, through its regulation of circadian rhythms and hormonal processes (Çelik et al., 2024; Yang & Jeon, 2020). Simultaneously, architectural theory positions light as a spatial tool that can shape user orientation, engagement and the atmosphere of learning environments (Lushington et al., 2016; Baker & Steemers, 2002).

In synthesising these fields, this research proposes a neuroarchitectural framework in which light is conceived not just as a passive element but as an active component in shaping the knowledge environment. This framework aims to go beyond functional or energy-efficient lighting design, proposing an evidence-based strategy for future library lighting landscapes, with the Royal Library in The Hague as a case study.

In order to operationalise this theoretical framework and test the central hypothesis, the research employs a mixed-method approach[9]. The details of which will be explained step by step in the next chapter.

9 A mixed-method approach is a research strategy that combines both qualitative and quantitative methods to gain a more comprehensive understanding of a complex topic. Integrating data from various sources, such as literature reviews, interviews, surveys, and design-oriented research, it allows for cross-verification of findings, bridging theoretical insights with empirical evidence and enhancing the depth, validity and applicability of research findings.

1.4 METHODOLOGY

In order to ensure a comprehensive exploration of the research questions, this study integrates three complementary methodological strategies (mixed-method approach): literature review, empirical research, and design-oriented research. The combination of these methods offers both theoretical insight and practical contributions, ensuring a comprehensive approach to the research questions. The next chapter explains how each method will be applied and its role in the overall research.

LITERATURE REVIEW

To establish a solid theoretical foundation, the study's literature review is structured around key themes that align with the main and sub-research questions. The selection of relevant academic and scientific sources is guided by carefully chosen keywords reflecting the core themes of this study. The primary keyword and main search term is "Library lighting design," which helps identify research related to lighting strategies in libraries. However, as this term alone does not cover all relevant aspects, additional search terms will be used, including "Lighting and cognitive performance," "Lighting design for study spaces," "Daylight strategies for academic environments," "Library lighting design and user engagement," "Lighting design in academic and heritage buildings," "Lighting impact on learning performances," and "Lighting effect on books."

The literature review is organised around two interconnected domains to provide a comprehensive understanding of the topic. First, literature on the effects of (day)light on neurological processes involved in knowledge acquisition and cognitive performance will be reviewed, integrating insights from neuroscience and environmental psychology. Second, research on (day)light architectural design and concepts will be explored, focusing on how lighting strategies in educational and cultural environments, including libraries, can enhance knowledge acquisition and cognitive performance. These are often explained through the investigation of usefull case studies, investigating real-world applications.

To maintain focus and feasibility, the literature study has been based on a carefully selected pool of approximately 20 to 30 sources. These sources were selected based on their direct relevance to the research questions, as determined by an evaluation of abstracts, methodologies, and conclusions. The integration of insights from diverse disciplines is intended to provide a comprehensive understanding of the relationship between (day)lighting, knowledge acquisition, cognitive performance, and their architectural context. Figure 1 presents a matrix of the selected sources that inform this literature review, highlighting the associated themes and keywords identified within each source.

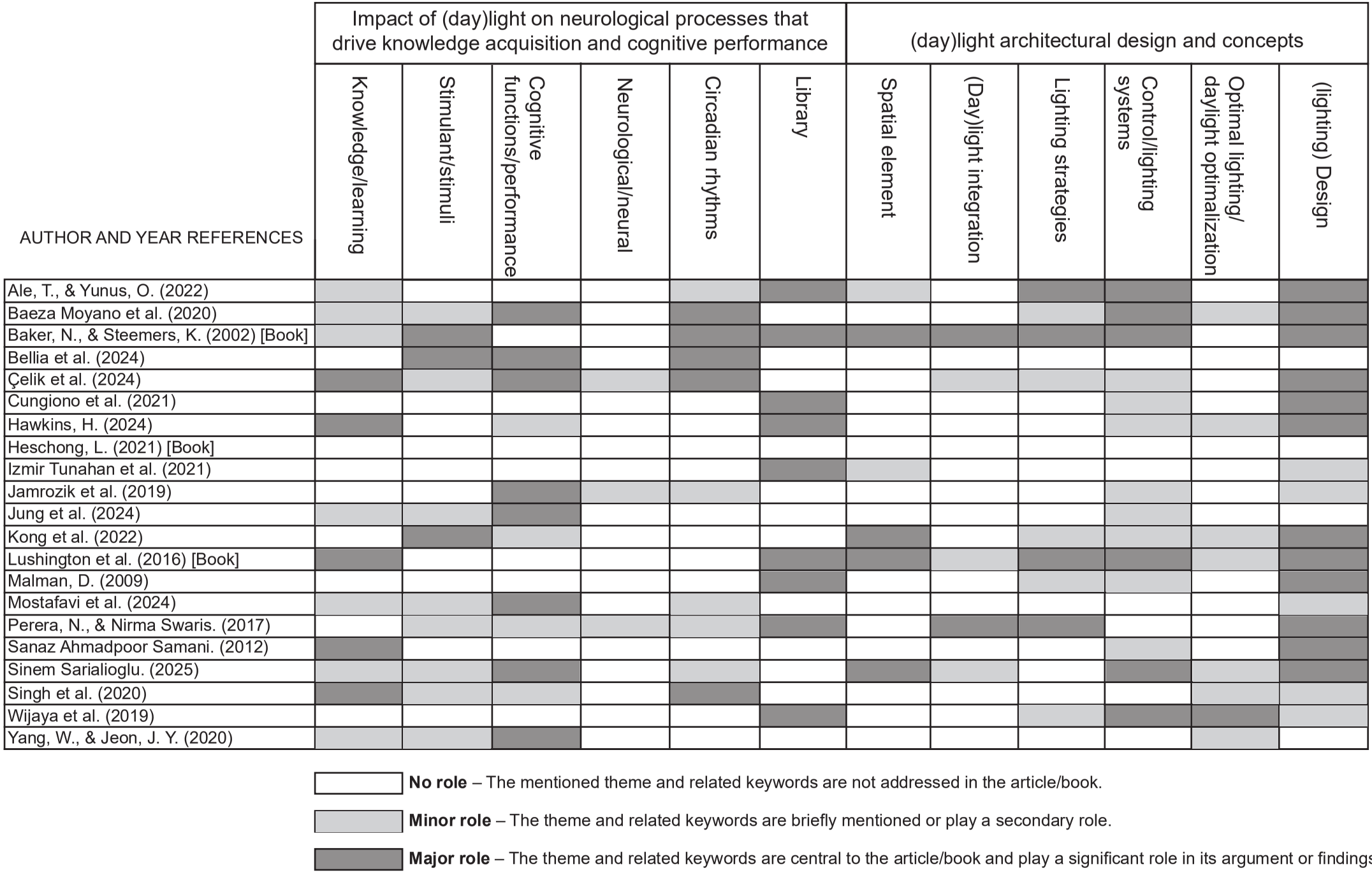


Figure 1. Literature matrix illustrating themes and keywords. Created by author.

EMPIRICAL RESEARCH

To complement the theoretical foundation established through the literature review, this study integrates empirical research via semi-structured interviews and a supporting survey. Together, these qualitative and quantitative instruments capture the experiences and preferences of the users of the Royal Library.

INTERVIEWS

Eleven interview sessions were conducted, each following the same protocol of fifteen targeted questions that map directly onto the study's main and sub-research questions. A total of twenty participants, all of whom were Royal Library users, shared detailed insights that are often absent from the scientific literature. Their responses were then coded and analysed thematically in order to reveal the buildings values, and user priorities.

SURVEYS

To broaden the empirical base, a survey was distributed and completed by thirty-six respondents. This quantitative instrument explores perceptions of visual comfort, concentration, productivity, and emotional well-being in the current Royal Library building. The survey data not only support the findings from the interviews but also highlight trends across a wider population.

The integration of these methodologies enables a comprehensive understanding of the subject matter, with interviews offering depth and context, and the survey supplying breadth and generalisability. The combination of these approaches serves to reinforce the study's empirical foundation, ensuring that the resulting insights are grounded in both theoretical reasoning and practical experience.

DESIGN ORIENTED RESEARCH (EXPERIMENTALISM)

In addition to the literature review and empirical research, design-oriented research will be carried out to explore how lighting strategies can be integrated into the existing structure of the Royal Library (KB) to enhance cognitive performance and knowledge acquisition.

As a preliminary step in this methodology, physical scale models and massing studies were used to experiment with different spatial configurations. The aim of these explorations was to assess how variations in volume and orientation influence the penetration and distribution of natural light within the library.

To build on these analogue studies with more precise data, digital simulations will be conducted using Sketchup software[10]. With this software, simulations can be created to model the interaction between natural lighting and artificial lighting across different times of day, seasons, and weather conditions within the space. This can provide insights into how these factors affect both spatial organisation and cognitive engagement. The results will inform evidence-based lighting design and contribute in forming a spatial lighting framework for future library spaces that enhance knowledge acquisition and cognitive performance.

10 Sketchup software is a professional design tool that is used to architectural spaces and concepts. In this study, it supports design-oriented research by modelling how lighting strategies affect cognitive performance and knowledge acquisition in the Royal Library.

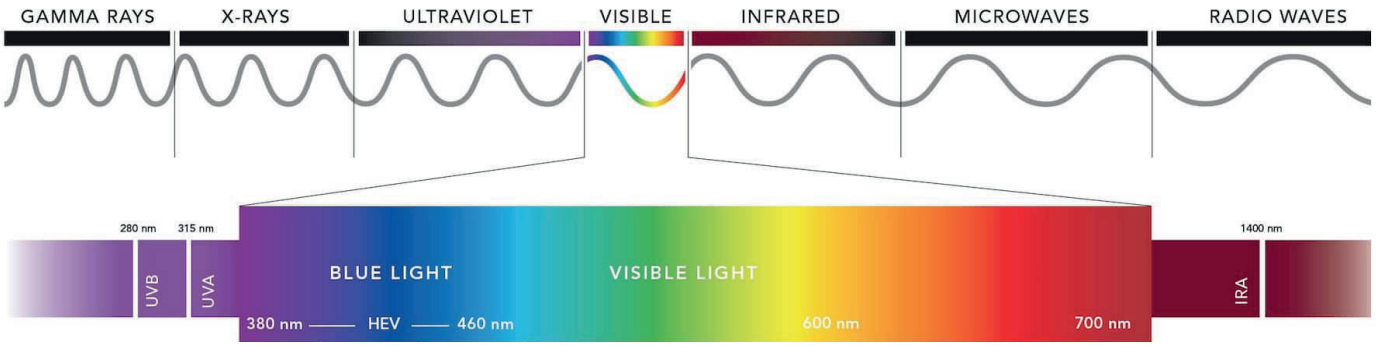
RESEARCH RESULTS

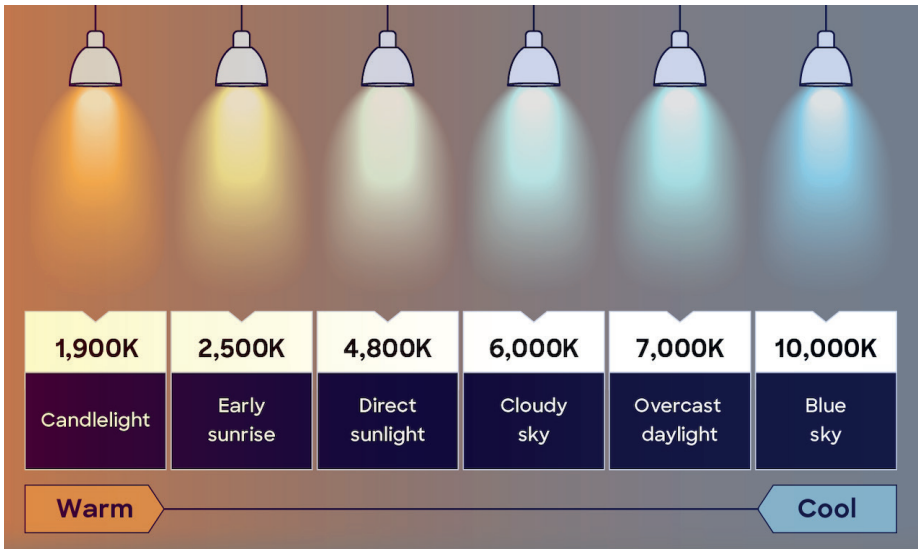
CHAPTER 2: What is the role of the lighting landscape in influencing the neurological processes that drive knowledge acquisition and cognitive performance in a library environment?

Far from being a purely visual phenomenon, light functions as a critical neurophysiological stimulus. The lighting landscape, which includes both natural light such as daylight and sunlight, as well as artificial illumination, together with its spatial distribution, spectral composition, and temporal variation, plays a vital role in shaping the neurological processes that support knowledge acquisition and cognitive functioning. This influence is mediated through both visual and non-visual pathways, such as visual comfort, circadian regulation, hormonal modulation, emotional states, and cognitive capacity. It is particularly relevant in library environments, where sustained attention and the acquisition of knowledge are central activities. This chapter synthesises current literature to examine how light affects fundamental neurological functions such as attention, memory, mood, and alertness.

1.1 Light and the Circadian System

At the core of light's neurological impact lies the circadian system. This internal mechanism has existed since the earliest stages of evolution, first emerging in single-celled organisms. To this day, it has been identified in the genetic structures of every life form studied on the surface of the planet. Functioning as the body's internal clock, the circadian system regulates sleep-wake cycles, hormonal activity, and metabolic processes in synchrony with the natural rhythm of light and darkness. One of its key characteristics is its ability to adapt to the continuously changing lengths of day and night. Human cognitive performance is significantly influenced by this system, which is primarily regulated by light-sensitive retinal cells known as intrinsically photosensitive retinal ganglion cells (ipRGCs). These cells transmit environmental light information to various regions of the brain (Heschong, 2021). To maintain proper circadian alignment, it is essential to follow balanced lighting cycles, including sufficient exposure to daylight during the day and darkness at night. Such regulation supports the optimal functioning of the circadian system and, by extension, cognitive performance (Baeza Moyano et al., 2020).





Top figure: **Figure 2.** Entire spectrum of visible light (Eyesafe, 2019) Bottom figure: **Figure 3.** CCT Chart (Fity.club, 2024)

2.2 Neurological and Psychological Responses to Light Exposure

Light exposure regulates the circadian system, which in turn governs hormonal activity essential for cognitive performance and learning. Specifically, the amount of light exposure during the day helps calibrate the internal biological clock, influencing various physiological cycles such as core body temperature and the onset of melatonin production (Çelik et al., 2024). Melatonin has been described as the conductor of the circadian orchestra, providing the 24-hour pulse to which all intracellular clocks in tissues throughout the body synchronize their rhythm (Heschong, 2021). In the morning, natural light is typically cooler and brighter, with a higher proportion of blue wavelengths (~460–480 nm) (see Figure 2), which suppresses melatonin production and helps align the biological clock with local Earth time. Exposure to this type of light not only supports circadian alignment but also signals the body to improve reaction time, enhance alertness, focus, and concentration, and reduce drowsiness during cognitive tasks, which is crucial for memory and attention processes (Çelik et al., 2024; Mostafavi et al., 2024; Sarialioglu, 2025).

Furthermore, Heschong (2021) indicates a correlation between episodic and spatial memory formation and the circadian cycle. These cognitive functions tend to operate most effectively under strong day/night lighting patterns, while they become less efficient under weaker cycles. Consistent with this, morning exposure to natural, bright light triggers wakefulness and improves cognitive efficiency. In addition, it reduces stress and improves mood by increasing serotonin production, thereby promoting a sense of well-being (Sarialioglu, 2025; Mostafavi et al., 2024). As the day progresses, natural light reaches its peak brightness around noon and displays a higher correlated color temperature (CCT) of around 6500K (see Figure 3), which is associated with improved alertness. Conversely, toward the evening, the quality of natural light shifts to warmer tones and reduced brightness. This gradual transition signals the body to prepare for sleep by promoting melatonin secretion once again (Çelik et al., 2024). As a result, exposure to warmer, softer, yellowish-white light with a lower CCT has been shown to induce relaxation, reduce stress, and positively affect memory consolidation (Mostafavi et al., 2024; Sarialioglu, 2025).

Insufficient light levels are associated with inadequate levels of hormone production, leading to negative cognitive effects (Baeza Moyano et al., 2020). Moreover, research has shown that insufficient exposure to daylight can disrupt the circadian cycle, resulting in melatonin being secreted at inappropriate times. This misalignment can cause chronic fatigue, depression, and other illnesses (Singh et al., 2020). More broadly, poor lighting conditions in indoor environments have been shown to negatively affect visual comfort and may lead to symptoms such as eye fatigue, eye strain and even sick building syndrome (Ale & Yunus, 2022). This issue is particularly relevant in library environments, where users are often engaged in prolonged periods of reading and close-up work. In such settings, inadequate lighting can significantly increase the risk of visual discomfort. Consequently, it is essential to consider lighting as a critical design factor in library environments, where inadequate lighting can significantly increase the risk of visual discomfort, leading to symptoms such as red or bloodshot eyes, restlessness, fidgeting, and skipping words or lines while reading or writing (Baeza Moyano et al., 2020; Sanaz Ahmadpoor Samani, 2012).

Timing is also a crucial factor when it comes to finding the right lighting conditions. On the one hand, exposure to cooler and brighter light with a higher proportion of blue wavelengths during nighttime can disrupt the body's circadian rhythm and natural sleep cycle. This disruption may lead to sleep disturbances, mood disorders such as depression and seasonal affective disorder (SAD), as well as strain on the visual system and impaired cognitive performance (Çelik et al., 2024; Mostafavi et al., 2024). On the other hand, insufficient exposure to daylight during the day, and consequently to blue-enriched light that suppresses melatonin production, can be equally disruptive to the circadian rhythm. In fact, this absence of daytime light exposure may have similar negative effects as nighttime exposure to artificial blue light (Heschong, 2021).

Notably, even very low levels of light, measured in just a few lux, can have a profound effect, particularly within the peak sensitivity range of the intrinsically photosensitive retinal ganglion cells (ipRGCs) in the blue light spectrum. However, it has since been recognized that the sensitivity of the circadian system is itself circadian. This means that while minimal amounts of blue light may significantly affect melatonin production during the night, increasing blue light exposure during the day may have little to no measurable impact, as melatonin suppression has already been fully achieved. It is not the specific minimum dosage of light, but rather the overall daily pattern of light and dark exposure that plays the most critical role in maintaining circadian health (Heschong, 2021). Therefore, ensuring adequate and well-timed lighting throughout the day is essential, especially in library design, where users often spend long periods indoors and may be entirely isolated from natural daylight.

2.3 Natural lighting and its effects

Light in architectural environments generally falls into two primary categories: natural light, which includes daylight and direct sunlight, and artificial light, which encompasses various forms of electric illumination. Both types of lighting are essential for creating balanced lighting landscapes; however, natural light holds distinctive physiological and neurological advantages that artificial systems often struggle to replicate. Specifically, when compared to various electric lighting options, natural light is a more efficient regulator of the body's internal clock. As a result, university students in classrooms with natural light scored significantly higher on exams compared to those in artificially lit rooms. In addition, natural light has the ability to enhance shadows, contrasts, and surface textures, making spatial cues more perceptible. Thanks to its color temperature of around 5,800K and a Color Rendering Index[11] (CRI) of 100, daylight offers the best visual clarity (Çelik et al., 2024; Sarialioglu 2025). While this subchapter focuses on the influence of daylight on the neurological processes that drive knowledge acquisition and cognitive performance, the next subchapter (2.4 Integration of Artificial Lighting) discusses the influence of artificial lighting. The effects of both natural and artificial lighting have been widely studied in educational and professional contexts, such as offices, schools, and universities. These findings are particularly applicable to libraries, due to their comparable functions and user needs.

Students who were exposed to higher levels of daylight in their classrooms achieved significantly better reading and math test scores, with improvements ranging from 7 to 26 percent depending on the school district, compared to those in classrooms with limited daylight exposure (Heschong, 2021). Moreover, increased illuminance levels have been shown to enhance students' academic performance, although this effect only persists up to a certain threshold, beyond which performance begins to decline (Singh et al., 2020). In addition natural light enhances productivity and focus, positively affects human performance, reduces eye strain, and lowers absenteeism. Besides stimulating the production of melatonin and serotonin, it also influences cortisol levels, thereby helping to regulate the body’s light-dark cycles and improving concentration (Baeza Moyano et al., 2020; Hawkins, 2024; Jamrozik et al., 2019; Heschong, 2021). Spending the afternoon in a naturally daylit environment, as opposed to one illuminated by artificial lighting, has been shown to significantly increase alertness, enhance mental clarity, and improve memory and problem-solving abilities. These findings suggest that regular daylight exposure not only aligns physiological rhythms but also optimises neurocognitive states essential for learning. Natural light was favoured by the participants because it reduced eye strain and improved visual comfort and productivity (Jamrozik et al., 2019; Çelik et al., 2024). Consistent with these findings, 47% of employees admit they feel tired or very tired from the absence of natural light and office workers consistently prefer to work under natural light conditions whenever possible (Heschong, 2021). In line with this, 90% of students surveyed indicated that natural lighting would be the optimal choice for study areas (Hawkins 2024; Jamrozik et al., 2019).

As a dominant source of sensory information, daylight is regarded as an essential component for the spatial orientation of an individual. This is primarily because daylight gives individuals a sense of place with the changing intensity and direction of illumination over time and potentially influences their spatial orientation within the environment (Izmir Tunahan et al., 2021). In addition to its spatial role, daylight exposure may have a significant impact on the consolidation of long-term memories processed in the hippocampus. For example, employees with the highest levels of horizontal daylight at their desks demonstrated a 20% improvement in working memory performance compared to those without daylight access. Given that intrinsically photosensitive retinal ganglion cell (ipRGC) projections extend directly to the hippocampus, it is reasonable to conclude that daylight exposure can influence key hippocampal functions related to memory.However, the association between daylight and mental or cognitive performance may be influenced by visual discomfort. Increased glare, which will be discussed in chapter 3**,** has been shown to negatively affect visual acuity and may therefore reduce the potential benefits of daylight exposure (Heschong, 2021). Strategies for reducing such negative effects of glare, as well as methods for leveraging the mental and cognitive benefits of both daylight and artificial lighting, will be addressed in a later chapter (chapter 3).

11 The Color Rendering Index (CRI) is a measure of the accuracy with which a light source reveals the colours of objects in comparison to natural light. Rated on a scale from 0 to 100, a higher CRI means better colour fidelity, which supports visual comfort and clarity in library environments.

2.4 Integration of Artificial Lighting

While natural light has shaped human biological rhythms for millions of years, regulating wakefulness, body temperature, digestion, and hormonal synthesis (Baeza Moyano et al., 2020), artificial lighting has become an essential supplement in contemporary society, particularly in environments where daylight is insufficient. This is particularly the case before sunrise and after sunset. However, electric light, in contrast to natural light, is dim, with low intensity and spectral deficiency, and therefore fails to provide the same strength of signal for circadian synchronization (Heschong, 2021). Nevertheless, the application of artificial lighting remains essential in library settings. At the same time, if poorly designed, artificial lighting in indoor environments can have profound negative health effects, including eye strain, headaches, fatigue, and mood disorders (Mostafavi et al., 2024). Therefore, well-designed artificial lighting solutions are crucial for visual comfort, task performance, and cognitive functioning (Wijaya et al., 2019).

To mitigate these effects, contemporary artificial lighting strategies increasingly seek to replicate the temporal and spectral qualities of natural light. Effective artificial lighting systems should include adjustable intensity (such as dimmers), a broad color spectrum, and flicker-free operation. When applied correctly, such artificial lighting strategies can positively influence primary cognitive performance and spatial memory (Wijaya et al., 2019; Sarialioglu (2025). In library environments, artificial lighting should be more intense and contain a higher proportion of blue-enriched light in the morning, peaking at mid-morning. As the day progresses, both the intensity and the proportion of blue-enriched light should gradually decrease. In addition, artificial lighting should not only vary throughout the day, but also be seasonally adaptive, with higher irradiance levels in autumn and winter, and lower levels in spring and summer, in response to the body's cumulative light absorption (Baeza Moyano et al., 2020).

In addition to supporting circadian regulation, bright white artificial light at intensities above 1000 lux has been shown to stimulate cognitive functions, including logical reasoning and creativity (see Figure 4 on different lux levels). It can also enhance social and emotional interaction, and has an activating effect linked to increased alertness, reduced drowsiness, and heightened vigilance during both day and night (Baeza Moyano et al., 2020).

Although artificial lighting cannot fully replicate the spatial and dynamic qualities of natural light, it offers distinct advantages in terms of flexibility and control that natural light cannot provide. Unlike natural light, which depends on architectural orientation and weather conditions and follows a fixed planetary rhythm, artificial lighting can be turned on and off at will and adjusted in terms of intensity, direction, and spectral composition. This controllability allows for consistent illumination regardless of the time of day or season, which makes it particularly valuable for task-based activities and reading zones in libraries. While natural lighting is determined by the design of the space, artificial lighting can be used to enhance it (Heschong, 2021).

Ultimately, the aim of artificial lighting in library environments is to complement natural lighting, not replace it. It should be integrated in a way that considers both biological principles and architectural intent, allowing it to serve as a powerful design tool that compensates where daylight is lacking, and supports users' visual comfort, health, focus and cognitive performance.

	LUX	DESCRIPTION
	50,000	British summer sunshine
	5,000	Overcast sky
	500	Well-lit office
	300	Minimum for easy reading
	50	Passageway/outside working area
	15	Good main road lighting
	10	Sunset
	5	Typical side road lighting
	2	Minimum security risk lighting
	1	Twilight
	0.3	Clear full moon
	0.1	Typical moonlight/cloudy sky
	0.001	Typical starlight
	0.0001	Poor starlight

Figure 4. LUX levels Chart (Artofit, 2022)

2.5. View to the outside

In addition to the crucial influence of both natural and artificial lighting on learning acquisition and cognitive performance, there is another spatial element whose value cannot be overstated: the presence of a view to the outside. A good view in architecture is not merely about offering something aesthetically pleasing. Rather, it reflects a carefully considered visual and spatial relationship between interior and exterior, supporting spatial orientation and reinforcing emotional and cognitive bonds with a place. In this way, a view to the outside can serve as a form of mental escape. Individuals working in windowless rooms frequently report feeling “confined, imprisoned, and constrained” (Heschong, 2021).

Importantly, a view does not require direct exposure to the external environment to be effective. Windows act as selective filters: they admit light, colour, motion, and natural imagery while simultaneously blocking out undesirable elements such as wind, cold, noise, pollen, odours, insects, and other discomforts. This selective permeability offers a unique psychological benefit, as it allows visual engagement with the outside world while maintaining physical comfort and a sense of protection within the interior space (Heschong, 2021).

Contrary to the common assumption that views to the outside are distracting, they can have positive effects on people's emotional states and cognitive performance. Such views are associated with improved memory formation, extended attention span, and higher levels of concentration. One explanation is that a view to the outside allows for short episodes of mind-wandering which are associated with beneficial outcomes such as increased self-awareness, enhanced working memory, problem incubation, and creative insights (Heschong, 2021).

Moreover, views to the outside deliver approximately ten times the circadian stimulus of basic daylight illumination alone, further supporting the biological and cognitive benefits of well-placed visual access to the outside world. Individuals with access to high-quality views have been shown to perform up to 25% better on memory and processing tasks than those without any view at all. Similarly, in educational settings, students who have access to pleasant, layered views that include elements such as vegetation, distant focal points, and signs of human activity consistently demonstrate improved learning outcomes. Notably, views to nature appear especially beneficial for tasks that demand creativity. Improvements have been most pronounced in writing performance and in the restoration of attentional resources (Heschong, 2021). In libraries, where mental stamina, creativity and focus are key, access to a view of the outside can thus serve as a silent yet powerful cognitive support system.

Beyond the presence of a view to the outside, its specific content significantly influences its cognitive and emotional impact. While individuals may not consciously articulate a desire for a specific type of view, there is a clear preference for scenes that include natural elements such as trees, sky, birds, and water, along with the subtle movement of people and passing vehicles. A 'high-quality view' offers variation, movement, and a sense of scale, while incorporating natural elements and providing emotional clarity and a sense of connection to the world beyond (Hawkins, 2024). Typically, a good view consists of three layers: a view of the sky, a view of the ground, and a middle layer in between (Heschong, 2021).

A view of the sky likely includes clouds, sunsets, birds, and horizon. The view of the ground can include pathways, waterways, meadows, agricultural fields, and people and cars moving along those horizontal surfaces. The middle layer in between consists of the vertical elements that shape our cities and countryside, such as buildings, trees, rocks, and walls, as well as any landmarks rising from the ground. People tend to be drawn to fractal patterns, visual ambiguity, motion, and changes in scale. This phenomenon may be partly attributable to our cognitive ability to mentally zoom in and out across multiple scales, allowing us to engage more deeply with complex visual scenes. The presence of such environmental complexity has been linked to enhanced memory formation and retrieval, suggesting that richer visual contexts may support cognitive performance more effectively than simplified ones. When a view incorporates the aforementioned three layers (see Figure 5), it ensures that there will be sufficient distance and complexity in our aspirations (Heschong, 2021).

At the same time, the value of a view must be balanced with the need for privacy. While people appreciate the ability to observe the outside world, they are often uncomfortable when they feel too visible themselves. Concerns are typically raised about views that are considered to be overly large or panoramic, and about the potential loss of privacy. The optimal view of the exterior environment provides a greater opportunity to observe, as opposed to being observed by others. Achieving the correct balance between engagement with the outside world and maintaining inward privacy, security and focus is therefore an important challenge.

Another noteworthy concept is the so-called "killer view," which refers to an iconic perspective typically associated with a specific city or place and often used in advertisements as a defining image. Such views capture the essence of a location and contribute to its unique identity. When accessible from within a building these views can significantly enhance the quality of the interior experience. The presence of such a view, or even something that evokes its qualities, can transform an ordinary window view into one that is highly desirable, offering not only aesthetic appeal but also emotional and cognitive benefits.

Ultimately, the quality of a view is also shaped by subjective perception. A good view is, quite simply, the one that people are most drawn to. Interestingly, individuals who had access to a view they appreciated were significantly less critical of other aspects of their indoor environment. In fact, when occupants were offered a meaningful visual connection to the outside, they were often willing to tolerate temporary discomfort, such as suboptimal temperature or glare, in order to maintain access to that view (Heschong, 2021). Perception of glare, too, was shown to be influenced by the presence of a view, suggesting that what people see beyond the window can shape how they judge the quality of light inside (Ale & Yunus, 2022)

Moreover, the longer one spends with a particular view, and the more opportunities there are to pause and reflect, the more likely it becomes that an emotional attachment will form. This is regardless of how visually impressive the view may have seemed at first. What matters most is that a view to the outside exists at all. It re-establishes a sense of connection with the world outside, offering glimpses of changing weather, the passage of time, and ongoing movement. It makes a space feel alive and engaging.

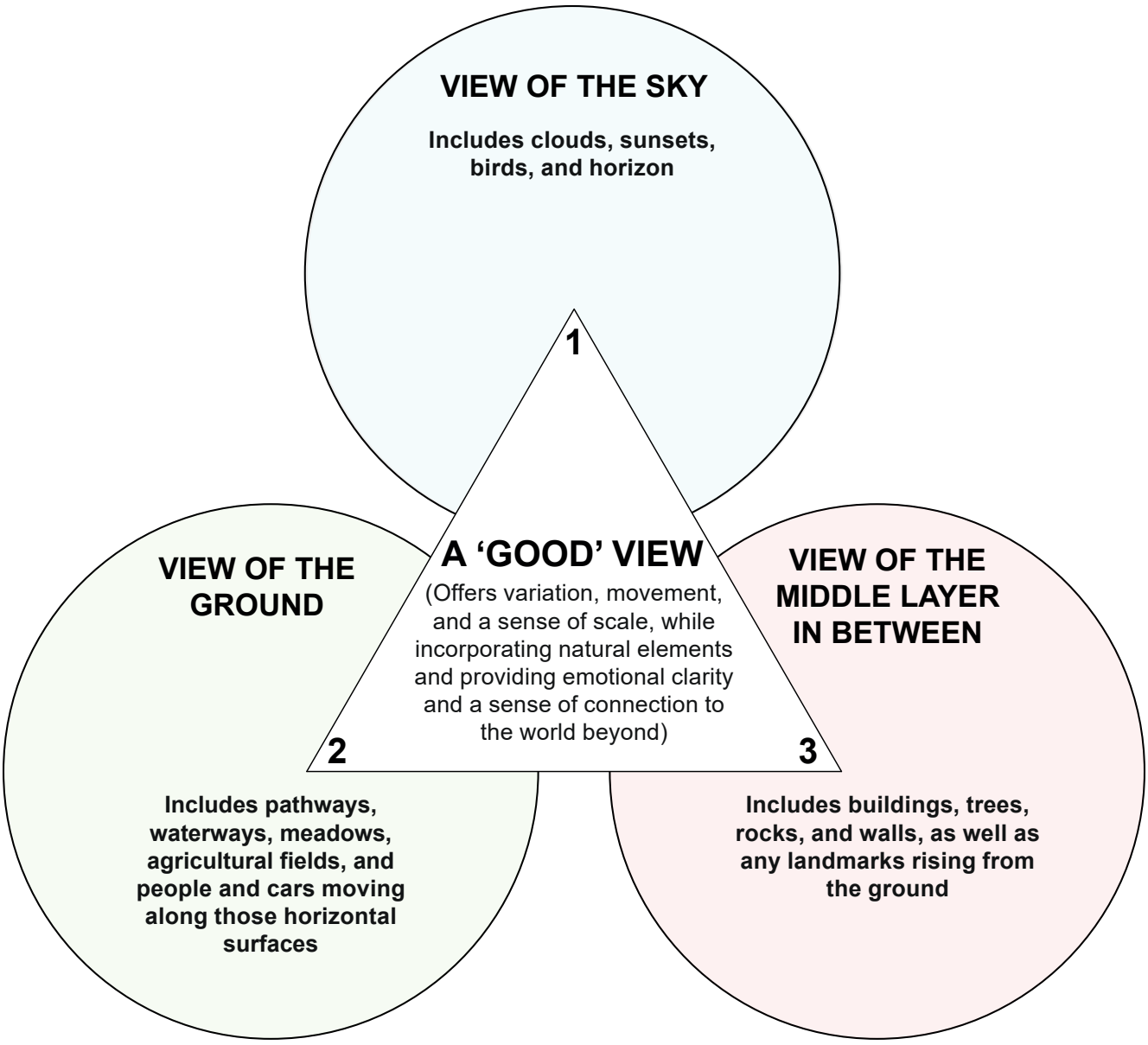


Figure 5. Principles of a 'good' view. Figure created by author (Mooren, 2025)

CHAPTER 3: What spatial lighting strategies enhance user-driven knowledge acquisition and cognitive performance within libraries?

Lighting design is a crucial aspect of architecture that is often overlooked, commonly regarded as a mere functional necessity. However, as outlined in previous Chapter 2, lighting plays a far more complex and impactful role. It is a fundamental architectural strategy that shapes how individuals perceive and inhabit space, and also directly influences cognitive performance and knowledge acquisition. Therefore, especially in educational settings, such as libraries, it is essential for designers to pay close attention to the non-visual effects of lighting. (Çelik et al., 2024).

Building on this, in contemporary society, the importance of thoughtful lighting design has never been greater. According to Heschong (2021), modern humans now spend over 90% of their time indoors. This represents a significant change from the lifestyle of just a century ago, when most daily activities took place outdoors. Moreover, around 20% of the population spends the majority of their daytime hours in dimly lit indoor environments, often with low physical activity and irregular sleep patterns (Heschong, 2021). This combination has been linked to chronodisruption, a condition that can lead to the development of serious health issues, including metabolic syndrome, cardiovascular disease, mood disorders, and cognitive impairment. This underscores the need for spatial lighting strategies that actively support human health and cognitive function.

3.1 Basics of a well illuminated design

As outlined in the previous chapter 2, a well-illuminated design relies primarily on the thoughtful integration of natural light as the main source of illumination, with artificial lighting serving as a complementary layer when daylight alone is no longer sufficient. Daylight is more than just a functional asset; it introduces dynamic variation that conveys a sense of time and place, making a space feel more vivid and alive. This effect has been shown to positively influence mental engagement and cognitive performance (Heschong, 2021). Designing such environments requires more than providing adequate illuminance; it involves deliberate attention to how light is distributed throughout the interior, how it interacts with surfaces, and how it evolves across the course of the day and year (Sanaz Ahmadpoor Samani, 2012).

According to Singh et al. (2020) and Perera and Nirma Swaris (2017), a well-illuminated environment depends on the direction of light relative to the eye, balanced brightness levels, sufficient surface reflectance, and effective glare control, all of which are essential for visual comfort and task efficiency. One of the most influential and enduring frameworks that addresses these principles in a spatial and perceptual context is Richard Kelly's concept of layered lighting. "According to Kelly, the three fundamental elements of light are, (1) Ambient Light or General Lighting, (2) Focal Glow, which is directive light, creates a bright center, and it tells us what to look at, organises, mark the most important element, (3) Sparkle (play of brilliants), this light attracts human attention, and create a feeling of curiosity, passion, and increase alertness" (see Figure 6) (Cungiono et al., 2021).

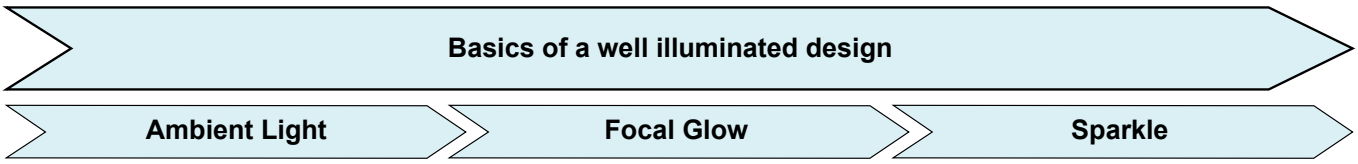


Figure 6. Basics of a well illuminated design. Figure created by author (Mooren, 2025)

Building upon these insights, several foundational lighting design strategies can be identified that contribute to the creation of a well-illuminated environment. One key aspect is the uniformity of light levels. Consistent and evenly distributed lighting helps to minimise visual distractions and supports sustained focus during reading and learning activities. One particularly effective method for achieving this is through the introduction of daylight from multiple directions. It was noted that focus was given to the reading area of the library through the provision of adequate windows on at least two sides of the wall in order to have a well-lit space (Heschong, 2021). By allowing light to enter from opposite angles, shadows cast by one window are softened by illumination from another, significantly reducing excessive contrast between bright openings and adjacent surfaces (Baker & Steemers, 2002). This approach not only mitigates glare but also enhances visual clarity of objects and facial expressions within the space.spaces illuminated from multiple directions with daylight offer superior visual conditions because natural light, when introduced from various angles, tends to balance itself. (Heschong, 2021).

In addition to uniform and consistently distributed lighting, another important aspect in achieving a well-illuminated interior lighting design is sufficient surface reflectance. A useful design principle is that any direct beam of sunlight should ideally be reflected at least once by a white or light-colored surface before it reaches the occupant's eyes. This approach helps diffuse the intensity of daylight and reduce glare, thereby creating a softer and more comfortable visual experience indoors (Heschong, 2021). For instance, low-angle sunlight entering through a side window can be redirected via adjacent light-colored walls, while high-angle sunlight from a skylight may be diffused within a light-reflective well or shaft. Even the exterior environment can support this effect: bright paving or reflective ground surfaces outside a window can bounce daylight into the interior, enhancing illumination without causing discomfort (Baker & Steemers, 2002). In this context, color becomes an integral design element because it interacts with lighting and therefore can enhance the impact on the buildings users. Light-toned finishes on ceilings, walls, and furniture can amplify daylight distribution and promote a sense of spaciousness and clarity (Sanaz Ahmadpoor Samani, 2012).

When considering the role of focal glow, another key aspect in creating well-illuminated interior lighting design is the use of brighter and more visually complex lighting designs, which have been found to enhance the perceived attractiveness of a space. Specifically, higher luminance levels on walls and ceilings are associated with increased impressions of spaciousness, attractiveness, and environmental as well as cognitive stimulation (Kong et al., 2022). Moreover, elevated wall illuminance has been shown to improve spatial appraisal and promote alertness (Bellia et al., 2024), while also reducing sensations of drowsiness (Jung et al., 2024). Taken together, these findings suggest that effective lighting design should prioritise high illuminance on vertical and overhead surfaces to support both visual comfort and cognitive engagement.

In addition to ambient and focal lighting, the inclusion of sparkle, or what Richard Kelly in (Heschong, 2021) described as "the play of brilliants," contributes an important role in creating well-illuminated indoor environments. Sparkle refers to small points of brightness, often created through highlights, glints, or reflections, that draw the eye and evoke feelings of curiosity, alertness, or even delight. Our visual system, shaped by evolutionary exposure to a directional sun and a three-dimensional world, is inherently attuned to expect bits of sparkle throughout the day. As a result, indoor environments benefit from the inclusion of such elements. These effects can be achieved through the use of shiny materials that enhance natural highlights, curved surfaces that focus ambient light via interreflection, or glimpses of direct sunlight entering through windows or skylights (Heschong, 2021). However, these small points of brilliance can quickly shift from delightful to distracting when they become too intense or are overabundant.

This is where the concept of glare becomes relevant. While sparkle stimulates attention, glare repels it. Glare occurs when brightness becomes excessive, uncontrolled, poorly positioned, or lasts too long. In such cases, it can cause significant visual discomfort, distraction, eye strain, headaches, and even impaired vision. In addition, glare may contribute to excessive solar heat gain, which further impacts comfort and performance (Singh et al., 2020; Heschong, 2021; Hawkins, 2024).

This has direct negative implications for cognitive performance and knowledge acquisition, therefore it is of high importance to reduce glare in indoor enviornments and to keep direct beams of sunlight out of people's eyes and away from visual tasks. Furthermore, glare can also result from extreme contrasts in luminance within the visual field (Singh et al., 2020). To mitigate this, a commonly recommended guideline is the 10:3:1 ratio, in which the task area has the highest brightness level (10), the immediate surroundings are moderately bright (3), and the general background is significantly dimmer (1) (Malman, 2009). Techniques such as skylights, various types of sidelighting, light shelves, shading systems, and carefully considered architectural decisions regarding the position, size, and orientation of windows can significantly reduce glare while enhancing daylight penetration (Çelik et al., 2024; Hawkins, 2024). The specific techniques and design solutions that support this will be explored in the following subchapters of chapter 3.

3.2 Differentiated Lighting Requirements Across Library Zones

Even though uniform lighting is often considered desirable across many library spaces, the specific lighting requirements within different areas of a library are far from uniform. This variation stems from the multiple functional roles that a library building fulfills. Therefore, effective lighting strategies must respond to the diverse activities taking place within different library zones, such as reading areas, book stacks, computer workstations, offices, individual or group study rooms, and exhibition spaces. Each of these spatial functions demands its own tailored lighting approach. These differences in lighting requirements can be understood through several key factors. Among them, the following five are particularly important:
1: Access to daylight and views: Does the space benefit from or require (direct or indirect) daylight? And does the space benefit from acces to a view to the outside?
2: Required illuminance levels: What are the necessary lux levels for the tasks performed in the space?
3: Recommended lighting type: Should the space utilize sidelighting, toplighting, or diffuse lighting strategies to best support the activities taking place?
4: Adjustability: Should the lighting be controllable by individual users (e.g., via personal task lighting), or should it be managed centrally for general consistency across the space?
5: Optimal correlated colour temperature (CCT): What colour temperature of artificial lighting is most appropriate for the task?
How these five factors manifest in the design of specific library zones will be explored in detail in the following subchapters of chapter 3**.**

To support designers in navigating these diverse lighting requirements, there is a need for clear and accessible tools that summarise essential guidelines for lighting within the different spaces of libraries. Accordingly, this thesis will conclude with such a tool, in addition to the development of an evidence-based spatial lighting framework for libraries. As outlined, libraries encompass a wide variety of spaces, each with distinct visual and functional needs. While an overview of this will be addressed in the final tool, this section places particular emphasis on the reading room, which is arguably the most cognitively demanding area in the library.

Here, lighting should be evenly distributed to minimise glare and visual fatigue, especially because users frequently shift their gaze between paper and screen, which requires high-quality horizontal illuminance (Sanaz Ahmadpoor Samani, 2012). Sudden brightness contrasts and the presence of glare, as discussed in Subchapter 3.1, can lead to discomfort and distraction during prolonged study sessions (Baker & Steemers, 2002). Additionally, as explored in the previous chapter 2, access to views in reading areas plays a vital role in supporting knowledge acquistion and cognitive performance. Illuminance levels of approximately 300–500 lux are recommended for general reading tasks, with higher levels needed for work involving fine detail (Lushington et al., 2016). Although the reading room is a central component of the library, other spaces also present distinct lighting requirements. These include variations in access to daylight, view, illuminance levels (lux levels), and the importance of glare control. These conditions are summarised in Figure 7. Further aspects, including recommended lighting types, the degree of adjustability, whether the focus should be on horizontal or vertical workplane illumination, and the ideal correlated colour temperature (CCT), will be addressed in the subsequent subchapters of chapter 3.

LIBRARY LIGHTING TYPOLOGY MATRIX REQUIREMENTS → ↓ TYPE OF ROOM	DAYLIGHT	VIEW	ILLUMINANCE	GLARE
	Is access to daylight required in this space?	Is visual access to the outdoors necessary?	What are the recommended illuminance levels (in lux)?	How critical is glare control for this space?
READING ROOM	ESSENTIAL	ESSENTIAL	300—500 lux	EXTREMELY IMPORTANT
COMPUTER ROOM (MULTI-MEDIA ROOM)	NEUTRAL	OPTIONAL	150—250 lux	CRITICAL
OFFICES	ESSENTIAL	ESSENTIAL	500 lux	EXTREMELY IMPORTANT
INDIVIDUAL STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT
GROUP STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT
STUDY CARRELS	VERY IMPORTANT	VERY IMPORTANT	500—1000 lux	EXTREMELY IMPORTANT
AUDITORIUM (LECTURE HALL)	OPTIONAL	NEUTRAL	300—500 lux	IMPORTANT
MAKERSPACE	ESSENTIAL	BENEFICIAL	500 lux	EXTREMELY IMPORTANT
STACK AREAS (ACTIVE)	NOT IMPORTANT (AVOID DIRECT SUNLIGHT!)	UNNECESSARY	300 lux	LOW CONCERN
STACK AREAS (INACTIVE)	AVOID IF POSSIBLE	UNDESIRABLE	50 lux	NOT RELEVANT
CIRCULATION SPACE	PREFERABLE	BENEFICIAL	200—300 lux	MODERATE CONCERN
CHILDREN PROGRAM ROOM	VERY IMPORTANT	VERY IMPORTANT	500 lux	IMPORTANT
FOOD SERVICES (RESTAURANT/CAFÉ)	VERY IMPORTANT	IMPORTANT	300—500 lux	MODERATE CONCERN
DEEP QUIET SPACE (MEDITATION ROOM)	OPTIONAL	OPTIONAL	100 lux	VERY IMPORTANT
BOOK RESTORATION SPACE	ESSENTIAL	VERY IMPORTANT	1000 lux	CRITICAL

Figure 7. Matrix based on different type of rooms and their requirements in terms of daylight, view, illuminance, and glare control. Figure created by author (Mooren, 2025)

3.3 Foundational Architectural Strategies for Daylight-Responsive Design

Although many books have been written about lighting design in architecture, lighting is still too often treated as a secondary consideration, addressed only after the spatial layout, volumes, and surfaces of a building have already been defined. Most lighting guides implicitly assume that the architectural framework is predetermined, positioning lighting design as a reactive rather than generative discipline. However, its full potential can only be realised when it is integrated from the earliest stages of architectural planning. As Stewart Brand explains (in How Buildings Learn), the physical form of a building, including its site, structure, and surface, represents one of the most enduring interventions within the built environment. From this perspective, the form of the building should not merely accommodate lighting; rather, it should be shaped by it. To support this approach, several architectural strategies can be deployed to optimise daylighting performance. These begin with four interrelated factors that form the foundation of any daylight-conscious design: building orientation, site location, architectural form, and obstructions (Heschong, 2021).

The orientation of a building plays a pivotal role in determining daylight availability, solar gain, and the spatial quality of interior illumination. This effect is, however, also strongly influenced by the geographical location of the site (Çelik et al., 2024). In the Northern Hemisphere, South-facing façades provide the most consistent exposure to sunlight throughout the year, especially during winter when the sun is lower in the sky. With appropriately dimensioned overhangs, such façades can effectively admit low-angle winter sunlight while blocking excessive summer heat and glare (Baker & Steemers, 2002). One potential drawback of South-facing façades, however, is that they often provide views toward shadowed surfaces and silhouettes, which may limit visual engagement with sunlit outdoor scenes.

By contrast, North-facing façades typically receive little to no direct sunlight, yet they offer stable and diffuse illumination throughout the day. Such façades often frame views of brightly sunlit exteriors, making them particularly valuable in environments where visual consistency and reduced glare are essential, such as in libraries where uniform lighting is critical for prolonged cognitive tasks (Ale & Yunus, 2022). East- and West-facing façades, meanwhile, present greater challenges. These orientations are subject to intense, low-angle sunlight during morning and late afternoon hours, which is often associated with thermal overload, visual discomfort, and glare, reducing cognitive performance (Heschong, 2021).Due to the low solar altitude during these times, effective shading would require overhangs that are exceptionally large and deep, which are often impractical in practice. As an alternative, vertical obstructions or fins may prove more effective in mitigating glare while maintaining daylight access. Specific strategies for controlling such conditions will be explored in the Subchapter 3.5: Daylight Controls. Ultimately, it is the architect's challenge to take full advantage of the unique lighting conditions that each orientation presents.

Because North- and South-facing façades can be more easily optimized for both daylight access and solar control, they are often preferable as the primary orientations for a building. Therefore, the building should be oriented so that its long axis runs East-West. In addition to orientation, the overall shape and layout of the building have a profound impact on how daylight is distributed. Long and narrow floor plans with generous perimeter exposure are particularly effective, as they allow daylight to penetrate more deeply into interior spaces, especially when façades are oriented to capture sky views and reflected light. In such configurations, it is important to avoid direct sunlight, particularly on south-facing façades, to prevent thermal and visual discomfort (Baker & Steemers, 2002).

Conversely, deep-plan buildings often struggle to provide adequately daylight beyond the immediate perimeter. However, a variety of architectural strategies can help overcome this limitation, including the incorporation of atria, courtyards, galleries, and light wells. These approaches will be examined in more detail in the Subchapter 3.4: Daylight and Building Openings.

A critical yet often underestimated and overlooked factor in the architectural optimisation of daylight is the presence of external obstructions. In dense urban environments, both existing and future structures can cast long shadows or block crucial sky views, significantly reducing the amount of natural light that can penetrate into a building. It is standard practice to assume that obstructions have a brightness that is only one-tenth of the brightness of the unobstructed part of the sky. Therefore, the obstruction can reduce the daylight contribution by up to 90% (Baker & Steemers, 2002). Given this, the primary objective in daylight-responsive design is to maximise the view of the sky from as many building openings as possible. This view can be achieved either above, beside, or between surrounding obstructions. Accordingly, a key consideration becomes the placement of the building on its site and its spatial relationship to adjacent structures. Design strategies such as adjusting the building layout to incorporate daylight courts, positioning windows for optimal exposure, or orienting façades away from obstructed directions can all support this goal. Even relatively modest interventions, such as increasing window height or incorporating clerestories, can significantly enhance the amount of daylight penetration. This principle applies not only to new constructions but also to existing buildings, many of which can be optimised through targeted interventions. These measures may include expanding the glazed area, retrofitting daylight-redirecting devices, or modifying the reflectance of surrounding surfaces to enhance light reflectivity and indirect sky brightness. Taken together, these findings reinforce the notion that, in addition to building orientation, site location, and architectural form, the early integration of obstruction analysis and sky access mapping is essential to any effective daylighting strategy.



Figure 8. Example of punched window KB (Mooren, 2025)



Figure 9. Example of strip window KB (Mooren, 2025)

3.4 Daylight and Building Openings

Following the optimisation of orientation, form, and obstruction management as discussed in the previous Subchapter 3.3: Foundational Architectural Strategies for Daylight-Responsive Design, the next critical step in daylight-responsive design involves the careful configuration of building openings. Two primary strategies are generally distinguished: sidelighting and toplighting. This subchapter begins with an exploration of sidelighting techniques. Toplighting systems will be addressed later on in the subchapter.

SIDELIGHTING

Sidelighting refers to the admission of daylight through vertical wall apertures such as windows. Beyond their visual role, side windows support circadian regulation, spatial awareness, and temporal orientation through dynamic light and external views (Heschong, 2021; Jamrozik et al., 2019). Moreover, side windows often serve as openings for natural ventilation, contributing to indoor air quality and comfort. Both of them are big advantages of side lighting. Despite these advantages, poorly designed sidelighting systems may introduce problems such as uneven daylight distribution, glare, and thermal discomfort. The brightness contrast between a single, intense light source (such as a small window) and its darker surroundings can lead to visual strain and distraction (Ale & Yunus, 2022). Without thoughtful placement and sizing, light levels can fall below useful thresholds just 4.5 to 6 meters from the window wall. A common rule of thumb states that without advanced daylighting techniques a room can be adequatly daylit for depth (distance from the facade) equal to twice the floor to ceiling height (strictly twice the floor to top of window height) (Baker & Steemers, 2002). Without complementary strategies, this natural falloff results in underlit interior zones, glare near the façade, and visual discomfort deeper in the space (Jamrozik et al., 2019). Ultimately, the success of sidelighting depends on the precise placement, dimensioning, and coordination with interior geometry and surfaces. Below key sidelighting strategies in increasing order of sophistication are outlined, each offering distinct advantages and challenges:

1. PUNCHED WINDOWS

Discrete, often rectangular, openings placed individually in the façade (see Figure 8). They are among the most common forms due to their simplicity and cost-efficiency. However, their small size and isolated placement often lead to intense luminance contrasts, glare, and underlit zones, which are particularly problematic in spaces requiring sustaind visual focus. Additionaly, their limited size also reduces the potential for deep daylight penetration (Heschong, 2021).

2. STRIP WINDOWS

Unlike punched windows, strip windows run continuously along a wall (see Figure 9). This helps reduce dark corners since there is no longer any opaque wall between each window opening, and distributes light more evenly along the wall. By creating a horizontal line of light, strip windows provide more even wall luminance and reduce the likelihood of intense glare compared to isolated punched windows (Kong et al., 2022; Heschong, 2021).

3. CORNER OR DUAL-ASPECT WINDOWS

Windows placed on adjoining walls in a corner, which allows light to enter from mulitple directions (see Figure 10). As discussed in subchapter 3.1: Basics of a well illuminated design, multi-directional daylighting enhances spatial uniformity, softening shadows and expanding the effective daylit zone.



Figure 10. Example of a corner or dual-aspect window (Pinterest, 2017)



Figure 11. Example of a curtain wall (Facadesplus, 2018)

4. CURTAIN WALL

These are large continuous floor-to-ceiling glazed systems that replace opaque wall sections entirely (see Figure 11). These allow deep daylight penetration and strong connections to the outside world. However, they also require advanced glare management and shading systems to prevent visual and thermal discomfort and distraction (Heschong, 2021). Subchapter 3.5: Daylight Controls, will discuss different shading systems.

5. CLERESTORY WINDOWS

These are side windows placed high on walls, increasing the visible sky angle resulting in a deeper daylight penetration within a room (see Figure 12). Clerestories can be combined with lower side windows to provide a more balanced daylight distribution. This can be particularly interesting in deep or tall spaces consisting of larger volumes like reading rooms in libraries (Baker & Steemers, 2002).

6. LIGHTSHELVES

Although not a window type per se, lightshelves are among the most effective tools for enhancing sidelighting performance.These horizontal reflective surfaces (mounted above eye-level either inside or outside the façade) redirect excessive incoming daylight in the front of a room onto the ceiling, which in turn diffuses the light more evenly into the depth room (see Figure 13). Lightshelves can also serve as a shading element, blocking high-angle sunlight and reducing glare. By illuminating deeper areas and mitigating glare near windows, lightshelves improve visual comfort, especially when combined with high-reflectance lightshelf surface and high-reflective ceilings (Baker & Steemers, 2002). In addition, lightshelves can be animated by subtle movements, such as reflections from wind-rippled water, which have been shown to lower occupants' heart rates and evoke a sense of calm visual delight (Heschong, 2021).

In sum, sidelighting is a versatile and essential daylighting approach. From basic punched windows to advanced systems like lightshelves and curtain walls, each configuration offers distinct advantages. When thoughtfully selected and integrated, these strategies form the foundation for effective daylight-responsive design in library environments.



Figure 12. Example of clerestory windows (Animalia-life, 2023)

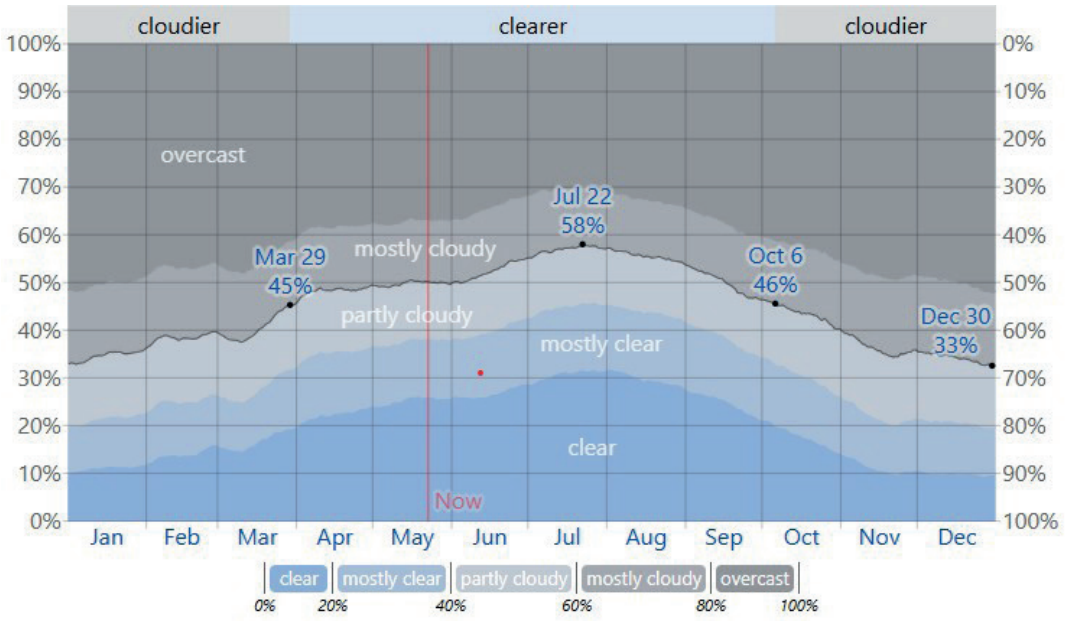


Figure 13. Example of lightshelves (2030Palette, 2017)

TOPLIGHTING

Following the exploration of sidelighting techniques in the previous section, this subchapter turns to toplighting strategies, which play an equally vital role in creating daylight-responsive, cognitively supportive library environments. Whereas sidelighting introduces daylight through vertical wall openings, toplighting brings natural light into a space from above. Toplighting strategies often provide more uniformly distributed natural light and more consistent lighting conditions throughout the day (Hawkins, 2024; Lushington et al., 2016). Light from above minimises directional shadows and ensures balanced illumination of horizontal task planes such as desks and tables, which are prevalent in libraries (Baker & Steemers, 2002). In particular, toplighting enables daylight to reach the central and rear areas of a space, where it is often most needed, especially in deep-plan buildings and large-volume interiors. Additionally, strategies with a three-dimensional form such as domes, bubbles, or pyramids are better able to capture low-angle sunlight during the morning and afternoon, when natural light is most limited and thus most beneficial. These characteristics make toplighting particularly effective in environments like libraries, where glare-free, diffused, and widespread lighting is desired (Ale & Yunus, 2022).

Under overcast sky conditions, the zenith is typically much brighter than the horizon. Since toplighting devices offer direct access to this brightest portion of the sky, they can deliver 2 to 3 times more daylight than comparable side openings (Baker & Steemers, 2002). Therefore, they are especially effective in climates with frequent overcast conditions, such as in The Hague, where the Royal Library of the Netherlands is located and serves as the case study of this research (see Figure 14).



Fraction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cloudier	65%	62%	59%	52%	50%	47%	43%	45%	50%	57%	64%	66%
Clearer	35%	38%	41%	48%	50%	53%	57%	55%	50%	43%	36%	34%

Figure 14. Annual sky conditions in The Hague (Weatherspark, 2025)

Toplighting is also advantageous for its potential to be orientation-sensitive, which allows for refined solar control strategies (which will be discussed in next subchapter 3.5: Daylight controls). For instance, north-facing devices harvest diffuse light with minimal solar gain, while south-facing systems can be paired with external shading. Despite these advantages, toplighting systems can also introduce design challenges, such as solar heat gain or glare under clear skies. These issues can be mitigated using diffusing materials, light-redirection films, and effective shading devices. Ultimately, the success of toplighting depends on careful calibration of aperture size, spacing, orientation, and reflectance in relation to the spatial geometry and daylighting needs. Below, key toplighting strategies are outlined in increasing order of architectural complexity. Each offers distinct advantages and design considerations.

1. SKYLIGHTS

These are the most popular and simplest toplighting devices, and they are well-suited for smaller spaces or to supplement sidelighting. They consist of clear of diffusing materials and are optimised to provide illumination, but they offer little or no view to the outside (see Figure 15). While modern skylights are typically composed of plastic materials that can be moulded into three-dimensional shapes, simultaneously providing a good weather seal, structural support and optical management. Domed or prismatic skylights are particularly effective at capturing low-angle sunlight in mornings and evenings. For optimal performance, skylight wells should be lined with light-reflective surfaces to improve light distribution. A common design guideline is to space skylights no more than one floor-to-ceiling height apart to achieve uniform daylight coverage (Heschong, 2021; Lushington et al., 2016).

2. ROOF WINDOWS

Different from skylights, roof windows are specifically intended to provide not only daylight but also visual access to the outdoors (see Figure 16). While skylights are often located above the normal line of sight and prioritise toplighting, roof windows are typically placed within the occupant's visual field and are well-suited for spaces where both illumination and a connection to the exterior environment are desirable. This makes them particularly effective in spaces with sloped ceilings. Roof windows are commonly operable, which can allow natural ventilation. Because roof windows are more likely to introduce direct sunlight, their design should consider orientation and user access, and incorporate effective shading or light diffusion strategies to prevent glare or overheating. A roof window is best thought of as a view window mounted at eye level in a sloped roof. Most roof windows are made of clear glass with thermal and solar coatings to enable a view and reduce thermal discomfort.



Figure 15. Example of skylights KB (Mooren, 2025)



Figure 16. Example of roof windows (worldarchitecture.org, 2019)

3. ROOF MONITORS

Unlike skylights or roof windows, which are integrated horizontally or diagonally into the roof plane, roof monitors are elevated structures with vertical glazing (see Figure 17). Because they are raised above the roof, this allows for more precise orientation and improved solar control, making them ideal for large, thermally sensitive spaces. In the Northern Hemisphere, north-facing monitors provide diffuse, glare-free daylight, while south-facing variants require sheading to prevent visual and thermal discomfort. East- and west-facing monitors may benefit from vertical louvers to block low-angle sun (which will be discussed in next subchapter 3.5: Daylight controls). The opaque part of the monitor can be dimensioned to block unwanted sunlight, and glazing can be oriented in multiple directions if needed. As with overall building orientation, a north–south alignment is preferred for effective shading and consistent daylighting (Baker & Steemers, 2002).

4. SAWTOOTH ROOFS

Similar to roof monitors, sawtooth roofs feature vertical or steeply angled glazing raised above the roof plane (see Figure 18). This toplighting strategy typically consists out of a series of repeated roof elements, most often toward the north in the Northern Hemisphere, in order to admit diffuse daylight while reducing glare and harsh shadows. For optimal uniformity, the spacing between sawtooth elements should be approximately two and a half times the smallest room height (Baker & Steemers, 2002).

Unlike dome or flat skylights, sawtooth and other directional systems are orientation-sensitive, offering greater potential for passive solar control. In contrast, flat or dome types often require additional shading, particularly during summer when horizontal surfaces receive maximum solar radiation (Baker & Steemers, 2002)



Figure 17. Example of roof monitors (Aadl.org, 2018)



Figure 18. Example of sawtooth roofs KB (Mooren, 2025)

Although atria, courtyards, internal and external lightwells, and galleries (see Figure 19) are not toplighting systems in themselves, they can significantly enhance the performance of toplighting strategies. These architectural features function as vertical conduits for daylight, increasing the penetration depth of natural light and allowing toplighting systems to illuminate lower floors or deeper zones within the building. Such spatial configurations should be considered when implementing toplighting solutions, as their effectiveness often depends on both climate and location. For instance, in colder or denser urban contexts, enclosed atria, internal lightwells, and galleries can deliver daylight while also shielding occupants from wind and precipitation. These spaces may even provide passive thermal benefits in winter months. In such cases, lower storeys benefit most when atrium-facing walls and floor surfaces are finished in high-reflectance materials, which help to reflect and distribute daylight downward through the building. In contrast, external courtyards and open lightwells are more suitable in warmer or temperate climates. They offer improved natural ventilation and help dissipate excess heat, whereas fully enclosed internal systems may exacerbate overheating in such conditions (Baker & Steemers, 2002; Heschong, 2021).

In multi-storey buildings, daylight penetration becomes progressively shallower at lower levels. To maintain adequate illumination and sky view angles, daylighting design should respond by increasing glazing size on the lower floors facing the atrium. In addition, if opaque surfaces such as atrium walls and floors are finished in light-reflective colours, they can serve as secondary sources of daylight through indirect reflection, enhancing the overall luminance within these interior spaces (see Figure 19) (Baker & Steemers, 2002; Heschong, 2021).

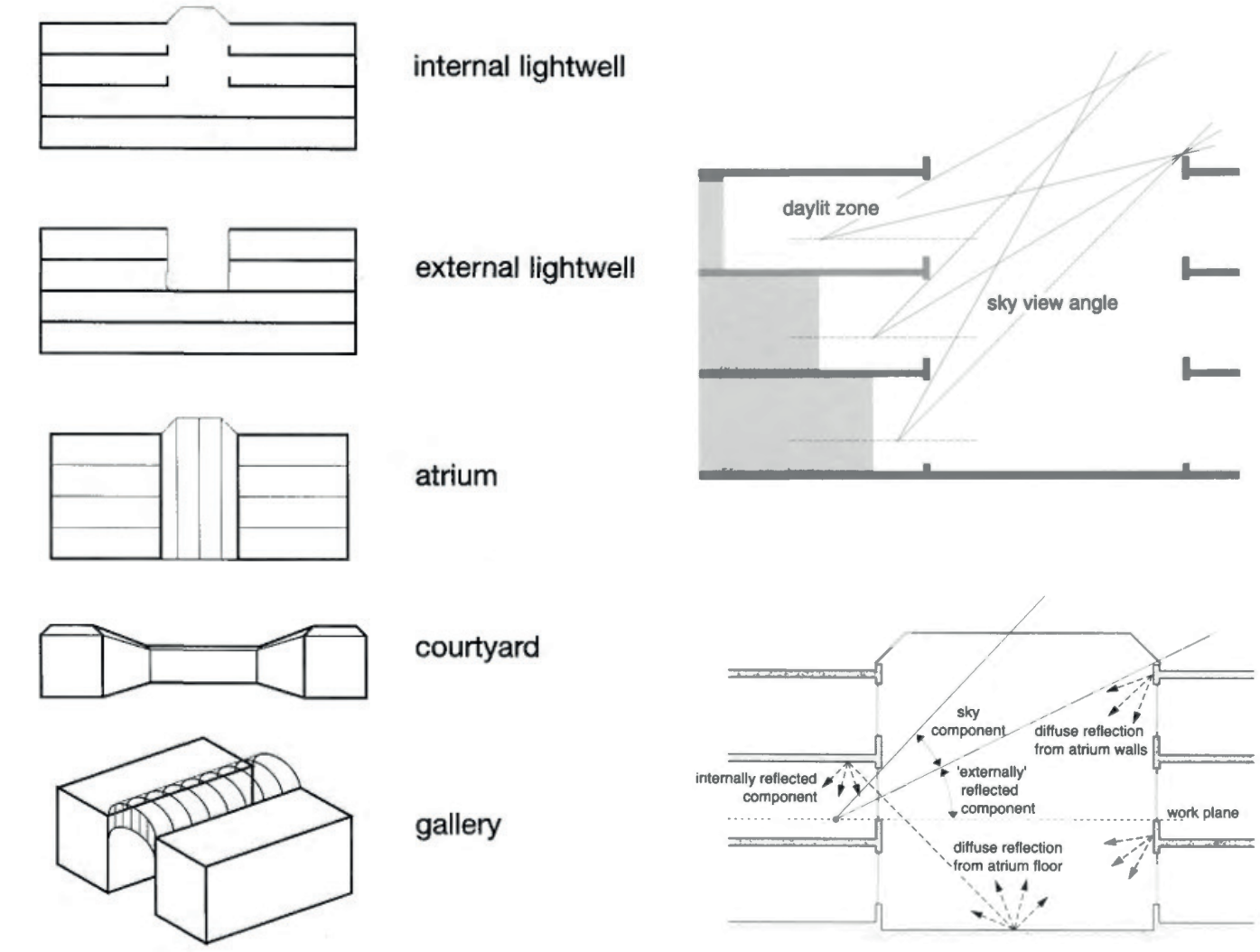


Figure 19. Simplified visualization architectural features (Baker & Steemers, 2002)

Toplighting strategies such as skylights, roof monitors, and sawtooth roofs provide effective means of bringing daylight deep into interior zones. Architectural elements like atria, courtyards, lightwells, and galleries can further support these systems by channeling daylight through the building and improving distribution in lower or more enclosed spaces. For each of the earlier discussed types of rooms in libraries their requirements according to the lighting type and plane level are shown in Figure 21.

In cases where none of these spatial or structural solutions can be applied, due to constraints in form, structure, or context, daylighting systems can serve as an alternative. These systems include devices such as light tubes and light guides, which use reflective materials and tubular conduits to capture and redirect daylight into parts of a building that would otherwise remain unlit (see Figure 20). Baker & Steemers (2002) identify four conditions under which daylighting systems may be appropriate:
1: The building is located in an environment where large surrounding obstructions block daylight access.
2: The interior space is so deep that conventional solutions involving sidelighting or toplighting cannot provide sufficient illuminance uniformity.
3: In sunny climates, where direct sunlight must be limited and redirected to deeper interior zones in order to reduce glare and overheating.
4: The space has unusually strict lighting requirements, such as in museums.

Although these systems offer valuable solutions in challenging situations, it is generally preferable to prioritise conventional architectural daylighting approaches. These approaches typically result in better light quality and stronger visual integration and connection to the outdoors. For this reason, conventional methods should always be evaluated first before considering more technical daylighting systems (Heschong, 2021; Baker & Steemers, 2002).

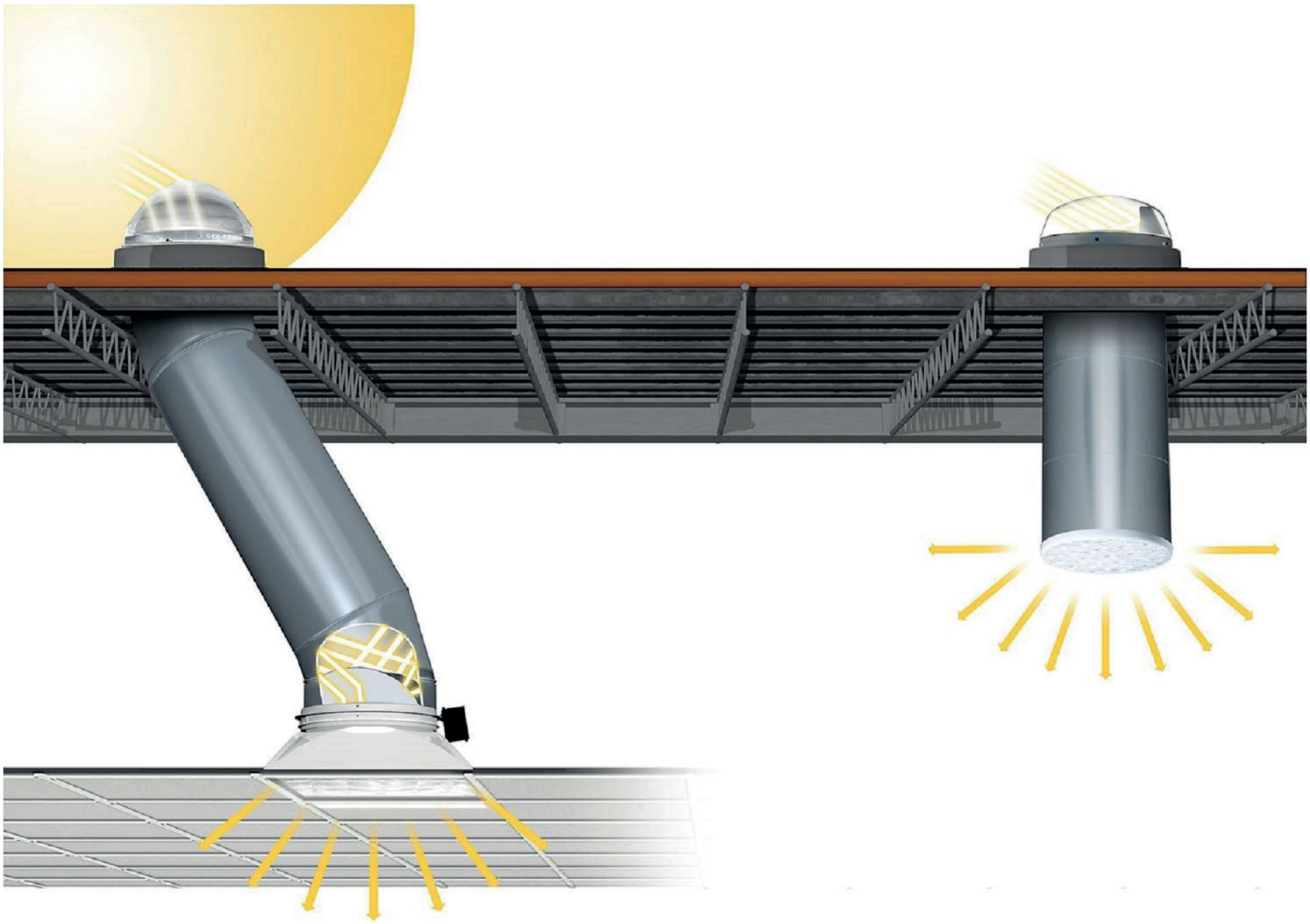


Figure 20. Simplified visualization daylighting system (CBGSouth, 2015)

LIBRARY LIGHTING TYPOLOGY MATRIX REQUIREMENTS → ↓ TYPE OF ROOM	DAYLIGHT	VIEW	ILLUMINANCE	GLARE	LIGHTING TYPE	PLANE LEVEL
	Is access to daylight required in this space?	Is visual access to the outdoors necessary?	What are the recommended illuminance levels (in lux)?	How critical is glare control for this space?	What type of lighting is most suitable for this space?	On what plane is lighting mostly needed?
READING ROOM	ESSENTIAL	ESSENTIAL	300—500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL
COMPUTER ROOM (MULTI-MEDIA ROOM)	NEUTRAL	OPTIONAL	150—250 lux	CRITICAL	PERPENDICULAR SIDELIGHTING + INDIRECT TOP	VERTICAL + HORIZONTAL
OFFICES	ESSENTIAL	ESSENTIAL	500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL (REAR)
INDIVIDUAL STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL
GROUP STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL
STUDY CARRELS	VERY IMPORTANT	VERY IMPORTANT	500—1000 lux	EXTREMELY IMPORTANT	SIDELIGHTING + TOPLIGHTING	HORIZONTAL
AUDITORIUM (LECTURE HALL)	OPTIONAL	NEUTRAL	300—500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL
MAKERSPACE	ESSENTIAL	BENEFICIAL	500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL
STACK AREAS (ACTIVE)	NOT IMPORTANT (AVOID DIRECT SUNLIGHT!)	UNNECESSARY	300 lux	LOW CONCERN	DIFFUSE TOPLIGHTING	VERTICAL
STACK AREAS (INACTIVE)	AVOID IF POSSIBLE	UNDESIRABLE	50 lux	NOT RELEVANT	DIFFUSE TOPLIGHTING	VERTICAL
CIRCULATION SPACE	PREFERABLE	BENEFICIAL	200—300 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL
CHILDREN PROGRAM ROOM	VERY IMPORTANT	VERY IMPORTANT	500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL
FOOD SERVICES (RESTAURANT/CAFÉ)	VERY IMPORTANT	IMPORTANT	300—500 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL
DEEP QUIET SPACE (MEDITATION ROOM)	OPTIONAL	OPTIONAL	100 lux	VERY IMPORTANT	DIFFUSE TOPLIGHTING	VERTICAL
BOOK RESTORATION SPACE	ESSENTIAL	VERY IMPORTANT	1000 lux	CRITICAL	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL

Figure 21. Matrix based on different type of rooms and their requirements in terms of lighting type and plane level.
Figure created by author (Mooren, 2025)

3.5 Daylight Controls

While daylight offers, as outlined in previous chapters, clear visual, physiological, and cognitive benefits, its uncontrolled presence can also lead to discomfort and distraction. Glare, excessive contrast, and overheating are among the most common causes of visual and thermal discomfort in libraries, and all have been shown to negatively affect concentration and task performance. Minimizing these stressors is therefore essential to maintaining the cognitive benefits of daylight. The challenge lies not only in allowing daylight to enter a space, but in regulating it effectively. This becomes especially relevant in geographic contexts such as The Hague, where the sun remains below 30 degrees of altitude for nearly two-thirds of the total daylight hours throughout the year. At such low angles, sunlight is more likely to enter spaces directly, bypassing horizontal shading elements and creating intense glare across work surfaces and screens. To address these conditions, various architectural strategies have been developed that integrate daylight control directly into the design of the building envelope. This subchapter introduces three core categories of daylight modulation strategies: 1) Static Architectural Shading Systems, 2) Dynamic or User-Operated Systems, and 3) Material-Based and Optical Daylight Modulation Systems.

1. STATIC ARCHITECTURAL SHADING SYSTEMS

These consist of fixed design elements that are strategically integrated into the architectural envelope to control solar radiation based on orientation and solar altitude. Static shading systems are passive by nature, and are most effective when their geometry is carefully calibrated to the sun's predictable seasonal path.

In the Northern Hemisphere, on south-facing façades, where the sun reaches higher altitudes during summer, horizontal overhangs and fixed light shelves (see Figure 22) can block direct solar gain while still allowing diffuse daylight and low winter sun to penetrate the interior. East- and west-facing façades, however, are exposed to low-angle sunlight in the early morning and late afternoon. Vertical fins or louvers, brise-soleil, and deep façade reveals can effectively shield against this lateral light while maintaining outward views and natural ventilation. When thoughtfully spaced, such elements also add a sense of rhythm and material depth to the façade (Ale & Yunus, 2022). Additional shading systems are for example perforated metal panels, mesh fabrics, or fixed textile screens that act as semi-transparent filters. These moderate brightness and soften contrast without completely obstructing views to the outside. When patterned, they can even enhance cognitive engagement by introducing subtle fractal geometries (Heschong, 2021). In more complex assemblies, the façade itself may become a layered shading system. Double-skin façades, which feature a ventilated cavity between two glazed surfaces, create a thermal and luminous buffer zone that moderates solar gain and daylight entry throughout the year. Especially in climates with significant seasonal variation in solar angle and daylight duration, such systems provide a more stable and diffuse interior light quality (Baker & Steemers, 2002).



Figure 22. Example of horizontal overhangs within a library building (Archdaily, 2018)

2. DYNAMIC OR USER-OPERATED SHADING SYSTEMS

This category includes both manual and automated elements that are movable, adjustable, or responsive, allowing users or control systems to modulate daylight in response to changing conditions. Unlike static solutions, these systems offer flexibility and adaptability throughout the day and across seasons, making them particularly effective in environments with fluctuating sunlight exposure or diverse user preferences.

A commonly used strategy is the implementation of adjustable shutters or louvered panels (either horizontal or vertical), typically installed on the building's exterior (see Figure 23). These can redirect sunlight upwards or sideways, reducing glare while maintaining outward views. A variation on this approach is the use of sliding screens, which can be slided manually or automatically to specific locations of the façade. Venetian blinds, operating on a similar principle, but are most often used internally, with either horizontal or vertical slats. While not typically part of the architectural composition, they allow precise modulation of daylight and glare. Mesh roller shades, made from semi-transparent textile materials, offer another layer of control by filtering sunlight, reducing heat gain, and maintaining visual connection with the outside. These perform best when installed on the exterior, although this comes with higher maintenance requirements. Curtains and fabric panels provide similar light-filtering benefits, though they are more often used for decorative purposes in interior applications. Retractable awnings or façade elements function similarly to fixed overhangs but can be extended or retracted based on need, either manually or via automation. While not always an intrinsic part of the architectural language, their flexibility adds practical value in highly exposed zones. A more technologically integrated solution is electrochromic glass, in which thin-film coatings allow for electronic tint adjustment based on light conditions. This system enables seamless, frameless modulation of daylight without the need for physical shading devices. However, studies have shown mixed user responses, particularly in larger rooms, where users may perceive the tint as too dark or inconsistent (Heschong, 2021; Baker & Steemers, 2002). Many of these systems can be integrated into sensor-based daylight-responsive controls, where shading elements adjust automatically according to solar intensity or interior illuminance levels. While these automated solutions promise optimal performance, research indicates that user satisfaction is often highest when manual override remains possible. This balance between automation and user agency will be explored further in subchapter 3.7: Task-Specific and User-Centered Lighting Control Systems.

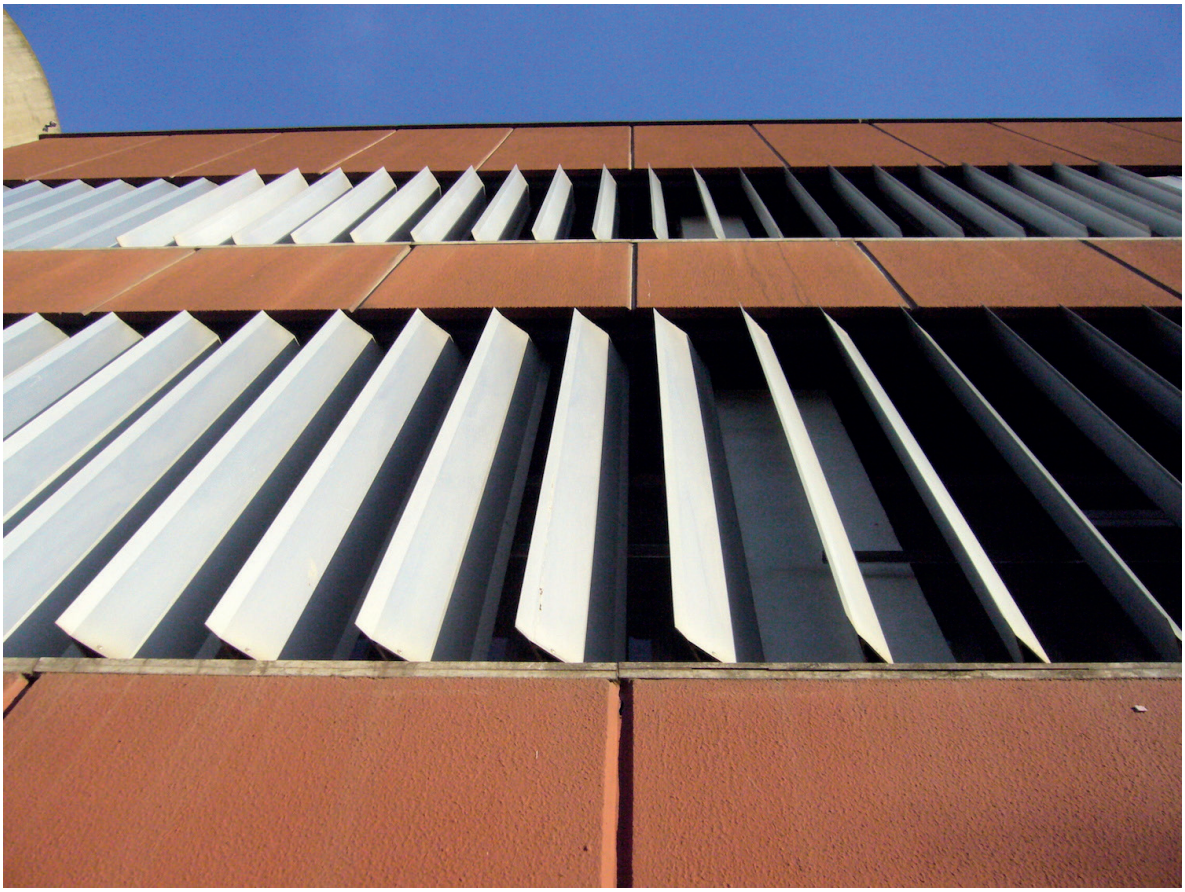


Figure 23. Example of adjustable vertical louvered panels (Filt3rs, 2015)

3. MATERIAL-BASED AND OPTICAL DAYLIGHT MODULATION SYSTEMS

In addition to structural and operable shading devices, a third category of daylight control involves material-based and optical strategies. These strategies operate at the level of glazing treatments, interior surfaces, and architectural detailing, offering subtle yet effective means of improving visual comfort, often without altering the building's massing or structure.

A primary area of intervention is glazing. Low-emissivity (low-E) glass incorporates microscopically thin coatings that reflect infrared radiation while allowing visible light to pass through, thereby reducing heat gain without compromising daylight levels. Fritted or patterned glass, often composed of ceramic dots or lines printed onto the surface, diffuses incoming light to reduce glare and contrast while preserving outward visibility (see Figure 24). Similarly, frosted or etched glass features a uniformly matte surface that scatters light more evenly, but also eliminates direct views. These diffusing strategies can be customized with a wide range of patterns to suit both functional and aesthetic intentions. A more advanced glazing solution is angular-selective glass, which functions like a dense array of microscopic louvers. The angular geometry filters out direct sun while transmitting diffuse daylight, creating comfortable lighting conditions in glare-sensitive areas such as reading rooms (Baker & Steemers, 2002).

Vegetation also plays an important role in light modulation. Green façades and adjacent green roofs can soften incoming sunlight and filter brightness, while simultaneously offering ecological and emotional benefits. As a form of natural shading, vegetation introduces seasonal variability and a biophilic quality that enhances user well-being (Heschong, 2021). Visual comfort can also be improved by regulating contrast through interior design. Three-dimensional elements near windows can catch and reflect spillover light, softening luminance gradients. In line with Heschong's (2021) insights, layered visual transitions around window openings can create nuanced shifts in brightness and depth that reduce perceptual discomfort while enriching the visual field. This can be done by using mullions, shaped moldings, or other architectural ornamentation. Finally, kinetic façades and dynamic shading skins represent a technologically expressive mode of daylight regulation. These systems allow parts of the façade to move or shift in response to solar conditions, offering real-time control of glare and daylight penetration. While their complexity and cost limit widespread use, they highlight the architectural potential of responsive light control and demonstrate how performance can be aesthetically articulated.

In summary, daylighting controls are not merely technical additions, but should be understood as essential components of an integrated architectural strategy. When skillfully designed, they create a refined balance between luminous comfort and cognitive support. The next subchapter 3.6: Artificial Lighting Design Strategies will turn from natural to artificial lighting systems, which remain equally crucial in library environments especially when daylight alone does not suffice.



Figure 24. Example of fritted or patterned glass (Architizer, 2018)

3.6 Artificial Lighting Design Strategies

While natural daylight remains the primary driver of circadian and cognitive regulation, artificial lighting plays an equally critical role. Artificial lighting systems must therefore be thoughtfully designed to complement daylight. As with daylight, both the visual and non-visual effects of artificial light depend on different factors. In artificial lighting these include spectral composition, correlated colour temperature (CCT), illuminance levels, glare control and adaptability. of which all will be discussed in this subchapter (Hawkins, 2024).

Historically, libraries have predominantly relied on fluorescent, incandescent and high-intensity discharge (HID) lamps due to their widespread availability and relatively high luminous efficacy. Fluorescent and HID lamps generate light by conducting an electric current through a gas medium, whereas incandescent lamps produce light by heating a tungsten filament until it emits visible radiation. These conventional sources are typically available in warm (3000K), neutral (3500K), and cool (4100K) correlated colour temperatures (CCTs), with 3500K being the most prevalent in library settings, as it offers a balanced and neutral appearance. However, despite their former ubiquity, these traditional technologies come with significant limitations. Incandescent lamps are inefficient and have short operational lifespans. Fluorescent and HID sources, while more energy-efficient, are prone to issues such as flicker, limited dimmability, and suboptimal colour rendering performance. Moreover, the ability to maintain even illumination is critical in library environments, where visual comfort and uniform lighting are essential. Consequently, these shortcomings have led to a widespread transition towards light-emitting diodes (LEDs) in contemporary library design. Compared to earlier light sources, LEDs provide higher energy efficiency, longer lifespan, improved colour rendering, and greater adaptability in terms of both luminous intensity and spectral composition (Heschong, 2021).

Recent developments in LED technology have introduced daylight-mimicking LEDs (DLMs), designed to replicate the spectral and temporal qualities of natural light. These systems are associated with improved mood, comfort and cognitive performance compared to standard LEDs. DLMs outperform conventional lighting systems in terms of environmental appraisal and cognitive-related metrics such as reaction time and focus (Bellia et al., 2024). While not all studies report significant improvements in task performance, the overall evidence suggests that DLMs offer meaningful advantages for supporting knowledge acquisition and cognitive functioning in library environments (Bellia et al., 2024).

As explored in subchapter 2.2 Neurological and Psychological Responses to Light Exposure**,** the correlated colour temperature (CCT) of artificial lighting exerts a significant impact on both visual comfort and cognitive performance (Mostafavi et al., 2024). Importantly, different library zones benefit from distinct CCT levels, depending on the specific functions performed and the nature of user activity within each space. To guide optimal application, Figure 26 provides an overview of recommended CCT values tailored to various library functions. Cool white light, typically ranging from 4000 K to 5000 K, creates a bright, stimulating atmosphere conducive to heightened alertness and sustained concentration. This makes it particularly suitable for task-intensive environments such as computer workstations and study carrels. In contrast, warmer lighting between 2700 K and 3500 K is more appropriate for fostering emotional comfort and relaxation. Such lighting conditions support informal interactions, presentation settings, and quiet zones, where a calming ambience is desirable. Moreover, exposure to high CCT levels around 6500 K, rich in short-wavelength (blue) light, has been shown to enhance cognitive arousal and visual alertness, especially during complex or multitasking activities. However, while these higher CCT levels may be effective in short bursts, they are not universally preferred for prolonged use, as they can contribute to visual fatigue or discomfort over time (Çelik et al., 2024; Jung et al., 2024)

Beyond these general recommendations, it is increasingly acknowledged that individual variability significantly shapes visual and cognitive responses to lighting. Consequently, it is essential to incorporate user-controllable lighting systems such as adjustable desk lamps into library environments. These allow users to tailor both illuminance and CCT to match personal comfort levels and task-specific requirements (Jung et al., 2024). In this context, LED-based systems with tunable colour temperature are particularly advantageous. They offer flexible, responsive lighting conditions that support a diverse range of activities, from digital reading to manual note-taking, thereby enhancing both autonomy and cognitive performance (Sarialioglu, 2025).

Just as with natural lighting, glare represents a major challenge in artificial lighting design. It typically occurs in two forms (see Figure 25): direct glare, which arises when light fixtures emit radiation directly into the user's eyes, and reflected glare, caused by excessive luminance bouncing off from objects or surfaces within the field of view (Cungiono et al., 2021). Both forms can compromise visual comfort and reduce task performance. To mitigate these effects, designers should consider using diffusing materials that soften light distribution and minimize luminance contrasts. Equally important is the selection of appropriate luminaire geometry. For example, parabolic reflectors are commonly employed in general lighting to distribute light evenly while shielding direct views of the light source (Heschong, 2021). This approach forms part of an indirect lighting strategy, in which luminous ceilings, created by uplighting fixtures or backlit translucent membranes, deliver soft, uniform illumination that reduces glare and eliminates harsh shadows on both horizontal and vertical planes. However, such uniformity may result in visual monotony, particularly in spaces dominated by light-coloured surfaces. In contrast, direct lighting introduces sharper contrasts and strong shadows, which can enhance spatial articulation and foster a sense of visual depth. While this form of lighting is particularly suitable for highlighting specific areas or objects (focal glow), its overuse can cause discomfort or visual fatigue. The most effective lighting design acknowledges both approaches and selects a balanced solution based on spatial context and visual tasks. Additionally, the direction of illuminance in relation to the user's viewing angle is vital; light directed straight down onto reading material helps avoid veiling reflections and supports a stable visual environment (Lushington et al., 2016).

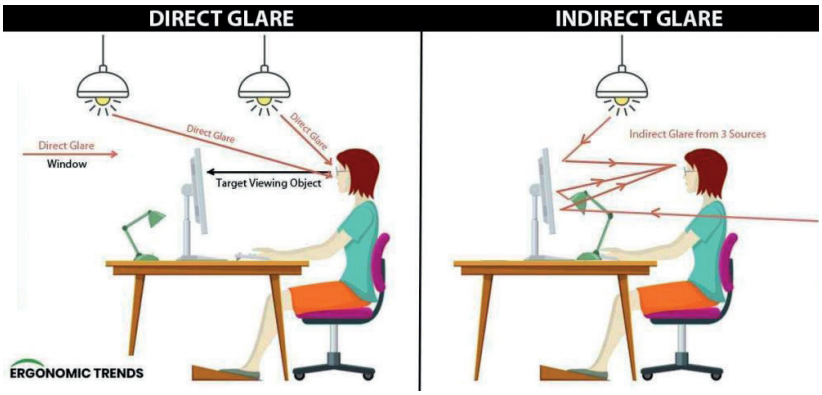


Figure 25. Principles of direct versus indirect glare (ErgonomicTrends, 2021)

A comprehensive artificial lighting scheme should therefore incorporate three complementary layers: ambient (indirect), task (direct), and accent (sparkle) lighting. As previously discussed in subchapter 3.1: Basics of a well illuminated design, sparkle lighting adds points of visual interest and perceptual brightness, particularly in environments lacking daylight. These can be achieved through tiny point sources in a chandelier, downlights, spotlights, LED strips, or string lights that enhance spatial richness while consuming minimal energy (Heschong, 2021). Even modest interventions of this kind can significantly improve environmental appraisal, shifting the perception of a space from dull to dynamic.

Although artificial lighting should primarily support and supplement daylight, it cannot fully replicate the physiological and psychological benefits associated with real natural light and outdoor views. Nonetheless, in daylight-deprived zones such as underground areas or deep-plan interiors, designers may consider simulation technologies such as holographic optical elements, light boxes, or biophilic illusions such as video-simulated skylights. While users tend to prefer these simulated alternatives over fully enclosed spaces, current research suggests that their effects do not equal those of authentic window exposure in terms of measurable cognitive and physiological outcomes (Heschong, 2021). Nevertheless, they may contribute meaningfully to the overall perceptual quality of windowless environments.

In conclusion, artificial lighting in libraries must be understood as a supportive and adaptive complement to natural lighting. It should not only fulfill basic visual requirements, but also accommodate the cognitive and emotional needs of diverse users across different spatial settings. By integrating LED technologies with daylight-mimicking spectra, appropriate colour temperature, task lighting, glare control, and visual dynamism, designers can create artificial lighting environments that elevate visual comfort and enhance cognitive performance.

LIBRARY LIGHTING TYPOLOGY MATRIX → / ↓ TYPE OF ROOM — REQUIREMENTS	DAYLIGHT	VIEW	ILLUMINANCE	GLARE	LIGHTING TYPE	PLANE LEVEL	CCT LEVELS
	Is access to daylight required in this space?	Is visual access to the outdoors necessary?	What are the recommended illuminance levels (in lux)?	How critical is glare control for this space?	What type of lighting is most suitable for this space?	On what plane is lighting mostly needed?	What CCT range is appropriate for the tasks in this space?
READING ROOM	ESSENTIAL	ESSENTIAL	300—500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL	4000-5000K
COMPUTER ROOM (MULTI-MEDIA ROOM)	NEUTRAL	OPTIONAL	150—250 lux	CRITICAL	PERPENDICULAR SIDELIGHTING + INDIRECT TOP	VERTICAL + HORIZONTAL	4000-5000K
OFFICES	ESSENTIAL	ESSENTIAL	500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL (REAR)	4000-5000K
INDIVIDUAL STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K
GROUP STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K
STUDY CARRELS	VERY IMPORTANT	VERY IMPORTANT	500—1000 lux	EXTREMELY IMPORTANT	SIDELIGHTING + TOPLIGHTING	HORIZONTAL	4000-5000K
AUDITORIUM (LECTURE HALL)	OPTIONAL	NEUTRAL	300—500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL	3500-5000K
MAKERSPACE	ESSENTIAL	BENEFICIAL	500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL	4000-6500K
STACK AREAS (ACTIVE)	NOT IMPORTANT (AVOID DIRECT SUNLIGHT!)	UNNECESSARY	300 lux	LOW CONCERN	DIFFUSE TOPLIGHTING	VERTICAL	3500-4000K
STACK AREAS (INACTIVE)	AVOID IF POSSIBLE	UNDESIRABLE	50 lux	NOT RELEVANT	DIFFUSE TOPLIGHTING	VERTICAL	3500-4000K
CIRCULATION SPACE	PREFERABLE	BENEFICIAL	200—300 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL	3500-4000K
CHILDREN PROGRAM ROOM	VERY IMPORTANT	VERY IMPORTANT	500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K
FOOD SERVICES (RESTAURANT/CAFÉ)	VERY IMPORTANT	IMPORTANT	300—500 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL	2700-3000K
DEEP QUIET SPACE (MEDITATION ROOM)	OPTIONAL	OPTIONAL	100 lux	VERY IMPORTANT	DIFFUSE TOPLIGHTING	VERTICAL	2700-3000K
BOOK RESTORATION SPACE	ESSENTIAL	VERY IMPORTANT	1000 lux	CRITICAL	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL	4000-6500K

Figure 26. Matrix based on different type of rooms and their requirements in terms of correlated colour temperature. Figure created by author (Mooren, 2025)

3.7 Task-Specific and User-Centered Lighting Control Systems

The success of lighting design in libraries not only depends on sufficient illumination but also on the ability to adapt the lighting conditions to different user needs. In commercial buildings, the choice of control can make 30-40% difference to the lighting energy use (Baker & Steemers, 2002). Moreover, inappropriate lighting control systems can result in eye strain, headaches, musculoskeletal injuries, increased body temperature, and ultimately diminished attention and task performance (Samani, 2012; Singh et al., 2020). In contrast, lighting control systems that support autonomy and task-specific differentiation have been shown to enhance both comfort and cognitive functioning (Samani, 2012; Heschong, 2021). Lighting control systems generally fall into two categories: manual and automatic. Manual systems rely on the occupant to adjust lighting parameters such as illuminance, the degree of shading, directionality of both illuminance and shading, and sometimes even correlated color temperature (CCT). Automatic systems, on the other hand, respond to environmental conditions through sensors or pre-programmed settings.

Although automatic systems are often assumed to optimise energy use, studies show that user-operated manual controls frequently outperform fully automated systems in both satisfaction and efficiency (Heschong, 2021; Jamrozik et al., 2019). Occupants tend to disable automated blinds or lighting systems when they feel a loss of control, especially when the system behaves unpredictably or interferes with visual tasks. For this reason, manual override options are considered essential, even in sensor-driven environments (Jamrozik et al., 2019). Usability plays a crucial role. As Heschong (2021) observes, controls that are physically out of reach or difficult to understand are rarely used. Simple manual switches, dimmers, and adjustable task lighting at study desks or carrels can significantly increase visual comfort and user satisfaction (Lushington, 2016).

Automatic systems can offer valuable baseline control. Daylight-linked photocontrols, for instance, dim or switch off electric lights when ambient daylight exceeds a preset lux level (Çelik et al., 2024). These systems are effective in high-traffic or communal areas such as atria, entrance halls, or circulation zones, where individual control is less critical (Baker & Steemers, 2002). Other sensor-based strategies include motion detectors for intermittently occupied spaces, though these should be used cautiously in areas where concentration and task performance is essential, due to the risk of disruptive false triggers. Time-based switching is another low-tech yet effective method: for example, scheduling a midday switch-off in summer, after which users can manually reactivate lights if needed. More refined strategies such as daylight-linked time delays or differential switching can reduce visual disruption by ensuring lights remain off only after sustained high daylight levels (Baker & Steemers, 2002). If automatic switching is applied, the most efficient results are achieved using daylight-linked time delays. In this approach, lighting remains on until daylight levels have exceeded a defined threshold for a set period of time, preventing unnecessary or premature switching. An alternative strategy is differential switching, where the illuminance level required to switch lights off is set higher than that required to switch them on. This ensures that the transition is less perceptible.

Manual switching tends to be more effective in smaller, individually occupied spaces such as private study rooms or cellular offices, where users have a clear sense of control. In contrast, larger, shared areas like atria, entrance zones, or open-plan offices benefit more from automatic systems, especially where no single occupant is responsible for lighting conditions. However, in some multi-user spaces, energy can still be wasted if lighting remains on unnecessarily. In such cases, localized switching provides greater flexibility and efficiency, particularly in open workstation layouts (Baker & Steemers, 2002). Figure 27 provides an overview of the required level of lighting adjustability per space type.

Ultimately, the most effective solution is a hybrid system that combines automated baseline operation with manual override. While automated controls maintain default efficiency and reduce worst-case scenarios, manual adjustment allows users to respond to changing conditions and personal preferences. This combination ensures both energy performance and occupant satisfaction (Baker & Steemers, 2002). In sum, differentiated lighting by zone and task, supported by flexible, user-centered control systems, is essential for optimising both cognitive performance and environmental comfort in libraries. Lighting control is not just a technical feature; it is a fundamental component of spatial management and cognitive design.

Figure 27 offers a synthesis of the differentiated spatial requirements across key library functions. It emphasises the fundamental conditions pertaining to lighting, view and adjustability for each primary room type.

LIBRARY LIGHTING TYPOLOGY MATRIX ↓ TYPE OF ROOM / REQUIREMENTS →	DAYLIGHT	VIEW	ILLUMINANCE	GLARE	LIGHTING TYPE	PLANE LEVEL	CCT LEVELS	ADJUSTABILITY
	Is access to daylight required in this space?	Is visual access to the outdoors necessary?	What are the recommended illuminance levels (in lux)?	How critical is glare control for this space?	What type of lighting is most suitable for this space?	On what plane is lighting mostly needed?	What CCT range is appropriate for the tasks in this space?	What lighting control system is needed?
READING ROOM	ESSENTIAL	ESSENTIAL	300—500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL	4000-5000K	ADJUSTABLE GENERAL
COMPUTER ROOM (MULTI-MEDIA ROOM)	NEUTRAL	OPTIONAL	150—250 lux	CRITICAL	PERPENDICULAR SIDELIGHTING + INDIRECT TOP	VERTICAL + HORIZONTAL	4000-5000K	TASK TUNABLE
OFFICES	ESSENTIAL	ESSENTIAL	500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL (REAR)	4000-5000K	ZONAL SWITCHING
INDIVIDUAL STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K	FULLY ADJUSTABLE
GROUP STUDY ROOM	VERY IMPORTANT	VERY IMPORTANT	300—500 lux	EXTREMELY IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K	FULLY ADJUSTABLE
STUDY CARRELS	VERY IMPORTANT	VERY IMPORTANT	500—1000 lux	EXTREMELY IMPORTANT	SIDELIGHTING + TOPLIGHTING	HORIZONTAL	4000-5000K	TASK TUNABLE
AUDITORIUM (LECTURE HALL)	OPTIONAL	NEUTRAL	300—500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL	3500-5000K	ZONAL SWITCHING
MAKERSPACE	ESSENTIAL	BENEFICIAL	500 lux	EXTREMELY IMPORTANT	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL	4000-6500K	TASK TUNABLE
STACK AREAS (ACTIVE)	NOT IMPORTANT (AVOID DIRECT SUNLIGHT!)	UNNECESSARY	300 lux	LOW CONCERN	DIFFUSE TOPLIGHTING	VERTICAL	3500-4000K	ZONAL SWITCHING
STACK AREAS (INACTIVE)	AVOID IF POSSIBLE	UNDESIRABLE	50 lux	NOT RELEVANT	DIFFUSE TOPLIGHTING	VERTICAL	3500-4000K	FIXED GENERAL
CIRCULATION SPACE	PREFERABLE	BENEFICIAL	200—300 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	VERTICAL	3500-4000K	AUTOMATED GENERAL
CHILDREN PROGRAM ROOM	VERY IMPORTANT	VERY IMPORTANT	500 lux	IMPORTANT	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL + VERTICAL	4000-5000K	ADJUSTABLE GENERAL
FOOD SERVICES (RESTAURANT/CAFÉ)	VERY IMPORTANT	IMPORTANT	300—500 lux	MODERATE CONCERN	SIDELIGHTING + OPTIONAL TOPLIGHTING	HORIZONTAL	2700-3000K	MANUAL OVERRIDE
DEEP QUIET SPACE (MEDITATION ROOM)	OPTIONAL	OPTIONAL	100 lux	VERY IMPORTANT	DIFFUSE TOPLIGHTING	VERTICAL	2700-3000K	ADJUSTABLE GENERAL
BOOK RESTORATION SPACE	ESSENTIAL	VERY IMPORTANT	1000 lux	CRITICAL	TOPLIGHTING + SIDELIGHTING	HORIZONTAL + VERTICAL	4000-6500K	FULLY ADJUSTABLE

Figure 27. Complete matrix based on different type of rooms and their requirements. Figure created by author (Mooren, 2025)

Figure 28 offers a concise synthesis of the differentiated spatial requirements across key library functions, focusing on lighting, view, and adjustability. Its abstracted format allows for quick visual comparison at a glance.

LIBRARY LIGHTING TYPOLOGY MATRIX ↓ TYPE OF ROOM REQUIREMENTS →	DAYLIGHT How important is access to daylight?	VIEW How important is having an outside view?	ILLUMINANCE How many lux are needed in this space?	GLARE How critical is glare control for this space?	LIGHTING TYPE What type of lighting is most suitable for this space?	PLANE LEVEL On what plane is lighting mostly needed?	CCT LEVELS Does this space need a high CCT level?	ADJUSTABILITY How adjustable should the lighting be for the users of the space?
READING ROOM	●	●	●	●	↓ + →	—	●	●
COMPUTER ROOM (MULTI-MEDIA ROOM)	●	●	●	●	↓ + →	| + —	●	●
OFFICES	●	●	●	●	→ (+ ↓)	— + |	●	●
INDIVIDUAL STUDY ROOM	●	●	●	●	→ (+ ↓)	— + |	●	●
GROUP STUDY ROOM	●	●	●	●	→ (+ ↓)	— + |	●	●
STUDY CARRELS	●	●	●	●	→ + ↓	—	●	●
AUDITORIUM (LECTURE HALL)	●	●	●	●	→ (+ ↓)	|	●	●
MAKERSPACE	●	●	●	●	↓ + →	— + |	●	●
STACK AREAS (ACTIVE)	●	●	●	●	↓	|	●	●
STACK AREAS (INACTIVE)	●	●	●	●	↓	|	●	●
CIRCULATION SPACE	●	●	●	●	→ (+ ↓)	|	●	●
CHILDREN PROGRAM ROOM	●	●	●	●	→ (+ ↓)	— + |	●	●
FOOD SERVICES (RESTAURANT/CAFÉ)	●	●	●	●	→ (+ ↓)	—	●	●
DEEP QUIET SPACE (MEDITATION ROOM)	●	●	●	●	↓	|	●	●
BOOK RESTORATION SPACE	●	●	●	●	↓ + →	— + |	●	●

Figure 28. Concise synthesis of matrix based on different type of rooms and their requirements. Figure created by author (Mooren, 2025)

3.8 Evidence-Based Library Lighting Framework

Following a comprehensive review of all previously discussed sources, an Evidence-Based Library Lighting Framework has been developed (see Figure 29). Drawing from interdisciplinary research in architecture, environmental psychology, neuroscience, and lighting design, this framework repositions lighting as more than a technical provision. It is conceived as a spatial and cognitive stimulant. It aims to support architects and lighting designers by providing practical, research-informed strategies for creating library environments that foster knowledge acquisition and cognitive performance through purposeful lighting interventions.

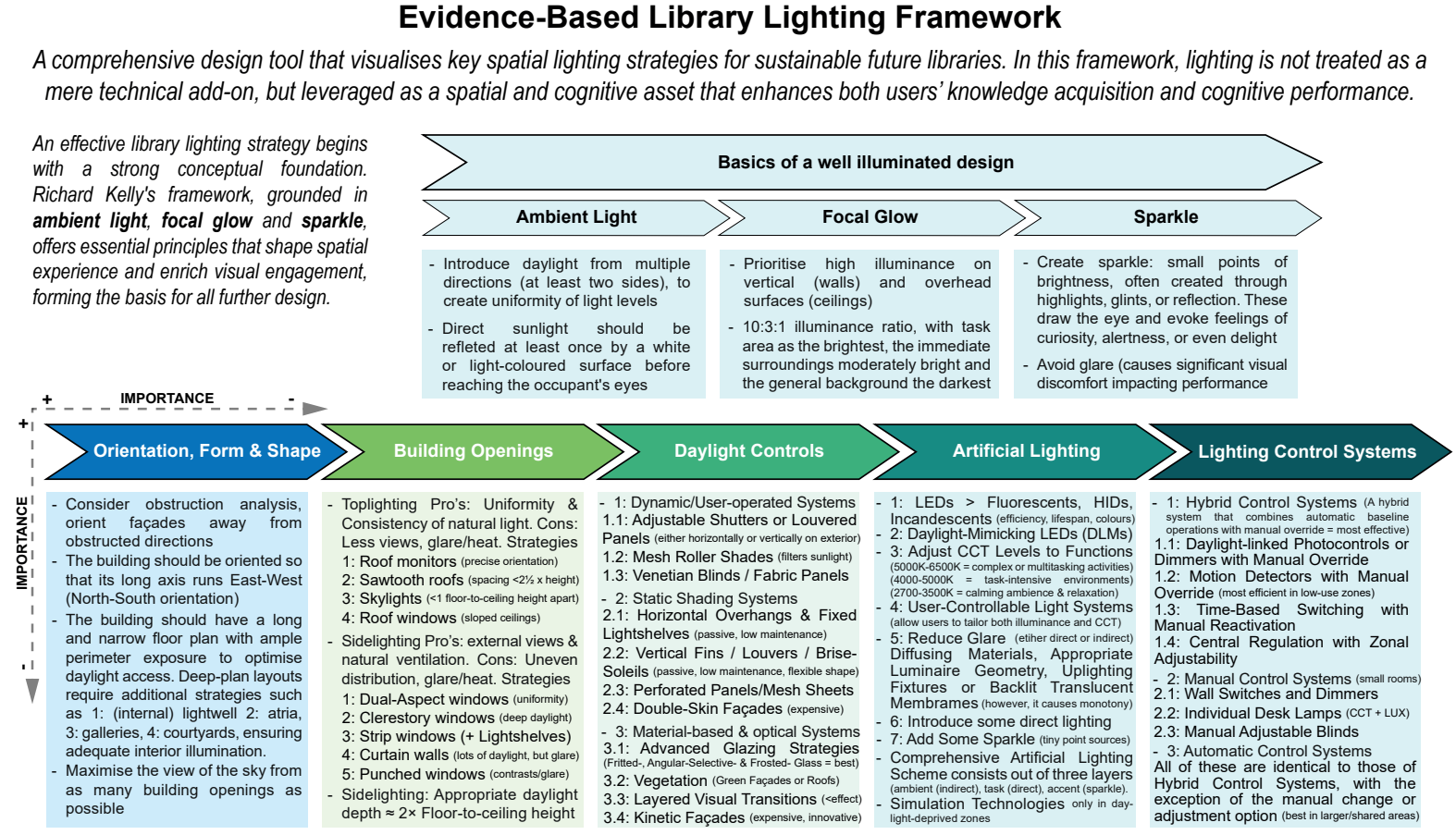


Figure 29. Evidence-Based Library Lighting Framework. Figure created by author (Mooren, 2025)

Figure 30 presents a concise synthesis of the Evidence-Based Library Lighting Framework, offering a clear visual overview that enables quick reference and comprehension at a glance.

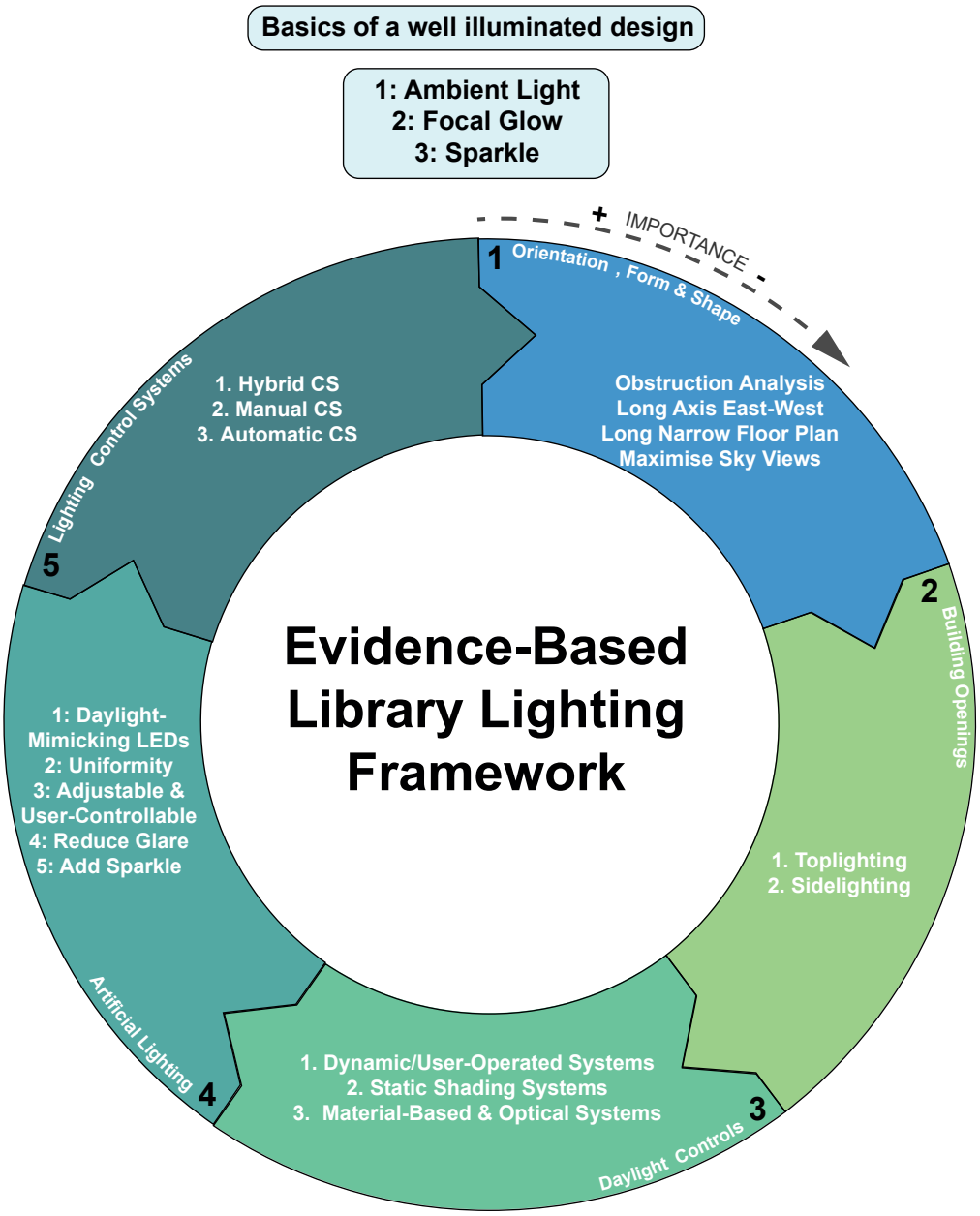


Figure 30. Concise synthesis of the Evidence-Based Library Lighting Framework. Figure created by author (Mooren, 2025)

CHAPTER 4: What are effective lighting strategies to integrate into the existing structure of the Royal Library to optimise knowledge acquisition and cognitive performance?

While an evidence-based library lighting framework has been established, the next step is to explore how it can be applied through a more practice-oriented approach. This chapter outlines the design-oriented and empirical research activities undertaken in the context of the Royal Library (KB) in The Hague. The objective is to investigate how conceptual lighting strategies can be translated into spatial interventions that enhance knowledge acquisition and cognitive performance.

Solar and view studies have been carried out, forming the foundation for a series of conceptual design proposals. These concepts were tested using physical models in the Artificial Sky, a controlled environment that replicates the solar path for a specific geographic location and time of year. This setup enabled a preliminary evaluation of daylight performance, glare risk, and the spatial experience generated by each proposed intervention.

In order to align these strategies with user perception, a combination of interviews and surveys was conducted among frequent users of the Royal Library building. These provided valuable insights into the current lighting and atmospheric conditions as experienced by the users. The results of both methods were then analysed and integrated into the ongoing design evaluation. All resulting data and materials are included in the appendix for transparency and further reference.

The subsequent phase of the research focuses on translating the analytical insights into an initial conceptual design. At this stage, the principles distilled from the literature review, empirical findings, and the Evidence-Based Library Lighting Framework begin to take spatial form. The schematic studies presented in appendix K reflect this early design development, showing how considerations of daylight, artificial lighting, spatial orientation and user autonomy are explored through iterative sketches. These explorations serve as a bridge between research and design, allowing the identified strategies to be tested, adjusted, and spatially articulated within the constraints of the existing Royal Library structure.

Following this conceptual phase, the design process progresses into a more refined stage in which emerging ideas are consolidated into a coherent architectural proposal. The final drawings and design outcomes included in appendix L illustrate how the concept evolves into a resolved lighting and spatial strategy, integrating the earlier research outcomes into material selections, spatial organisation, and the calibration of daylight and artificial lighting conditions. The final representations form the basis of the methodological sequence, illustrating how the theoretical and empirical insights of this thesis inform a design proposal that is tailored to enhance cognitive performance and knowledge acquisition within the Royal Library.

CHAPTER 5: DISCUSSION AND CONCLUSION

The objective of this study was to explore how the lighting landscape of future library environments can be designed to stimulate user-driven knowledge acquisition and cognitive performance. The findings confirm the central hypothesis that light is not merely a visual phenomenon, but a significant neurological stimulant that influences the cognitive and emotional state of users through both visual and non-visual pathways.

A first key insight from the research is the fundamental role of circadian-responsive lighting. Both literature and empirical findings indicate that stable, well-calibrated light–dark cycles directly support attention, memory, mood, and overall cognitive capacity. In this instance, the quality and timing of light exposure were found to be critical factors. A second key finding relates to the importance of visual dynamism and access to views of the outside. Views with layered depth and natural elements have been shown to be associated with extended attention spans and improved memory formation. A third finding reveals that well-illuminated environments benefit from the integration of layered lighting, including ambient light, focal glow, and sparkle, as conceptualised by Richard Kelly. These lighting layers enhance stimulation and alertness. Finally, the importance of user autonomy over lighting conditions, supported through adjustable luminaires, personal task lighting, and flexible control systems, was demonstrated in promoting knowledge acquisition and cognitive performance.

Together, these insights formed the basis for the development of an evidence-based library lighting framework. This framework identifies and organises spatial lighting strategies according to thematic categories, offering design guidance for those seeking to enhance cognitive and perceptual performance in library environments. The most critical themes, in order of importance, include orientation, form and shape, building openings, daylight controls, artificial lighting, and lighting control systems. When applied from the earliest design phases, the framework provides designers with a practical structure for creating environments that support both visual comfort and cognitive performance.

Nonetheless, several limitations remain. First, it is inherently difficult to quantify the direct impact of architectural lighting decisions on knowledge acquisition and cognitive performance. While the framework offers clear direction based on interdisciplinary evidence, the extent to which specific strategies enhance cognitive outcomes cannot always be precisely measured. Second, the applicability of individual recommendations depends heavily on contextual factors such as geographic location, climate, site surroundings, heritage values, and whether the project concerns a new or existing structure. These variables make it difficult to prescribe universal solutions. Rather than offering rigid rules, the framework provides a broad yet research-informed foundation that encourages critical reflection during the design process. Third, the current version of the framework does not extensively incorporate interior elements such as furniture and surface finishes. This is due to their highly project-specific nature. Nonetheless, such elements can significantly influence the factors of illumination and thus also impact the cognitive and visual quality of the environment.

In conclusion, this thesis demonstrates that light, whether natural or artificial, is far more than a means of illumination. It is a spatial and neurological medium that can support or hinder cognitive processes central to library use. In environments where knowledge acquisition and cognitive performance are primary objectives, lighting design must therefore be approached not merely as a technical or aesthetic concern, but as an integral part of spatial cognition. The evidence-based library lighting framework developed in this study provides designers with clear priorities and applicable strategies to consider in the early stages of the design process, encouraging environments that are not only visually coherent but cognitively responsive.

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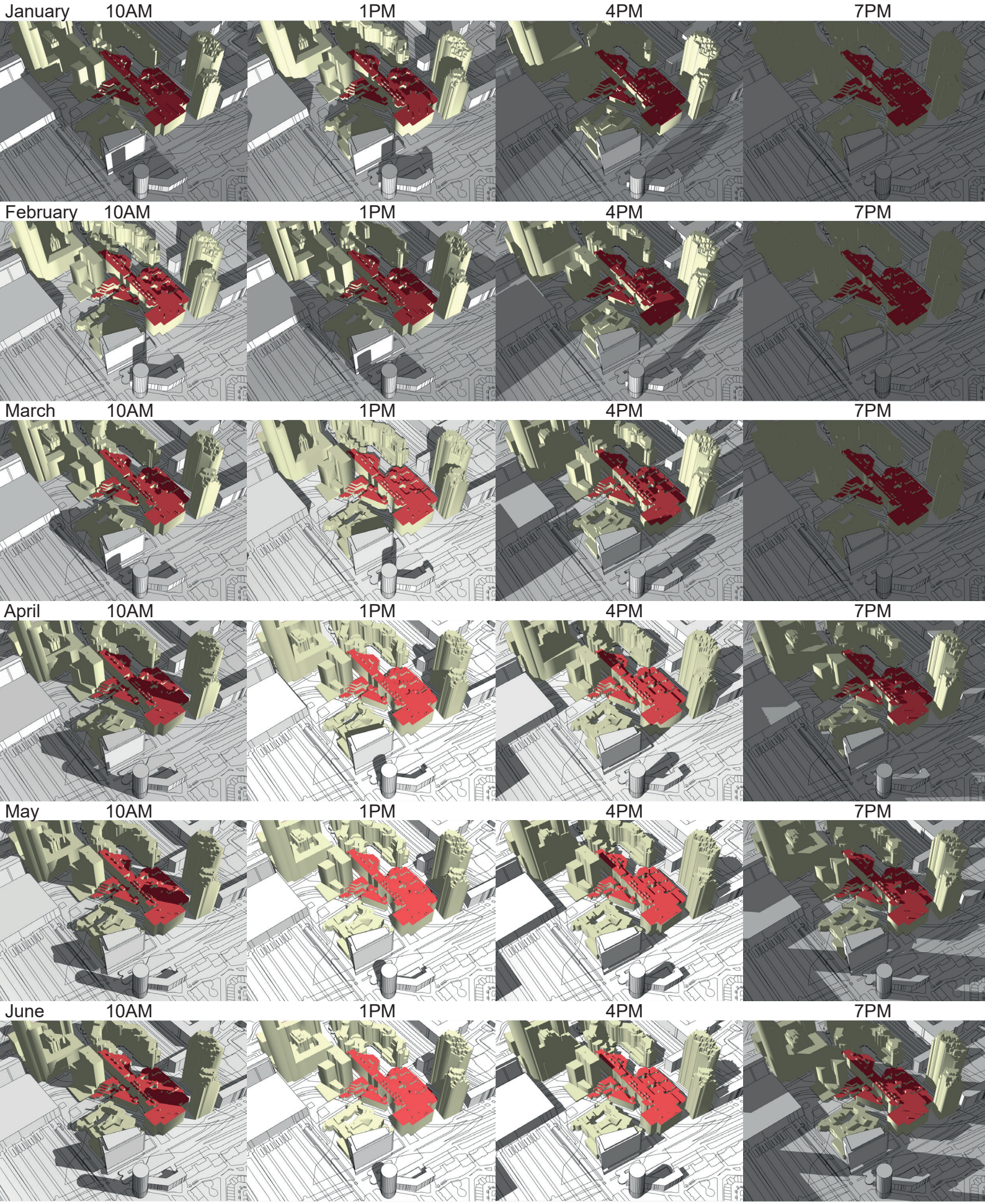
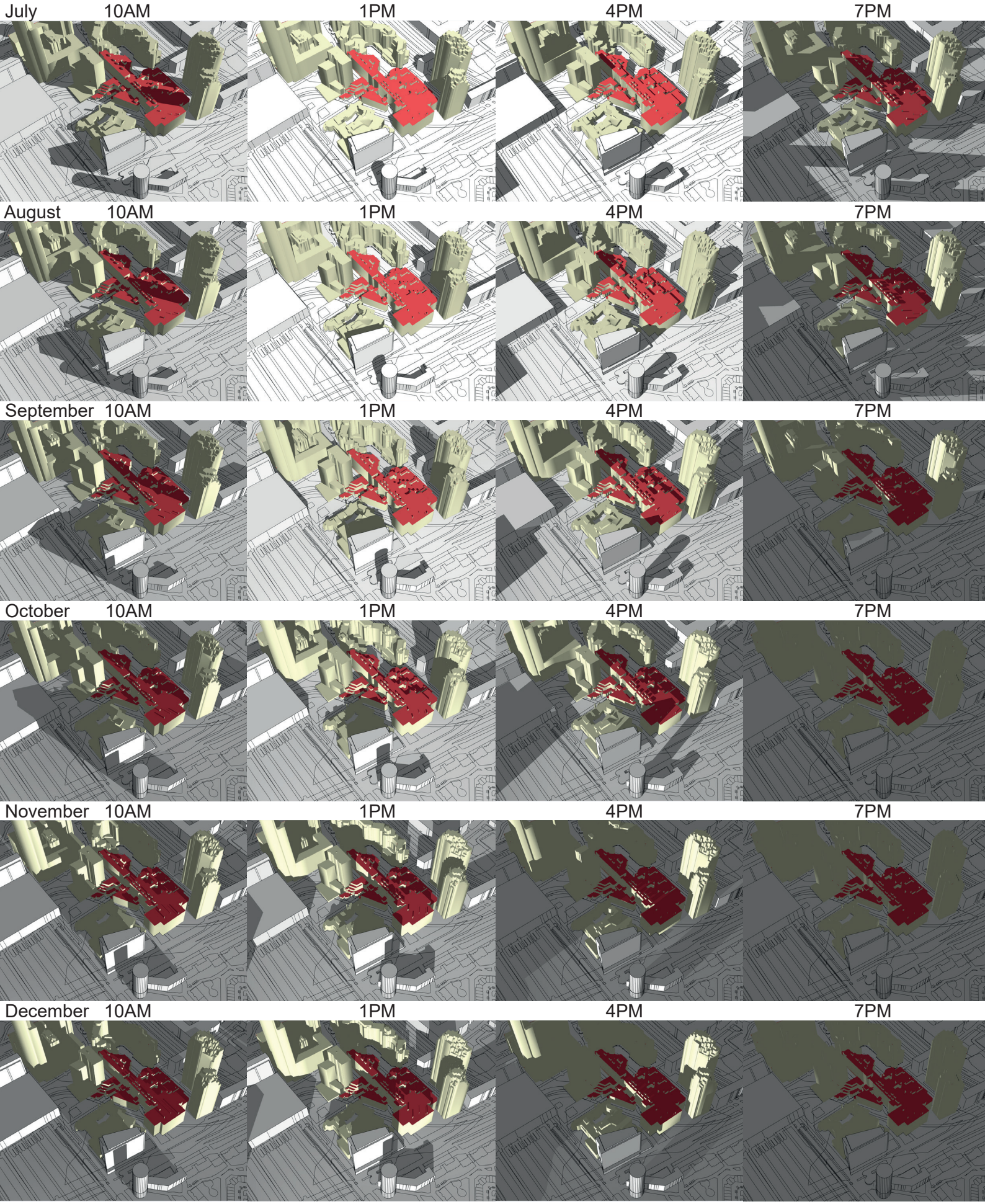
APPENDICES: Appendix A, Solar study Axonometry

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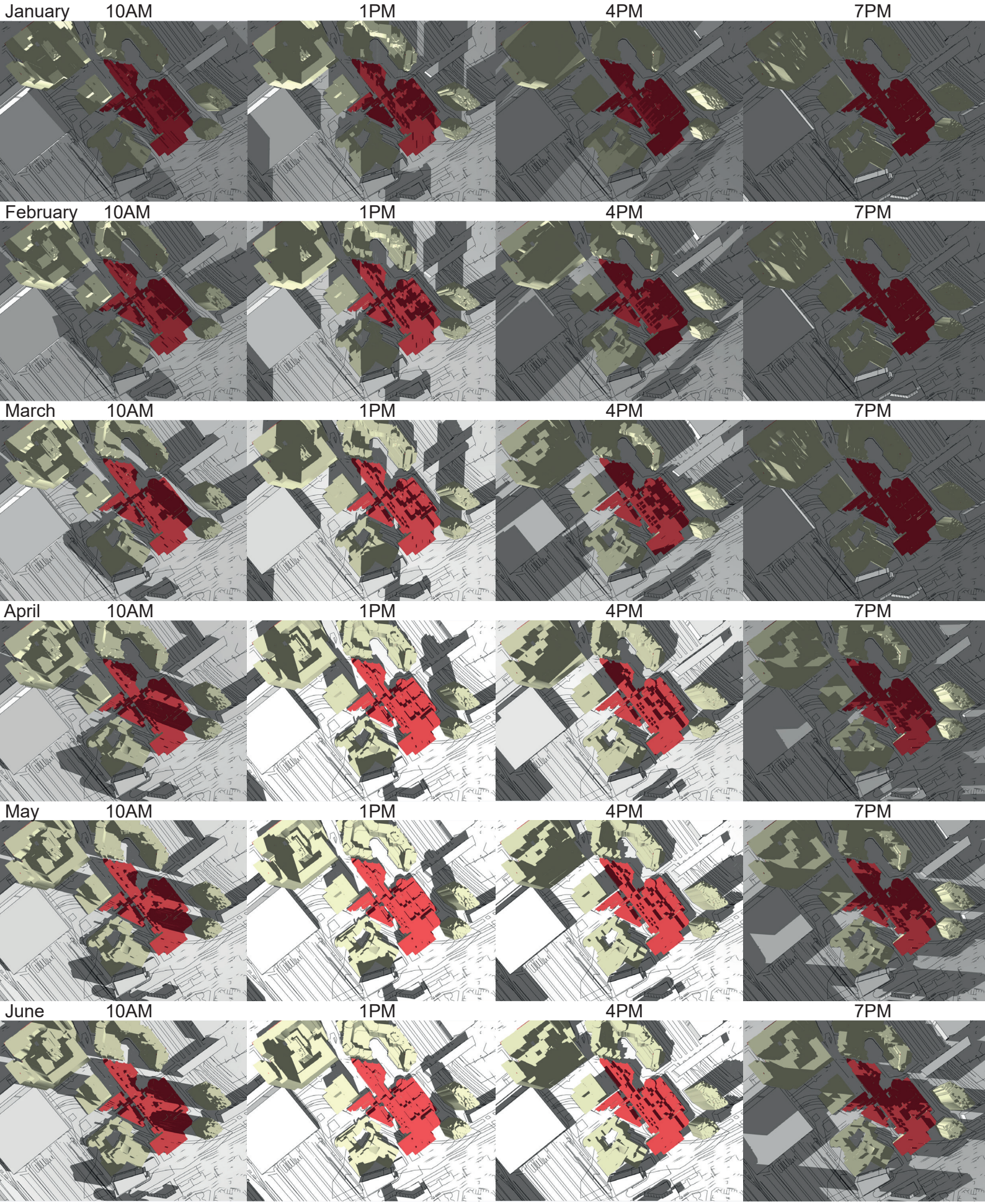
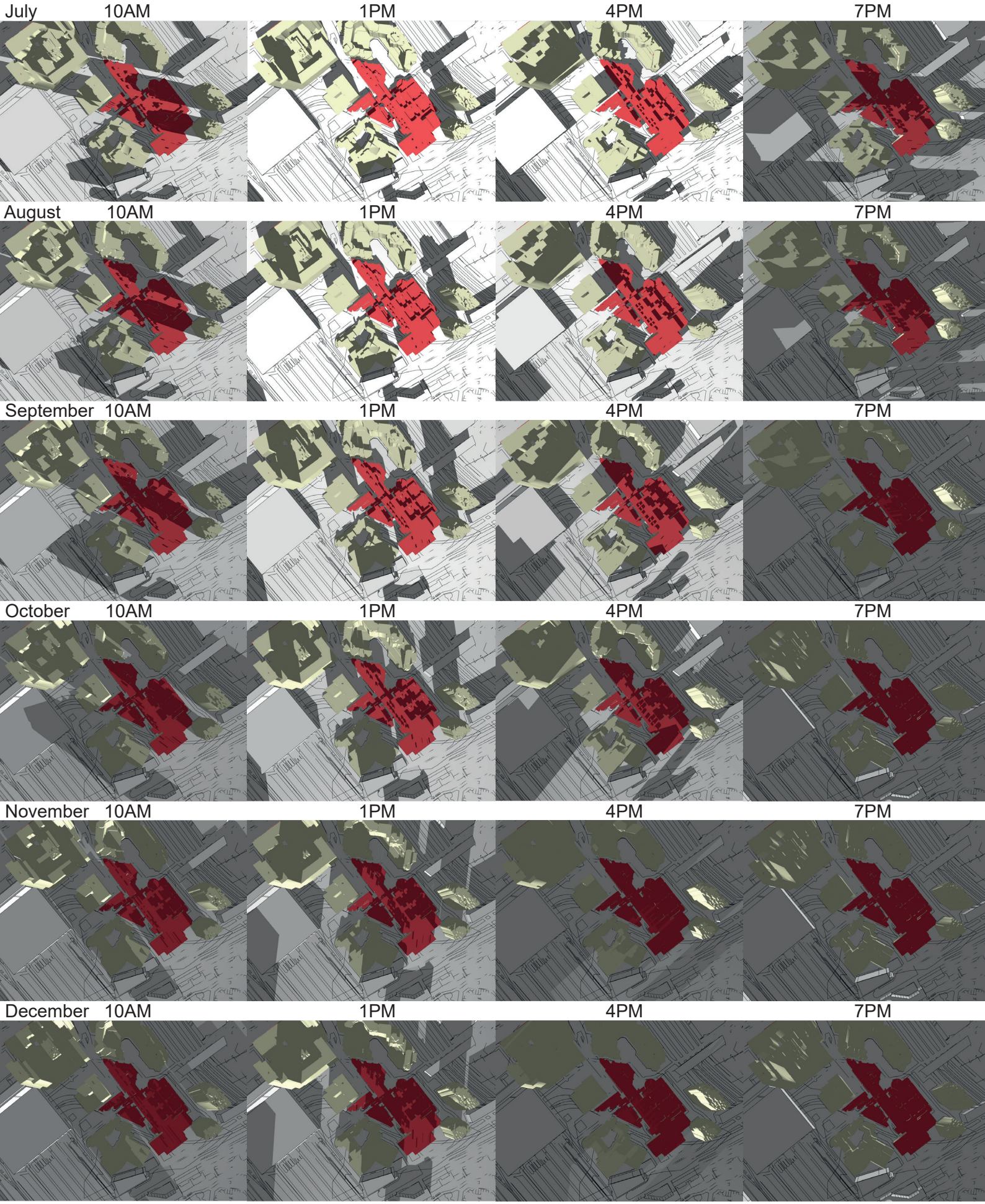
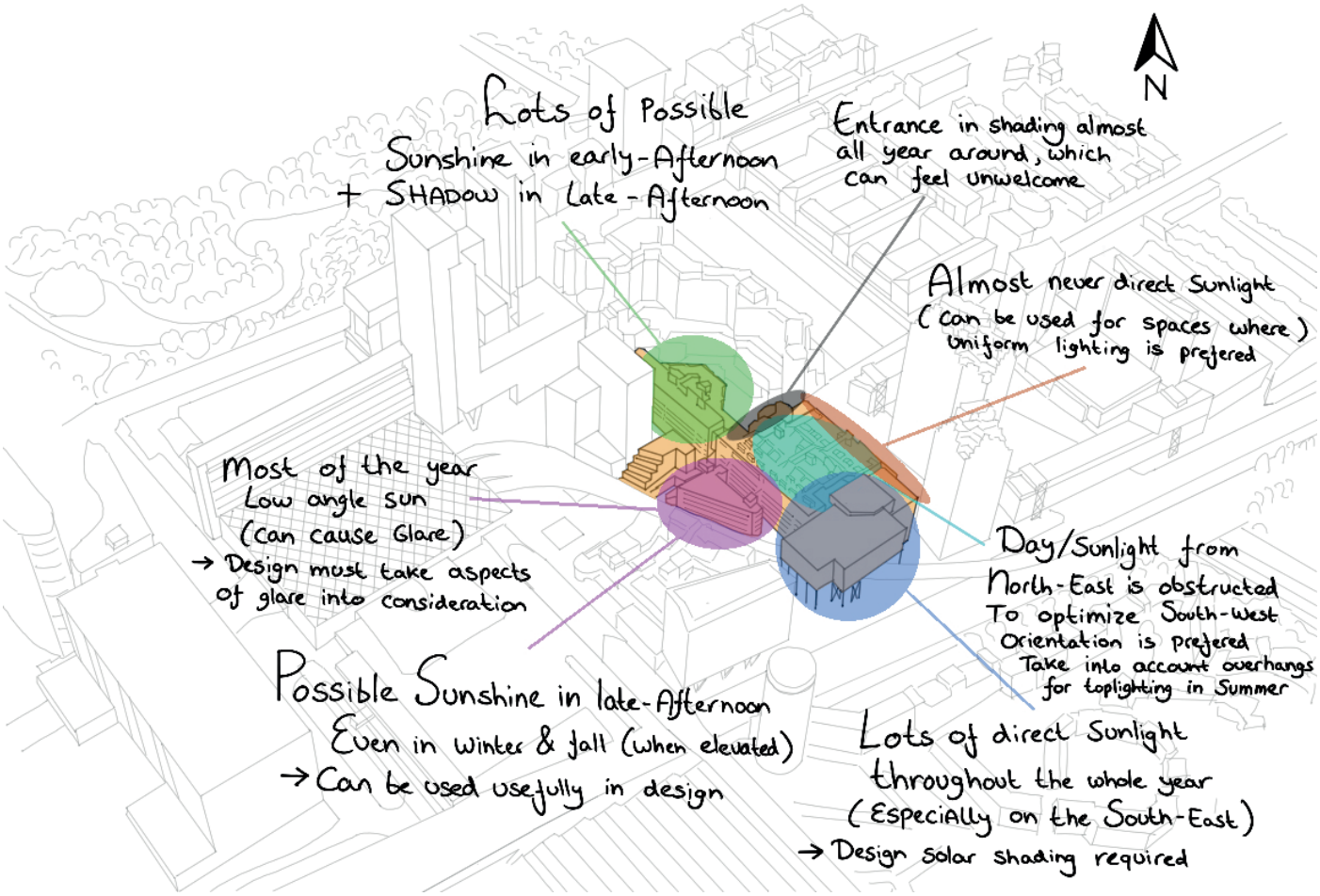
7PM

APPENDICES: Appendix A, Solar study Top-view



APPENDICES: Appendix A, Solar study Top-view




N
Lots of Possible
Sunshine in early-Afternoon
+ SHADOW in Late-Afternoon
Entrance in shading almost
all year around, which
can feel unwelcome
Almost never direct Sunlight
(can be used for spaces where)
Uniform lighting is prefered
Most of the year
Low angle sun
(can cause Glare)
→ Design must take aspects
of glare into consideration
Day/Sunlight from
North-East is obstructed
To optimize South-West
Orientation is prefered
Take into account overhangs
for toplighting in Summer
Possible Sunshine in late-Afternoon
Even in Winter & fall (when elevated)
→ Can be used usefully in design
Lots of direct Sunlight
throughout the whole year
(Especially on the South-East)
→ Design Solar shading required

APPENDICES: Appendix B, View study, Desired views

DESIRED VIEW 1 'Killer-view' or Iconic view of the Hague



DESIRED VIEW 2 View consisting out of the three layers mentioned before



DESIRED VIEW 2 Location of the building where this view can be created



DESIRED VIEW 2

Location of the building where this view can be created



DESIRED VIEW 3

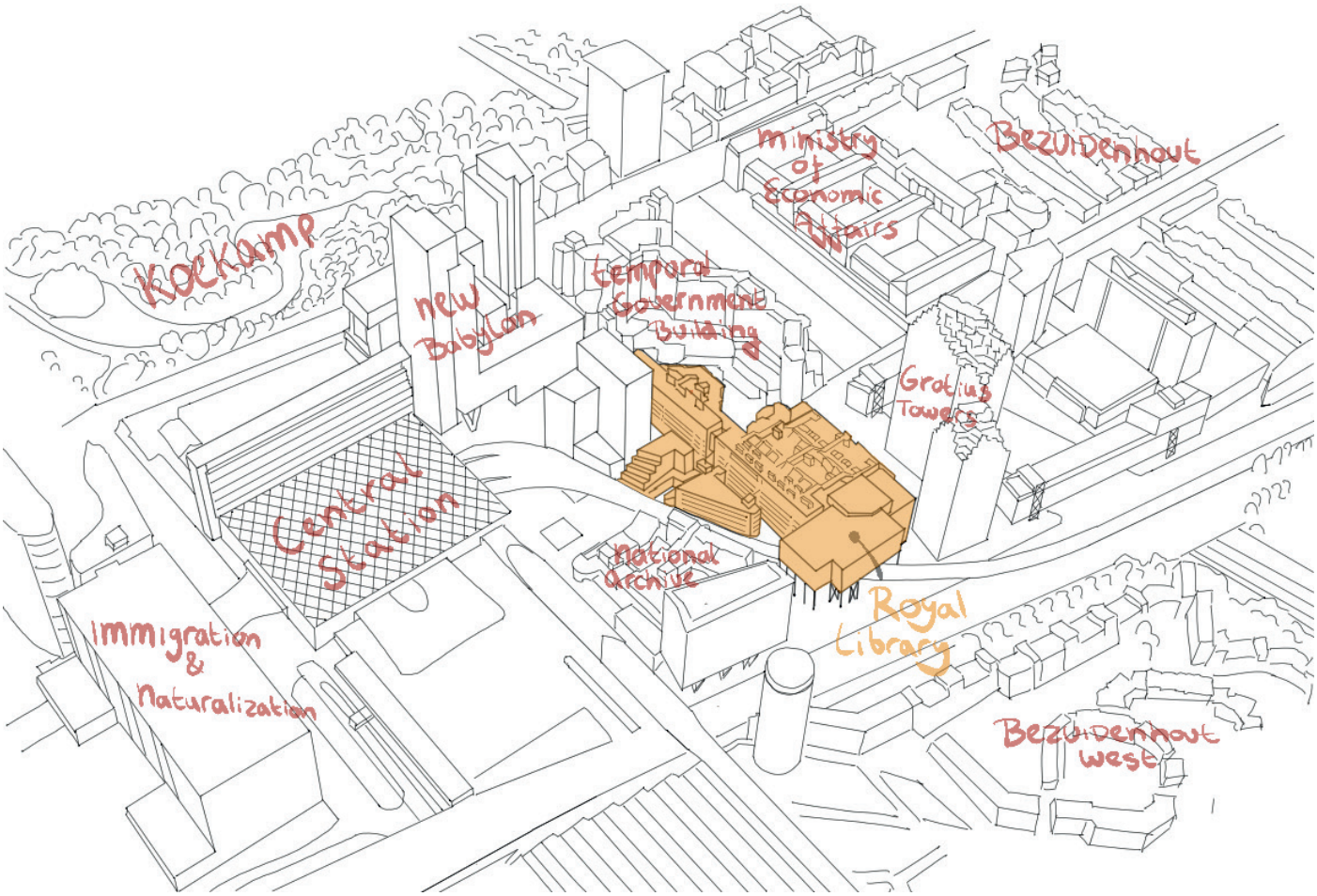
View consisting out of the three layers mentioned before + future nature

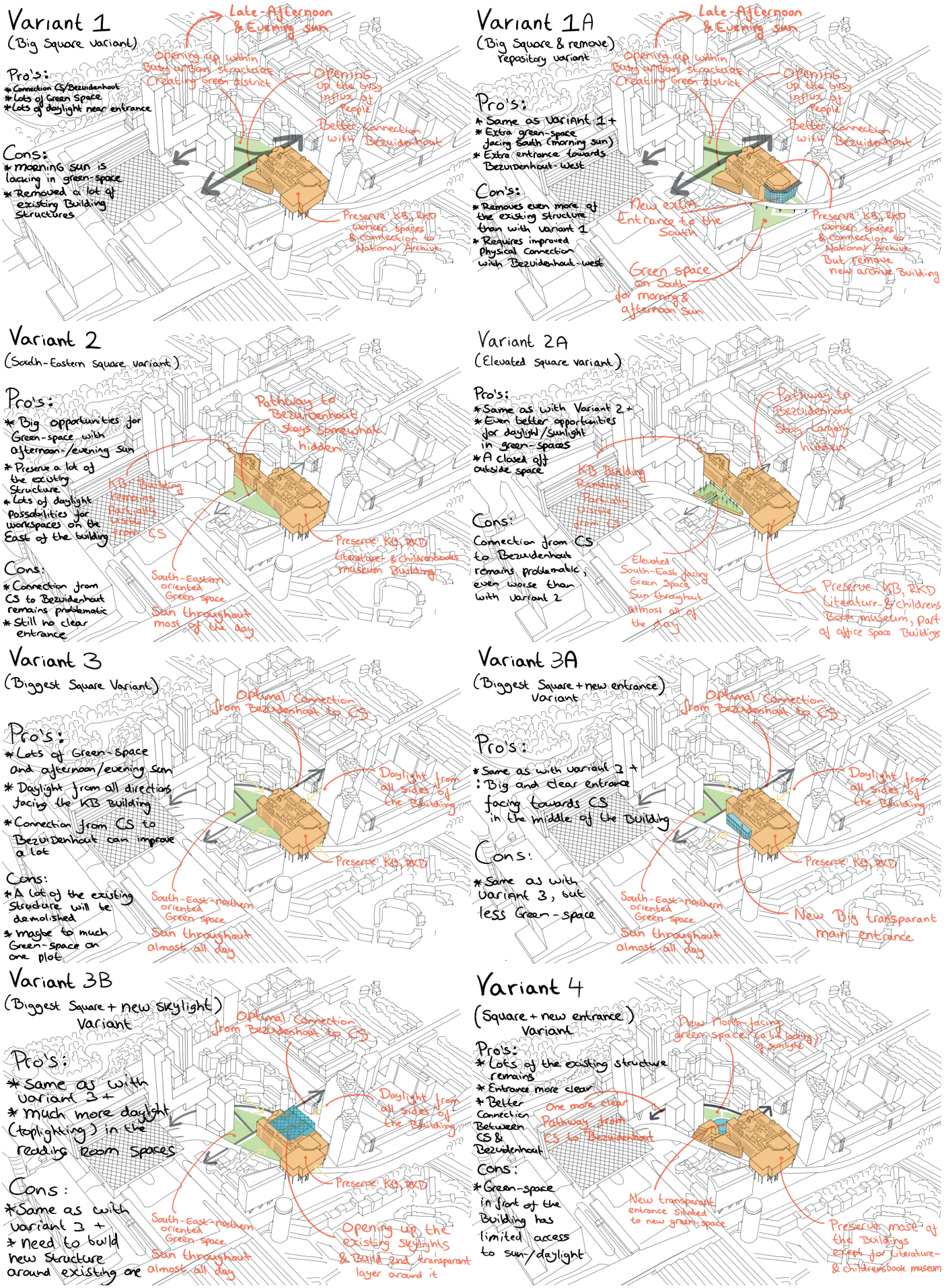


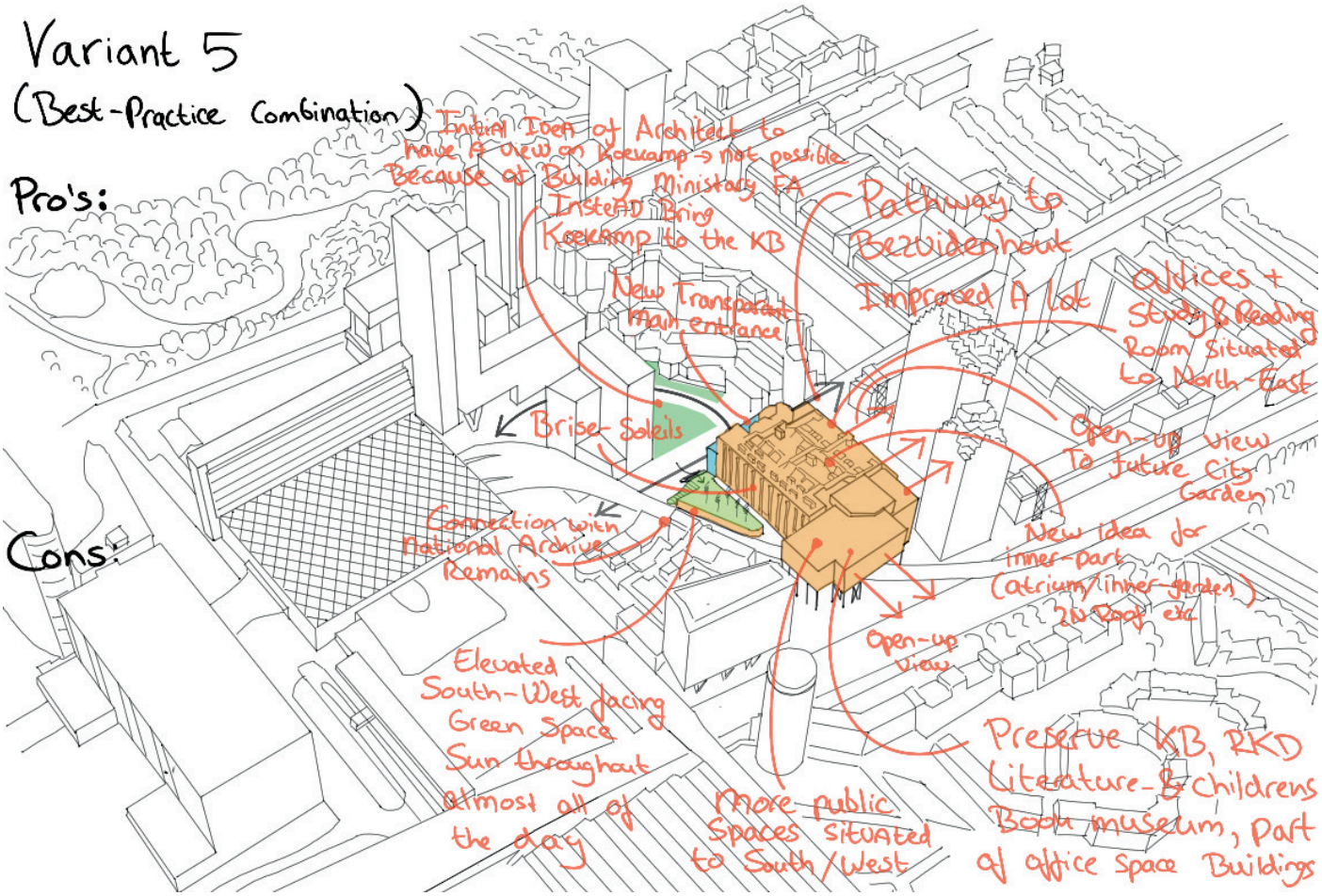
DESIRED VIEW 3

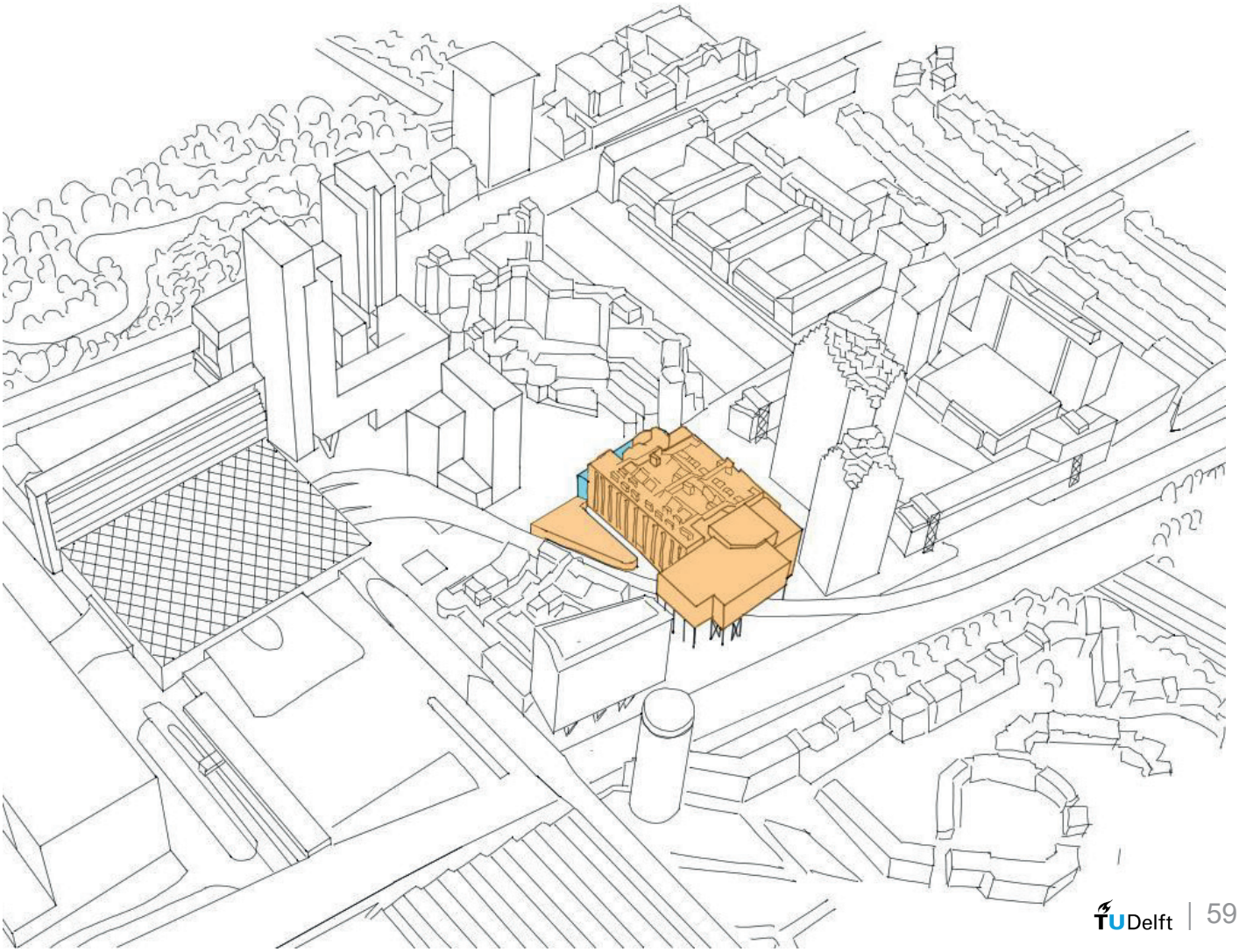
Location of the building where this view can be created



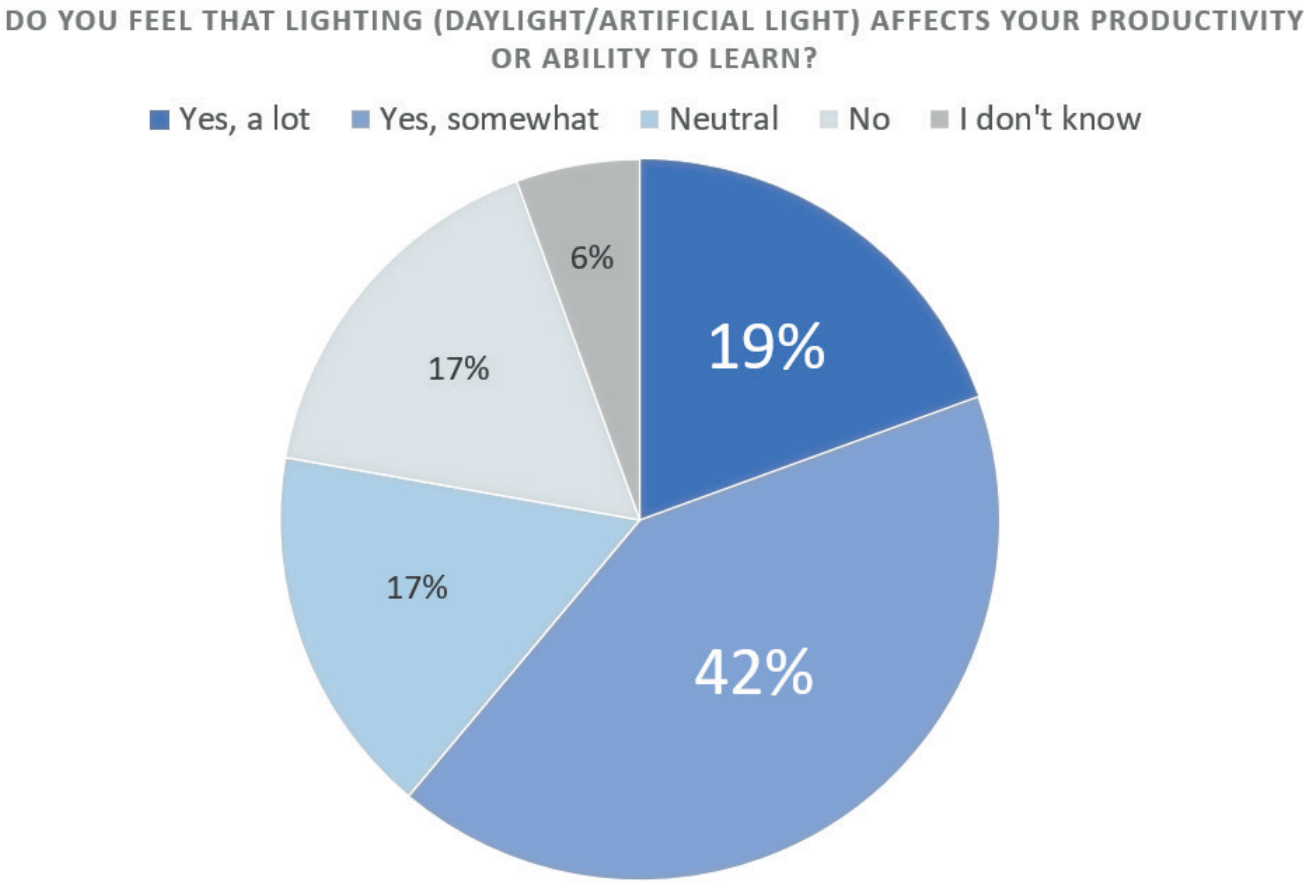

Ministry of Economic Affairs
Bezuidenhout
Kolkamp
new Babylon
temporal Government Building
Gratius Towers
Central Station
National Archive
Immigration & Naturalization
Royal Library
Bezuidenhout west

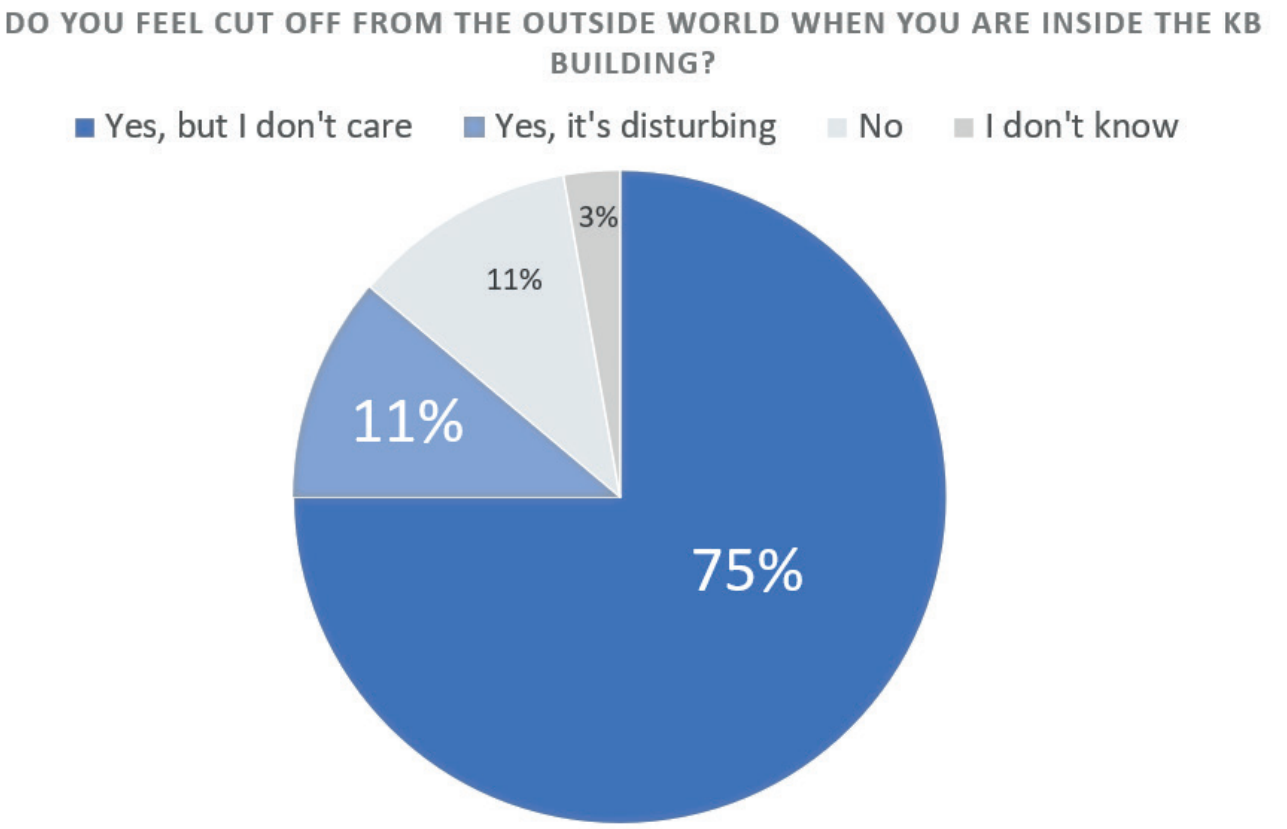

Variant 1
(Big Square variant)
Pro's:
* Connection CS/Bezuidenhout
* Lots of Green Space
* Lots of daylight near entrance
Cons:
* Morning sun is lacking in green-space
* Removed a lot of existing Building structures
Late-Afternoon & Evening sun
Opening up within busy urban structure Creating Green district
Opening up the busy influx of people
Better Connection with Bezuidenhout
Preserve KB, RKD workers spaces & connection to National Archive
Variant 1A
(Big Square & remove)
Repository variant
Pro's:
* Same as Variant 1 +
* Extra green-space facing South (morning sun)
* Extra entrance towards Bezuidenhout-west
Con's:
* Removes even more of the existing structure than with variant 1
* Requires improved physical connection with Bezuidenhout-west
Late-Afternoon & Evening sun
Opening up within busy urban structure Creating Green district
Opening up the busy influx of people
Better Connection with Bezuidenhout
New extra Entrance to the South
Green space on South for morning & afternoon sun
Preserve KB, RKD workers spaces & connection to National Archive But remove new archive Building
Variant 2
(South-Eastern square variant)
Pro's:
* Big opportunities for Green-space with afternoon-/evening sun
* Preserve a lot of the existing Structure
* Lots of daylight possibilities for workspaces on the East of the building
Cons:
* Connection from CS to Bezuidenhout remains problematic
* Still no clear entrance
Pathway to Bezuidenhout stays somewhat hidden
KB Building remains Pathway blocked from CS
Preserve KB, RKD Literature & Childrensbooks museum Building
South-Eastern oriented Green space
Sun throughout most of the day
Variant 2A
(Elevated square variant)
Pro's:
* Same as with Variant 2 +
* Even better opportunities for daylight/sunlight in green-spaces
* A closed off outside space
Cons:
Connection from CS to Bezuidenhout remains problematic, even worse than with variant 2
Pathway to Bezuidenhout Stay Largely hidden
KB Building Remains Pathway blocked from CS
Elevated South-East facing Green Space Sun throughout almost all of the day
Preserve KB, RKD Literature & Childrens Book museum, part of office space Buildings
Variant 3
(Biggest Square Variant)
Pro's:
* Lots of Green-Space and afternoon/evening sun
* Daylight from all directions facing the KB Building
* Connection from CS to Bezuidenhout can improve a lot
Cons:
* A lot of the existing Structure will be demolished
* maybe to much Green-Space on one plot
Optimal Connection from Bezuidenhout to CS
Daylight from all sides of the Building
Preserve KB, RKD
South-East-northern oriented Green space
Sun throughout almost all day
Variant 3A
(Biggest Square + new entrance)
Variant
Pro's:
* Same as with variant 3 +
: Big and clear entrance facing towards CS in the middle of the Building
Cons:
* Same as with Variant 3, but less Green-Space
Optimal Connection from Bezuidenhout to CS
Daylight from all sides of the Building
Preserve KB, RKD
South-East-northern oriented Green space
Sun throughout almost all day
New Big transparant main entrance
Variant 3B
(Biggest Square + new skylight)
Variant
Pro's:
* Same as with Variant 3 +
* much more daylight (toplighting) in the reading Room spaces
Cons:
* Same as with Variant 3 +
* need to build new structure around existing one
Optimal Connection from Bezuidenhout to CS
Daylight from all sides of the Building
Preserve KB, RKD
South-East-northern oriented Green space
Sun throughout almost all day
Opening up the existing Skylights & Build and transparant layer around it
Variant 4
(Square + new entrance)
Variant
Pro's:
* Lots of the existing structure remains
* Entrance more clear
* Better Connection Between CS & Bezuidenhout
Cons:
* Green-space in front of the Building has limited access to sun/daylight
New North-facing green space (a bit lacking) of sunlight
One more clear Pathway from CS to Bezuidenhout
New transparant entrance situated to new green-space
Preserve most of the Buildings except for Literature- & Childrensbook museum

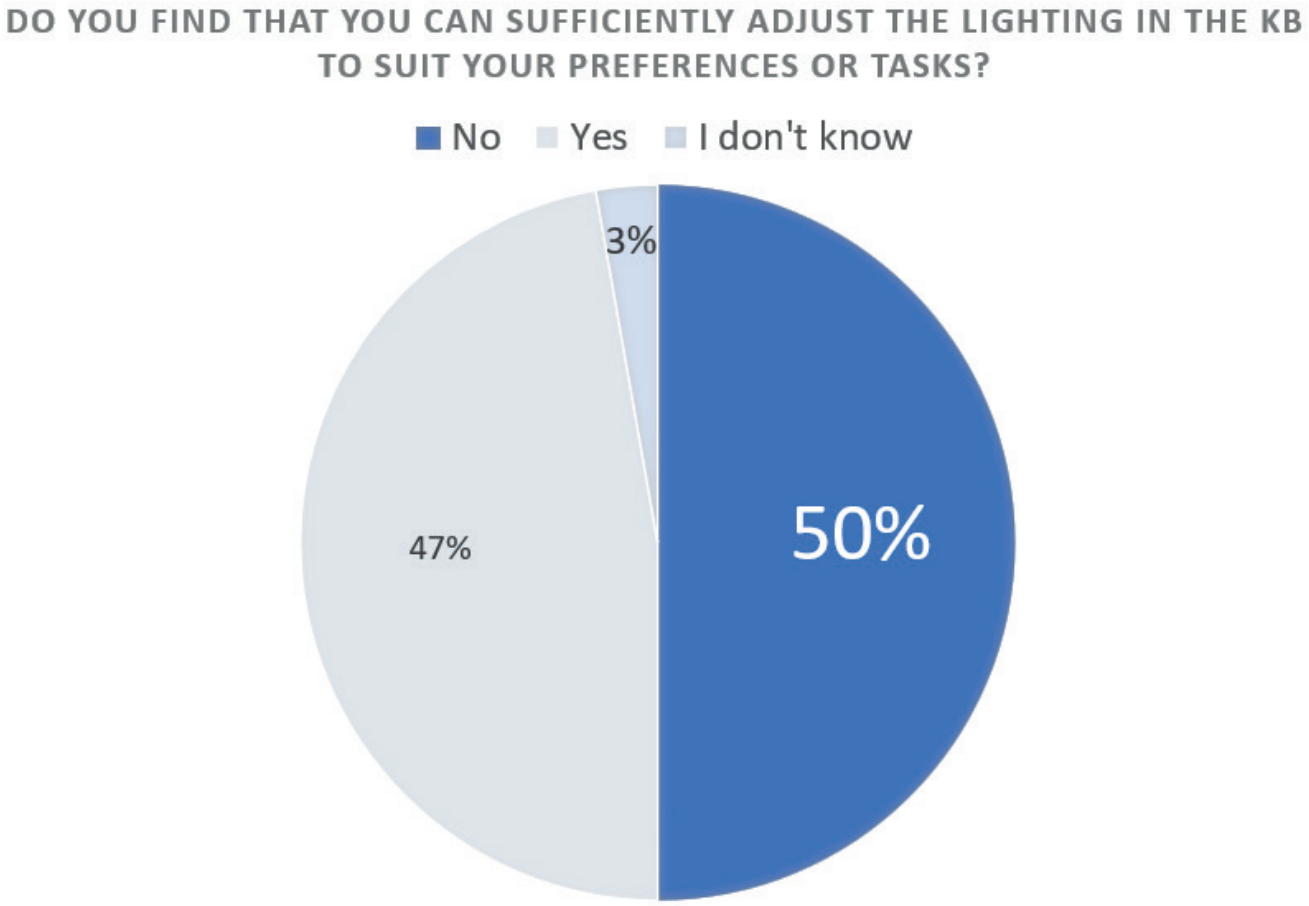

Variant 5
(Best-Practice Combination)
Pro's:
Cons:
Initial Idea of Architect to have a view on Koekamp → not possible Because of Building Ministary FA
Instead Bring Koekamp to the KB
New Transparant Main entrance
Pathway to Bezuidenhout Improved A lot
Offices + Study & Reading Room situated to North-East
Brise-Soleils
Open-up view To future City Garden
Connection with National Archive Remains
New idea for inner-part (atrium/inner-garden) 2e Roof etc.
Open-up view
Elevated South-West facing Green Space Sun throughout almost all of the day
More public Spaces situated to South/West
Preserve KB, RKD Literature- & childrens Book museum, Part of office Space Buildings

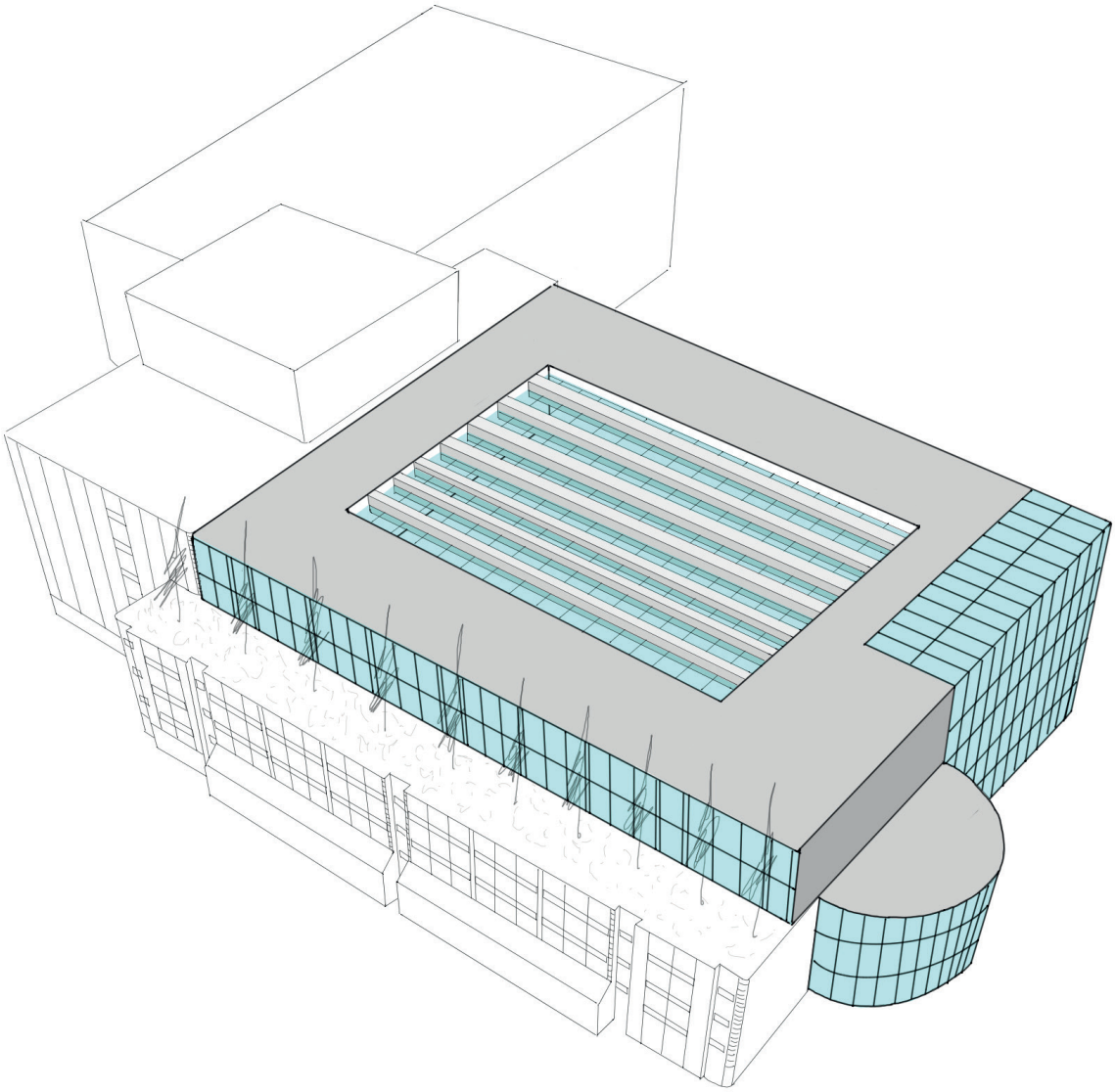


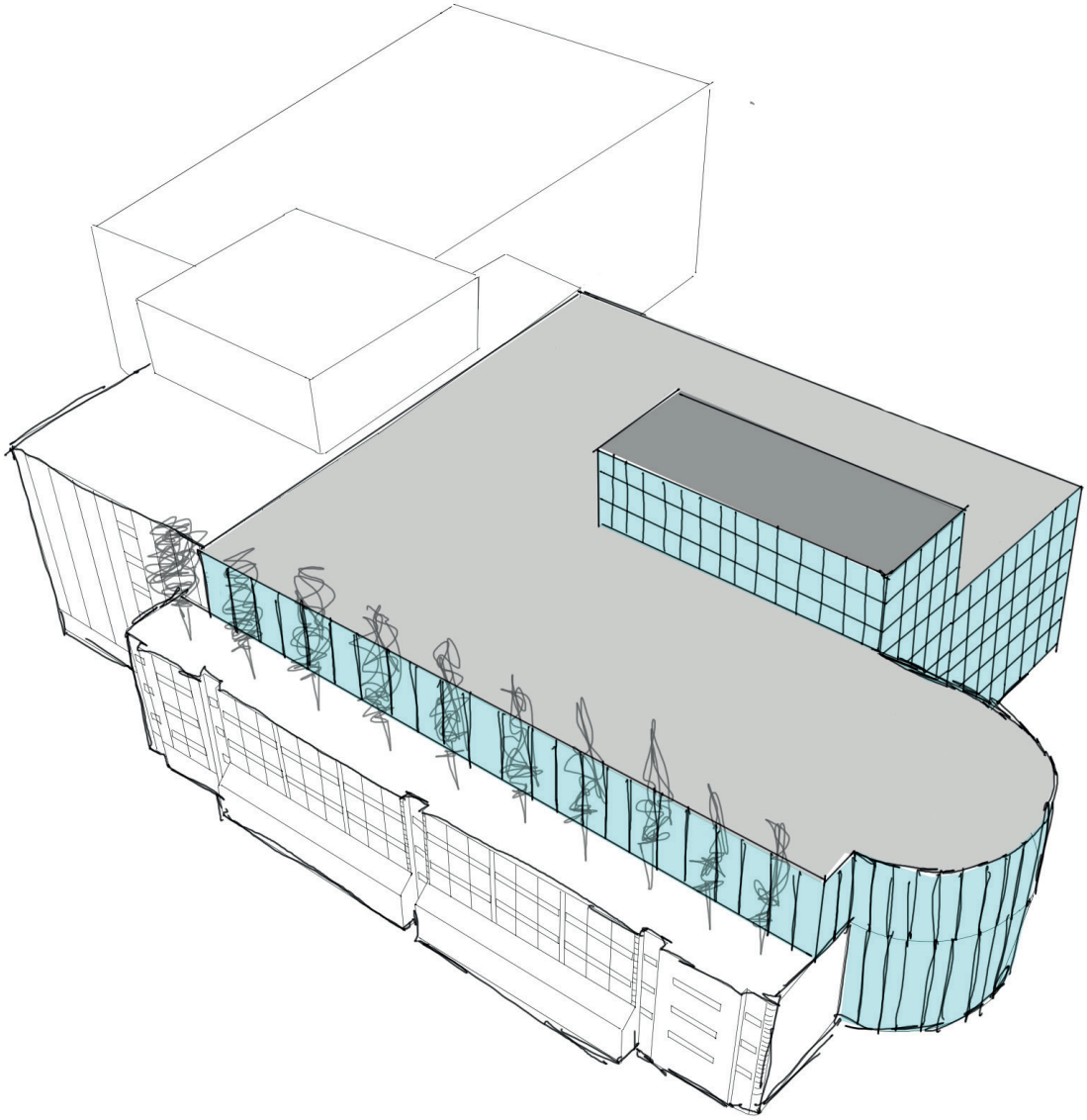

Exterior stateliness
Green design
Hybrid program
Accessibility
Daylight
Green spaces
Bicycle parking
Sustainability
Difference public/private
Sunlight
Individual spaces
View
Silence
Adaptability
Natural light
Sculptural shape
Flexibility
Rest
Easy to navigate
Cosy ambiance

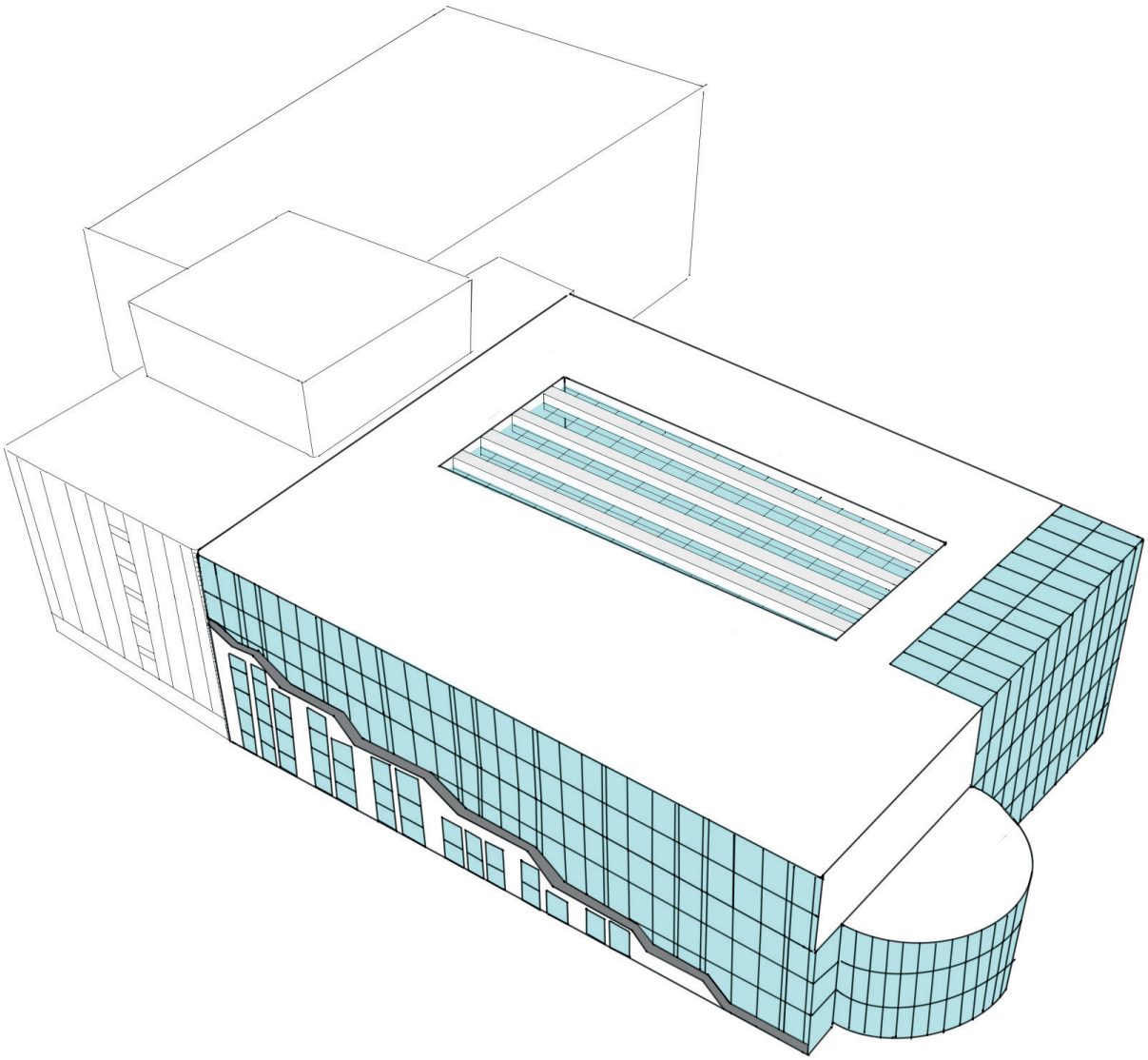

DO YOU FEEL THAT LIGHTING (DAYLIGHT/ARTIFICIAL LIGHT) AFFECTS YOUR PRODUCTIVITY OR ABILITY TO LEARN?
Yes, a lot
Yes, somewhat
Neutral
No
I don't know
19%
42%
17%
17%
6%


DO YOU FEEL CUT OFF FROM THE OUTSIDE WORLD WHEN YOU ARE INSIDE THE KB BUILDING?
Yes, but I don't care
Yes, it's disturbing
No
I don't know
75%
11%
11%
3%


DO YOU FIND THAT YOU CAN SUFFICIENTLY ADJUST THE LIGHTING IN THE KB TO SUIT YOUR PREFERENCES OR TASKS?
No
Yes
I don't know
3%
47%
50%







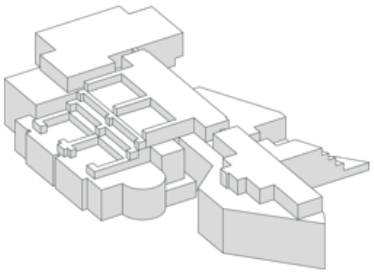


Optimize Natural Lighting

Let the View Shape the Design

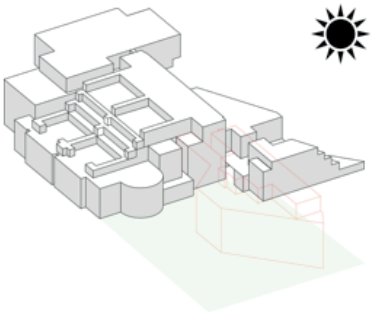
Sufficient Adjustability

Current Situation



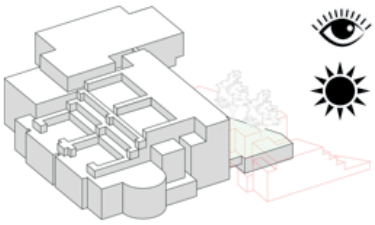
Current situation as it is, with KB, Repository, Literature Museum, RKD & Childrens-Book Museum

Adjustment 1



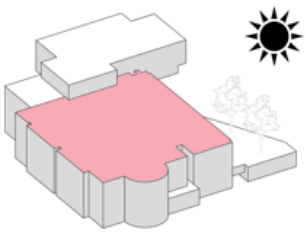
Removing Northwest part for better Access and Natural Lighting Potential

Adjustment 2



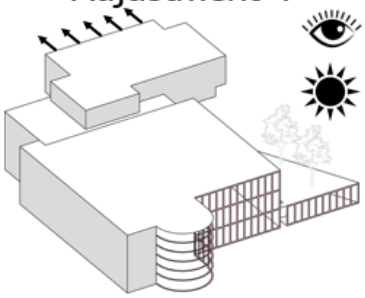
Lowering the Building facing the National Archives to improve Daylight, Views, and Green Space

Adjustment 3



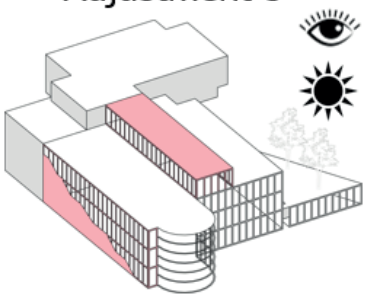
Replacing the existing roof to enhance Daylight Penetration

Adjustment 4



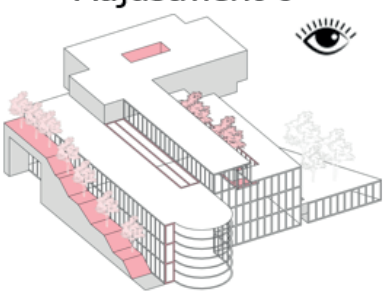
Opening the North & South Façade to improve Accessibility, Daylight and Views

Adjustment 5



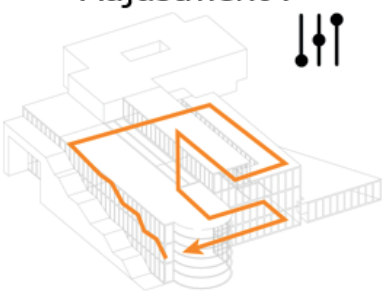
Enhancing Daylight Penetration and Views by opening up the East and West Façades and Uplifting the roof

Adjustment 6

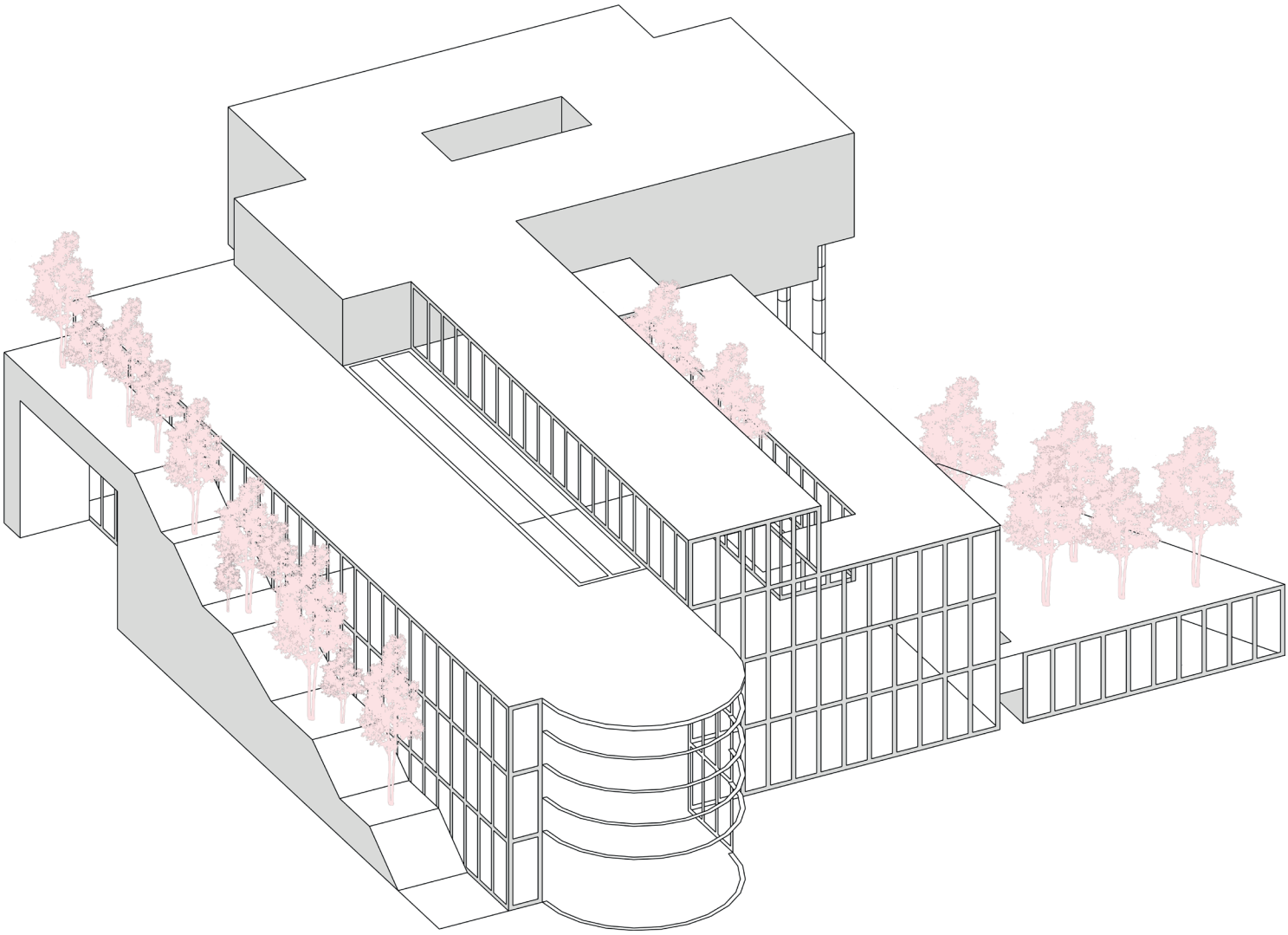


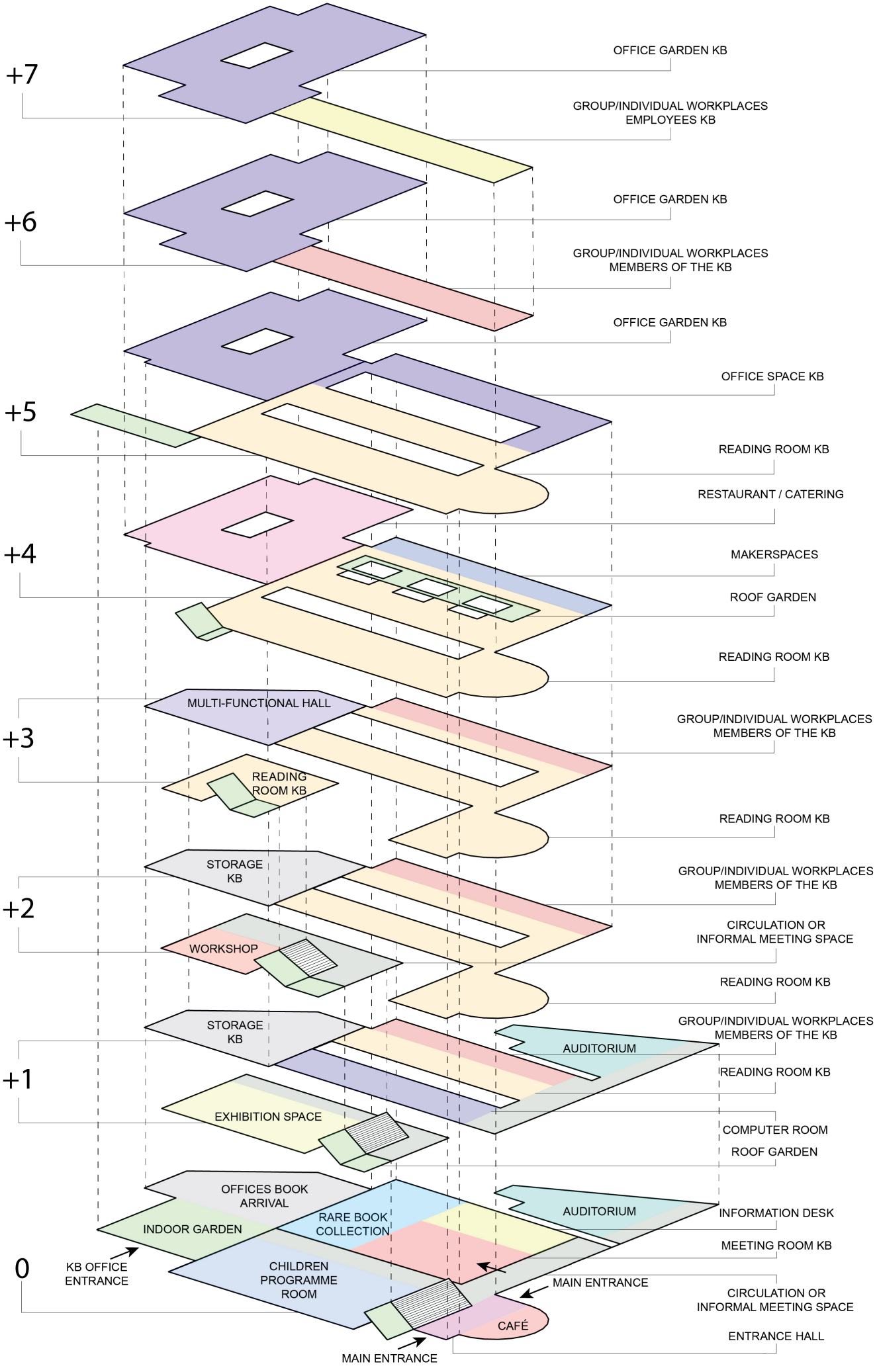
Creating an Inner Courtyard and Roof Garden to Improve Views While Preserving a Sense of Enclosure

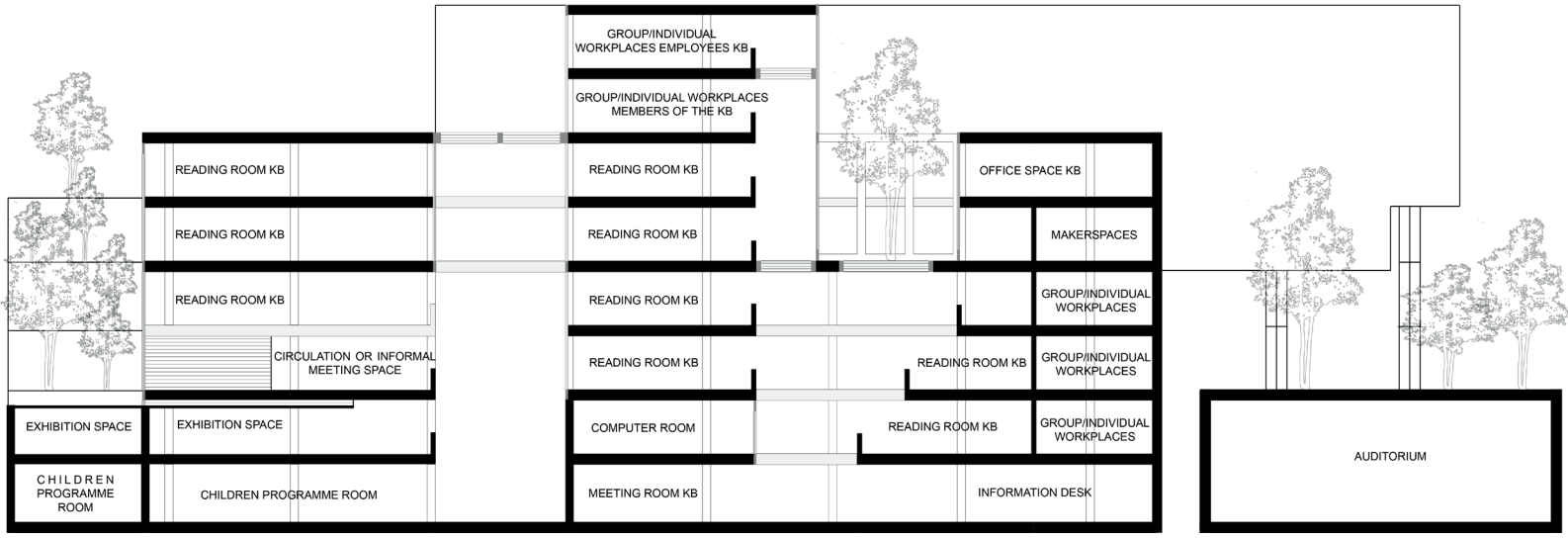
Adjustment 7

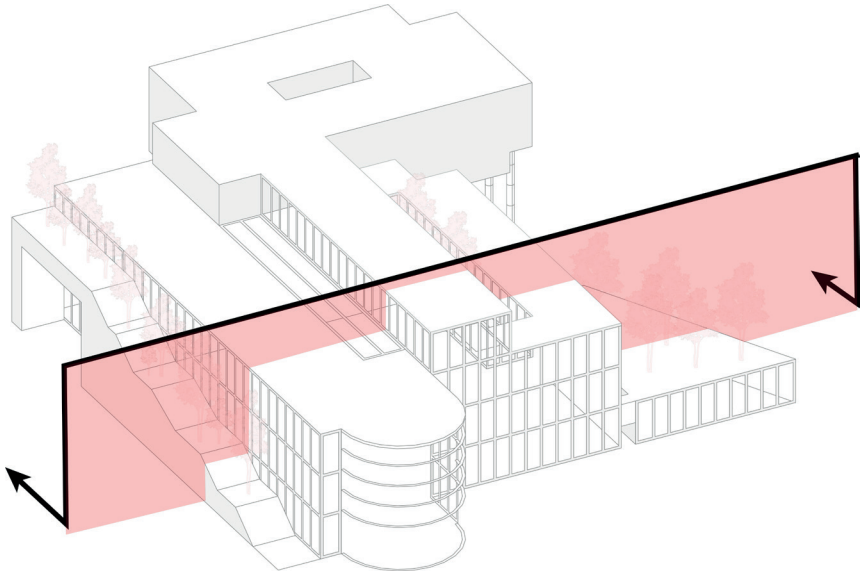


Creating a Continuous Circulation Loop to Support Spatial Flow, Adjustability and User Autonomy

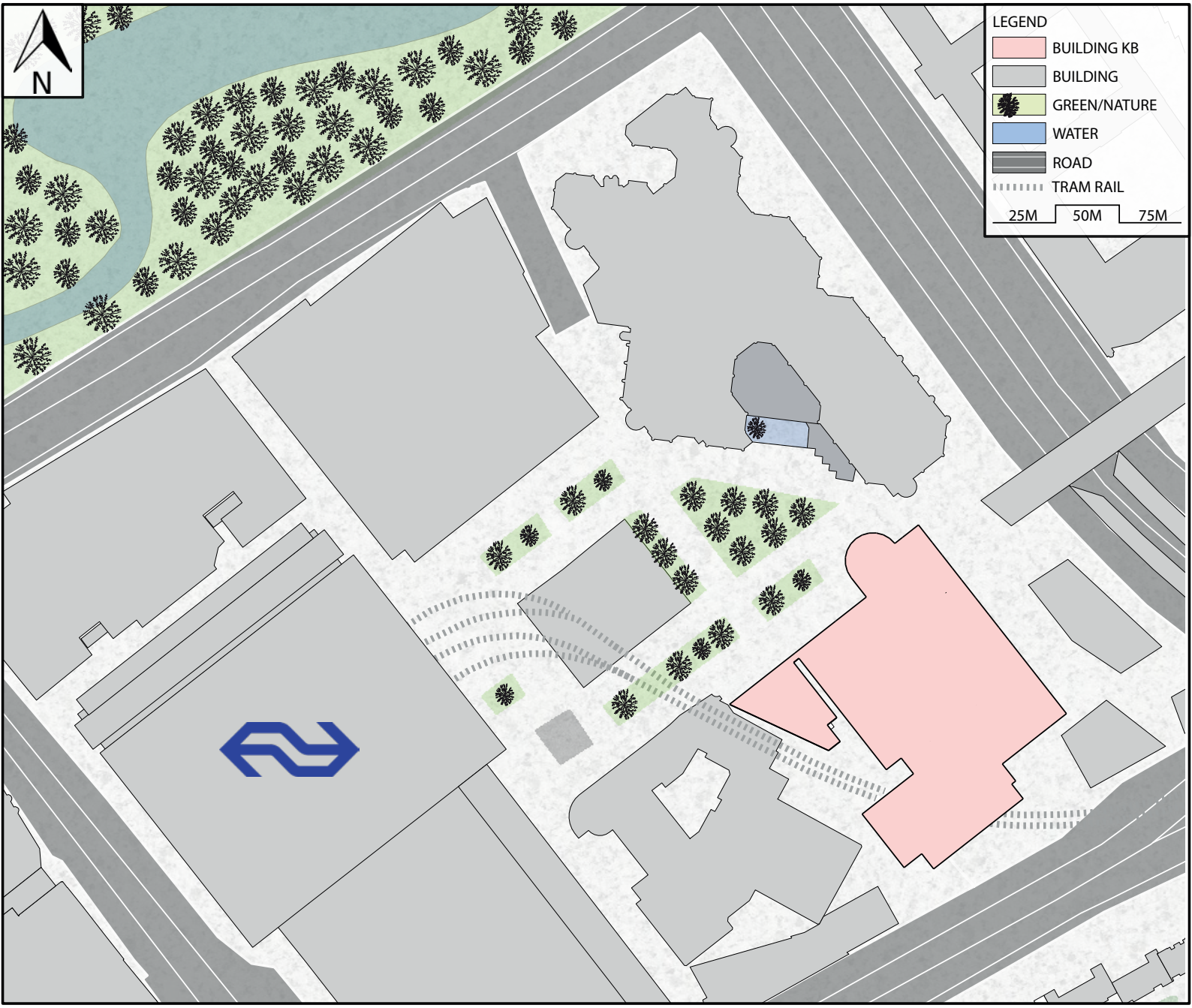


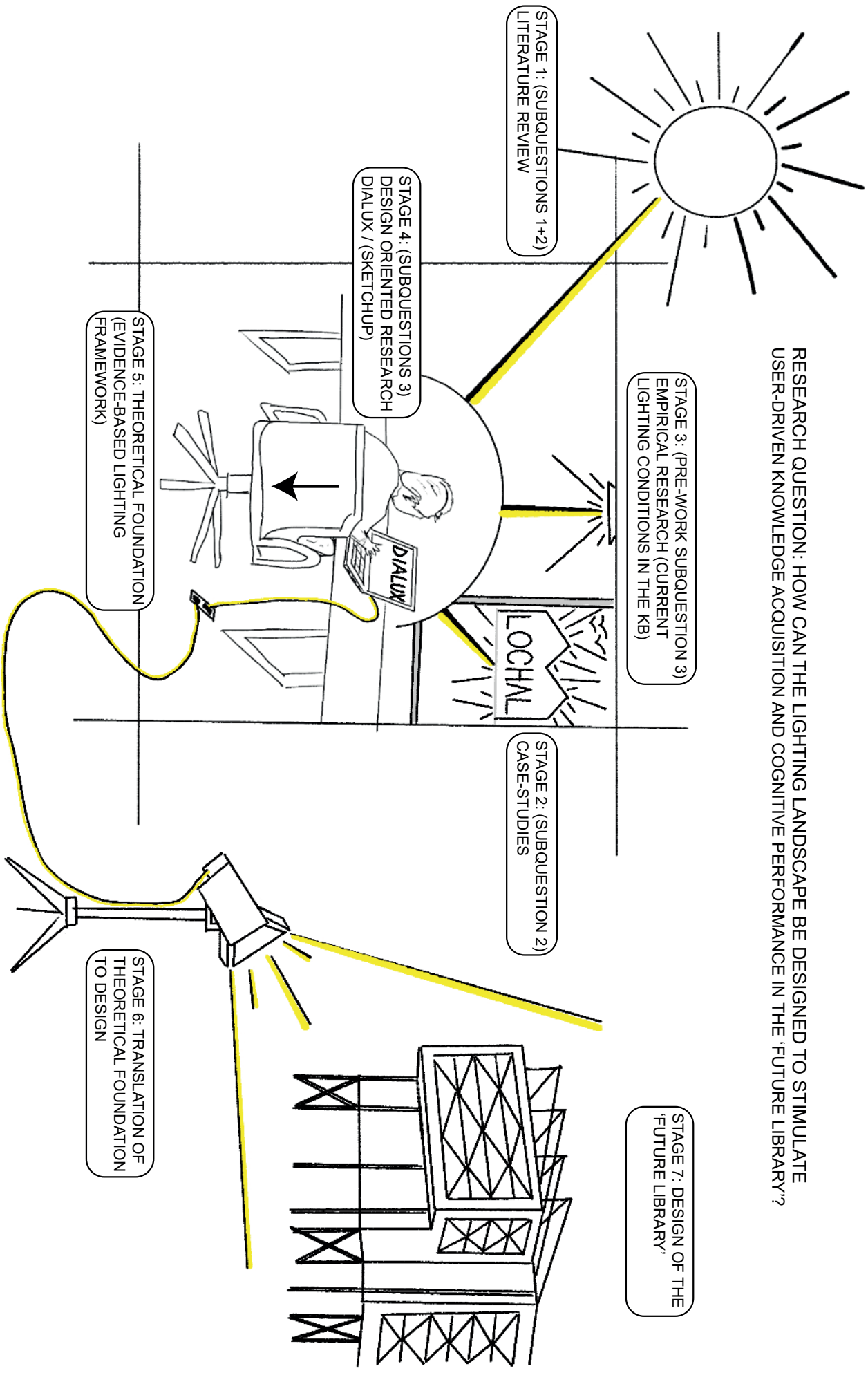

+7
OFFICE GARDEN KB
GROUP/INDIVIDUAL WORKPLACES
EMPLOYEES KB
+6
OFFICE GARDEN KB
GROUP/INDIVIDUAL WORKPLACES
MEMBERS OF THE KB
OFFICE GARDEN KB
+5
OFFICE SPACE KB
READING ROOM KB
RESTAURANT / CATERING
+4
MAKERSPACES
ROOF GARDEN
READING ROOM KB
MULTI-FUNCTIONAL HALL
+3
GROUP/INDIVIDUAL WORKPLACES
MEMBERS OF THE KB
READING
ROOM KB
READING ROOM KB
STORAGE
KB
GROUP/INDIVIDUAL WORKPLACES
MEMBERS OF THE KB
+2
CIRCULATION OR
INFORMAL MEETING SPACE
WORKSHOP
READING ROOM KB
STORAGE
KB
GROUP/INDIVIDUAL WORKPLACES
MEMBERS OF THE KB
AUDITORIUM
+1
READING ROOM KB
EXHIBITION SPACE
COMPUTER ROOM
ROOF GARDEN
OFFICES BOOK
ARRIVAL
AUDITORIUM
INFORMATION DESK
INDOOR GARDEN
RARE BOOK
COLLECTION
MEETING ROOM KB
KB OFFICE
ENTRANCE
CHILDREN
PROGRAMME
ROOM
MAIN ENTRANCE
0
CIRCULATION OR
INFORMAL MEETING SPACE
CAFÉ
ENTRANCE HALL
MAIN ENTRANCE

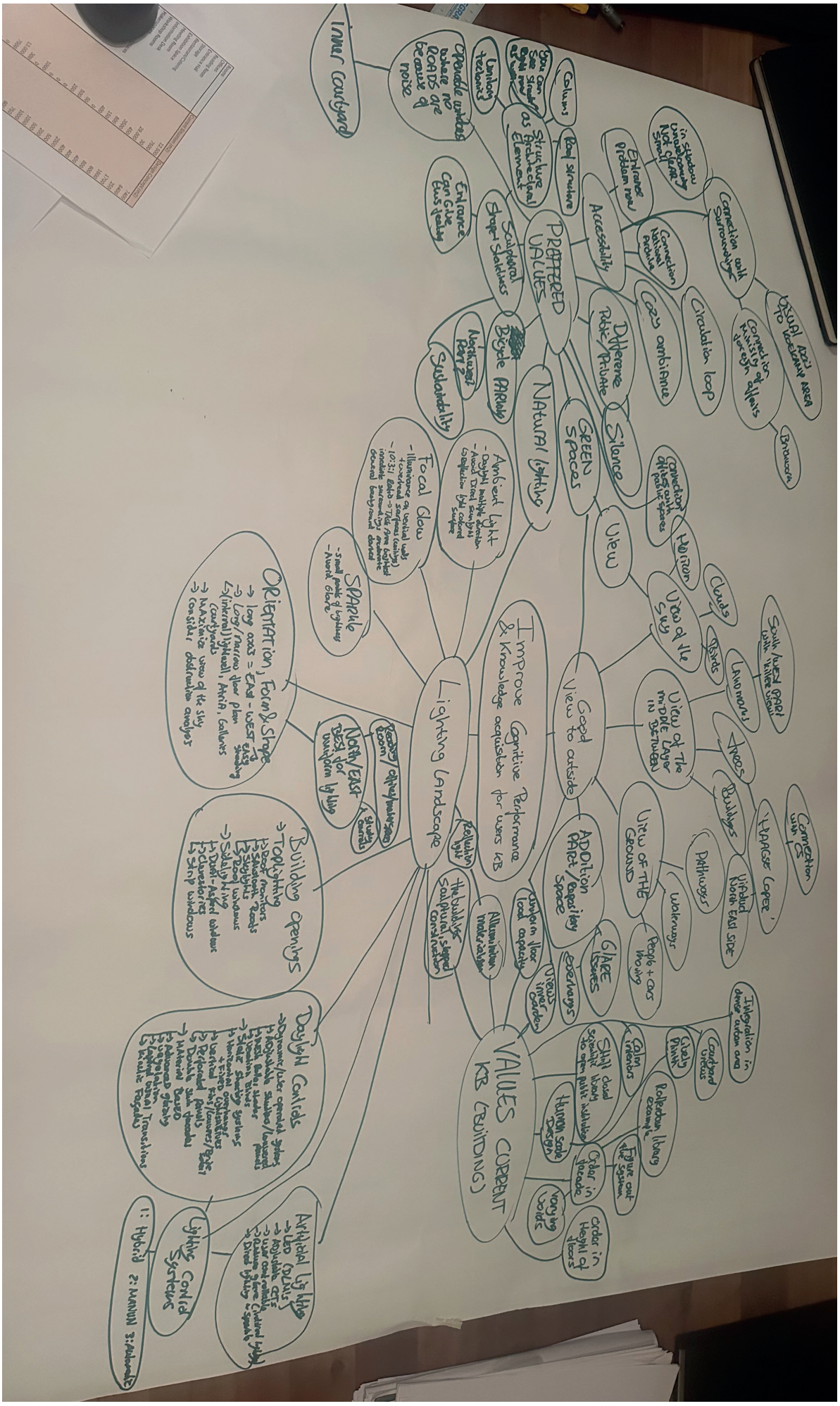




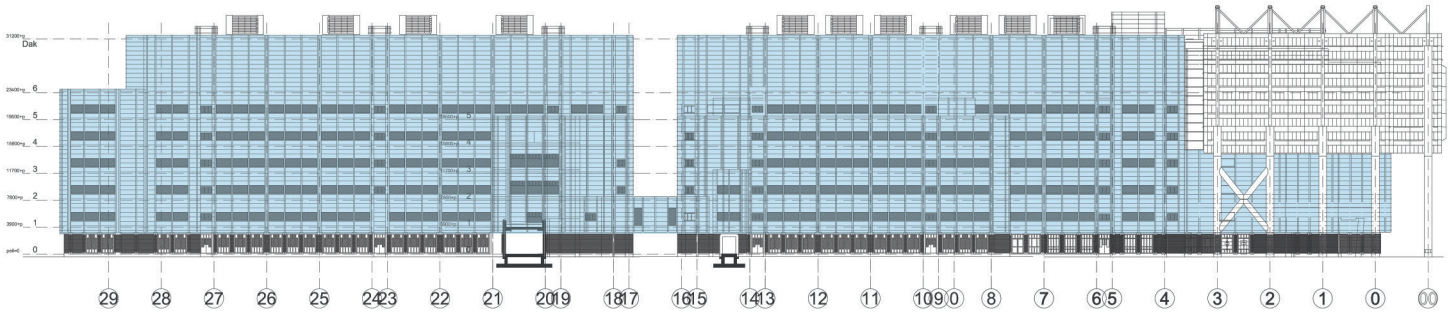
Rooms	Current Situation (m2)	Design Concept (m2)
Offices	12.500	7400
Reading Room	7500	8400
Entrance Hall	30	250
Storage	29.000	1700
Restaurant/Catering	450	1600
Exhibition Space	3500	600
Meeting Room	800	800
Information Desk	150	400
Workshop Rooms	400	400
Makerspaces	0	400
Group/Individual Workplaces	50	2500
Computer Room	500	500
Café	250	200
Indoor Garden	0	500
Rooftop Garden	0	1050
Children Program Room	0	1000
Rare Book Collection	1000	750
Auditorium	0	600
Multifunctional Hall	300	800
Circulation	13.000	4000
Technical Room	7500	T.B.D.
Meditation Room	0	T.B.D.
Cycle Parking Space	0	T.B.D.
Sanitary	850	1000
TOTAL:	77.780	34.850


N
LEGEND
BUILDING KB
BUILDING
GREEN/NATURE
WATER
ROAD
TRAM RAIL
25M
50M
75M


RESEARCH QUESTION: HOW CAN THE LIGHTING LANDSCAPE BE DESIGNED TO STIMULATE USER-DRIVEN KNOWLEDGE ACQUISITION AND COGNITIVE PERFORMANCE IN THE 'FUTURE LIBRARY'?
STAGE 1: (SUBQUESTIONS 1+2) LITERATURE REVIEW
STAGE 2: (SUBQUESTION 2) CASE-STUDIES
STAGE 3: (PRE-WORK SUBQUESTION 3) EMPIRICAL RESEARCH (CURRENT LIGHTING CONDITIONS IN THE KB)
STAGE 4: (SUBQUESTIONS 3) DESIGN ORIENTED RESEARCH DIALUX / (SKETCHUP)
STAGE 5: THEORETICAL FOUNDATION (EVIDENCE-BASED LIGHTING FRAMEWORK)
STAGE 6: TRANSLATION OF THEORETICAL FOUNDATION TO DESIGN
STAGE 7: DESIGN OF THE 'FUTURE LIBRARY'
DIALUX
LOCHAL

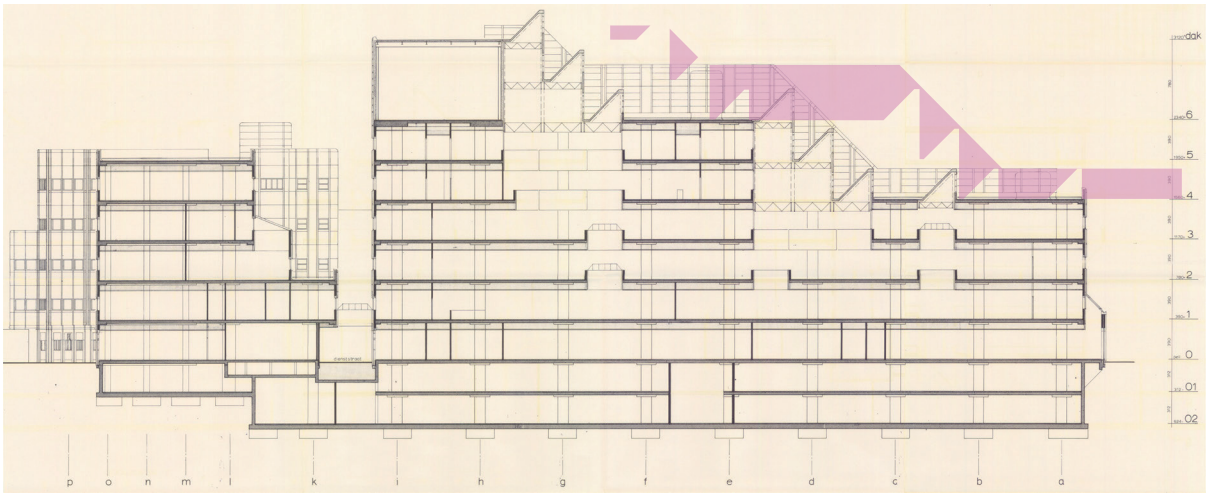

Inner Courtyard
Columns
Structure as Architectural Element
Roof structure
Entrance Problem now
Connection with Surroundings
Accessibility
Connection National Archive
Cozy ambiance
Circulation loop
Visual Axis to Lookout Area
Connection Ministry of Foreign Affairs
Brownsea
Entrance Can Give Bus feeling
Sculptural Shape + Statistics
PREFFERED VALUES
Difference Public/Private
Silence
Bicycle Parking
Northwest Part 2
Sustainability
Natural lighting
GREEN SPACES
Connection offices with public spaces
Horizon
Clouds
View
View of the Sky
Birds
Landmarks
South/West Part with 'killer view'
Trees
Buildings
'Haage Lopez'
Connection with CS
Pathways
Waterways
Uitvlud North East Side
View of the middle layer in between
View of the ground
Good View to outside
Addition Part/Repository Space
Glare issues
People + cars moving
Everyways
Uniform floor load capacity
Allumination materialism
Reflection light
Improve Cognitive Performance & Knowledge acquisition for users KB
Ambient Light
Focal Glow
Sparkle
Lighting Landscape
North/East Best for uniform lighting
Reading room/office/meeting spaces
Study Corridors
Orientation, Form & Shape
Building openings
Toplighting
Daylight Controls
Artificial Lighting
Lighting Control Systems
1: Hybrid 2: Manual 3: Automatic
VALUES CURRENT KB (BUILDING)
Integration in dense urban area
Courtyard views
Lively Plinth
Calm interiors
Still closed scientific library to open public institution
Rotterdam library example
Human scale Design
Figure out the system
Order in facade
Varying voids
Order in Height of floors
Views inner garden

Most Relevant



‘Sculptural’ Aluminium Façade Cladding (‘The Iceberg’)

- SOCIAL
- ECONOMIC
- POLITICAL
- HISTORIC
- AESTHETICAL
- SCENTIFIC
- AGE
- ECOLOGICAL

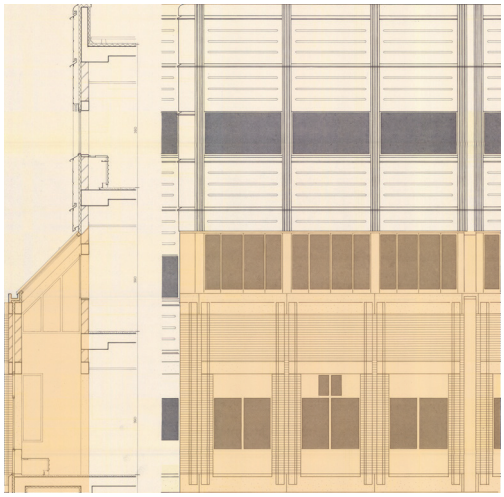


Stepped Roof Structure (Climate Installations)

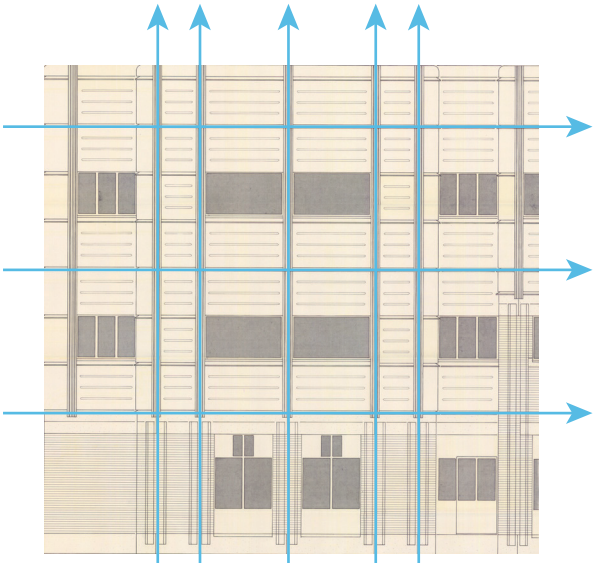
Heritage Values



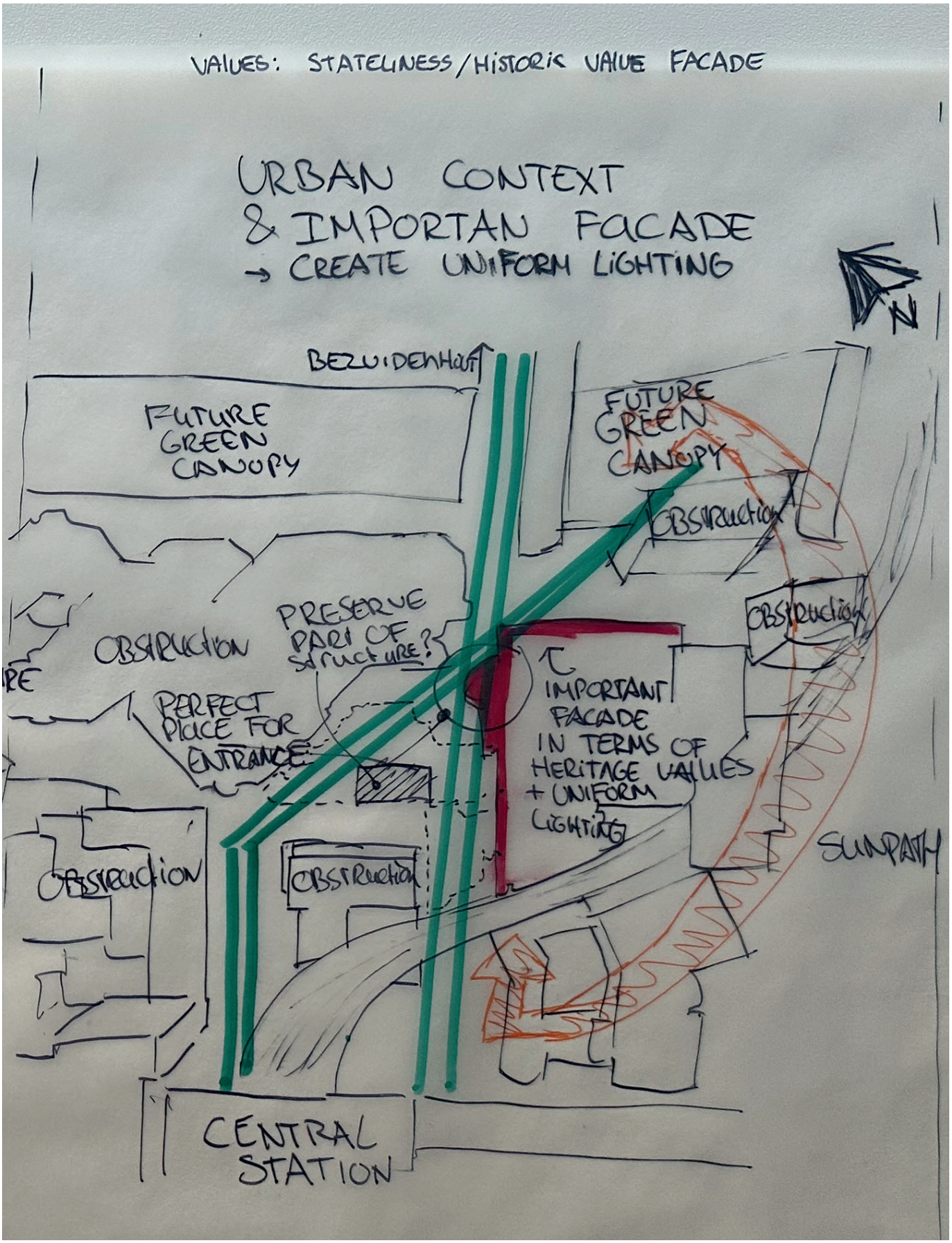
Human-Scale Brick Ground Floor Façade

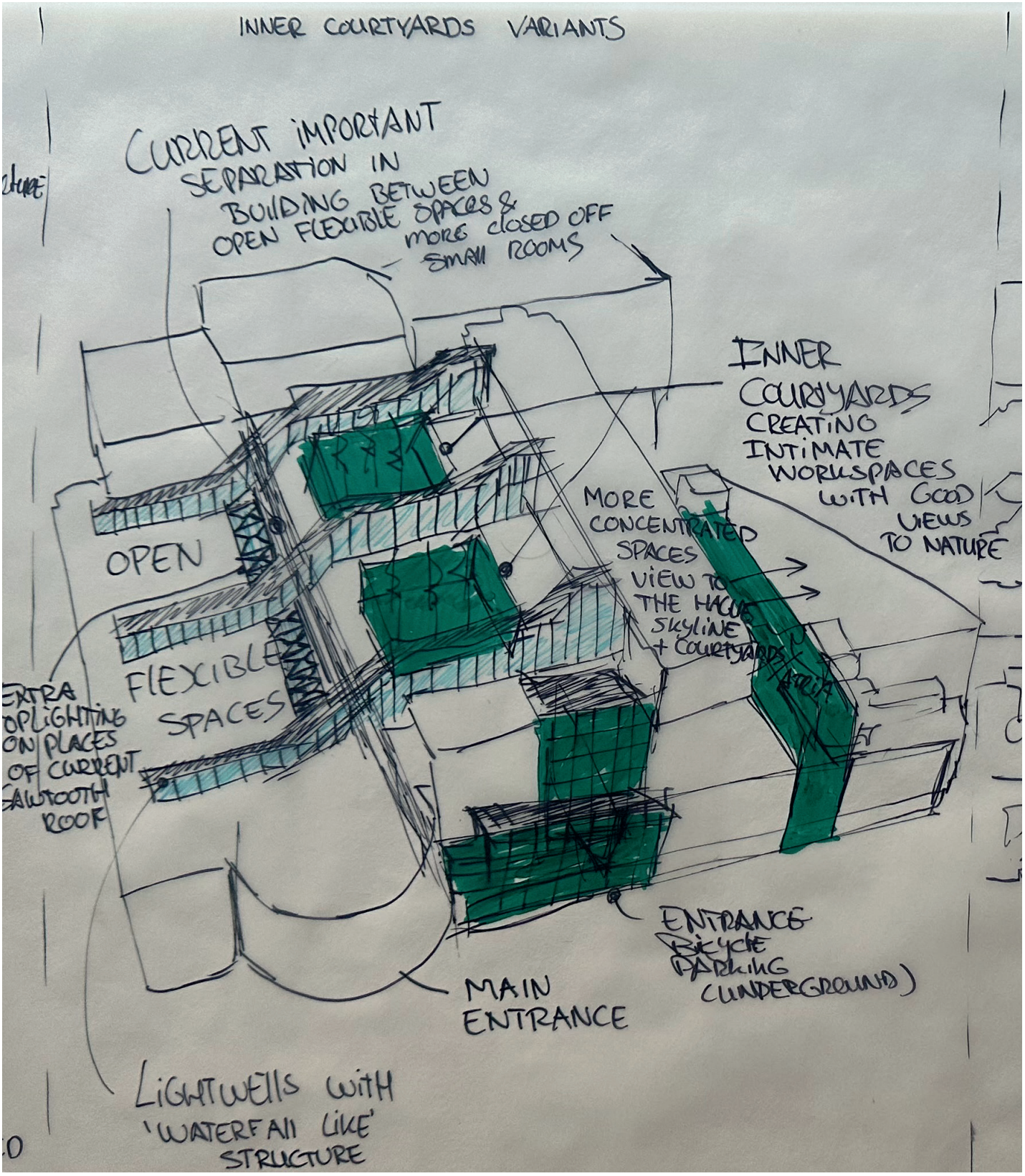


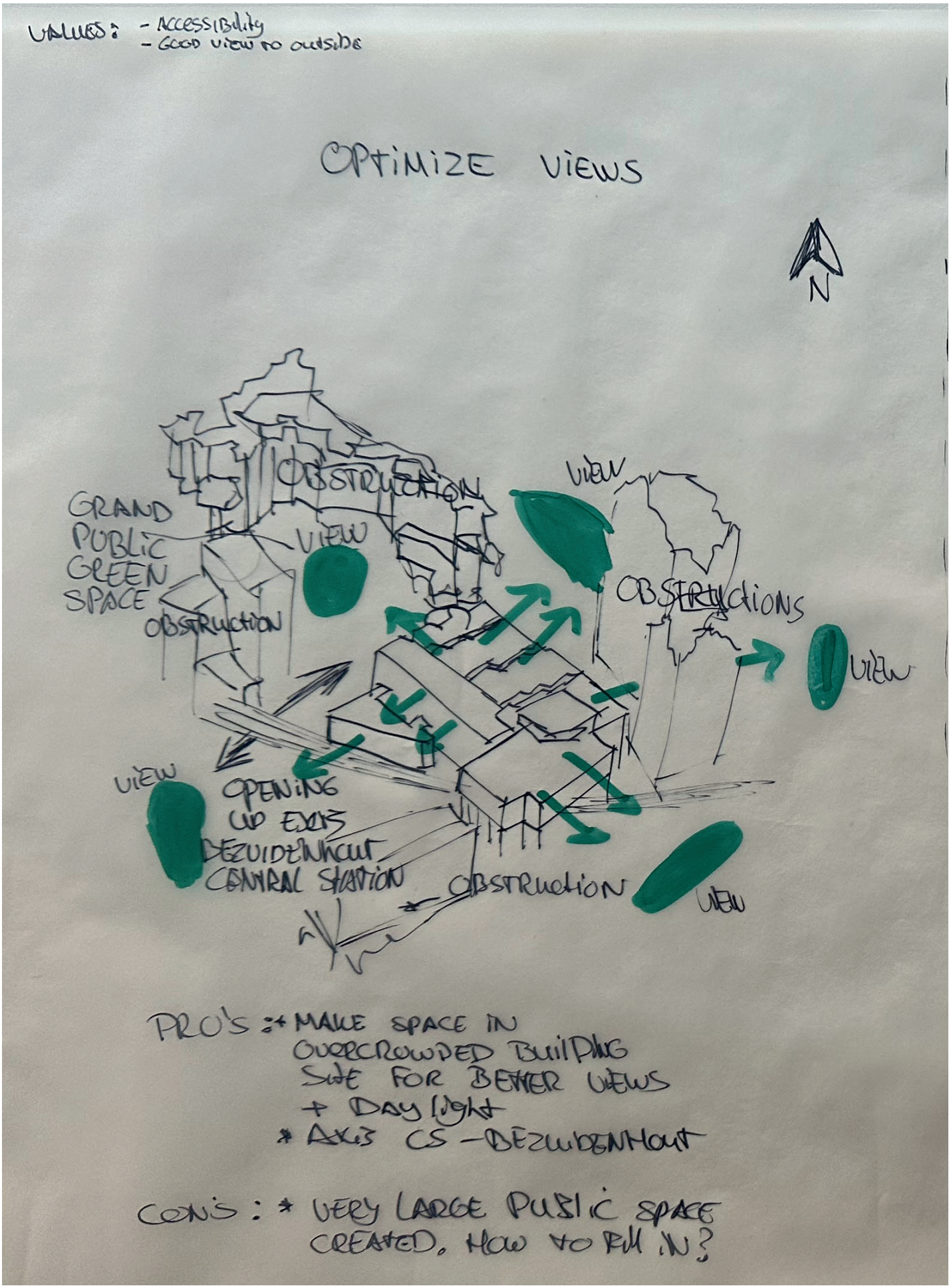
Skylights East-Façade

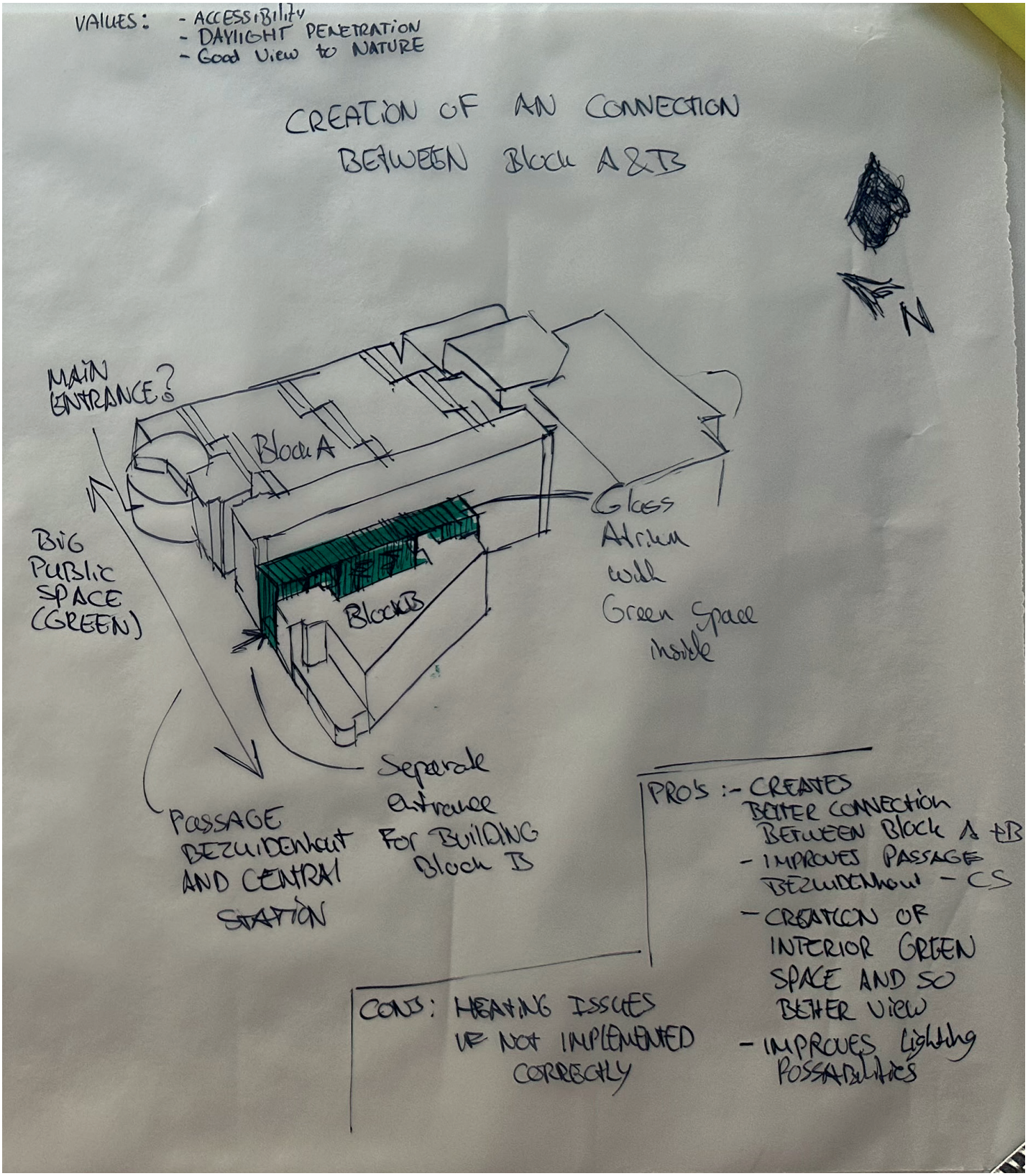


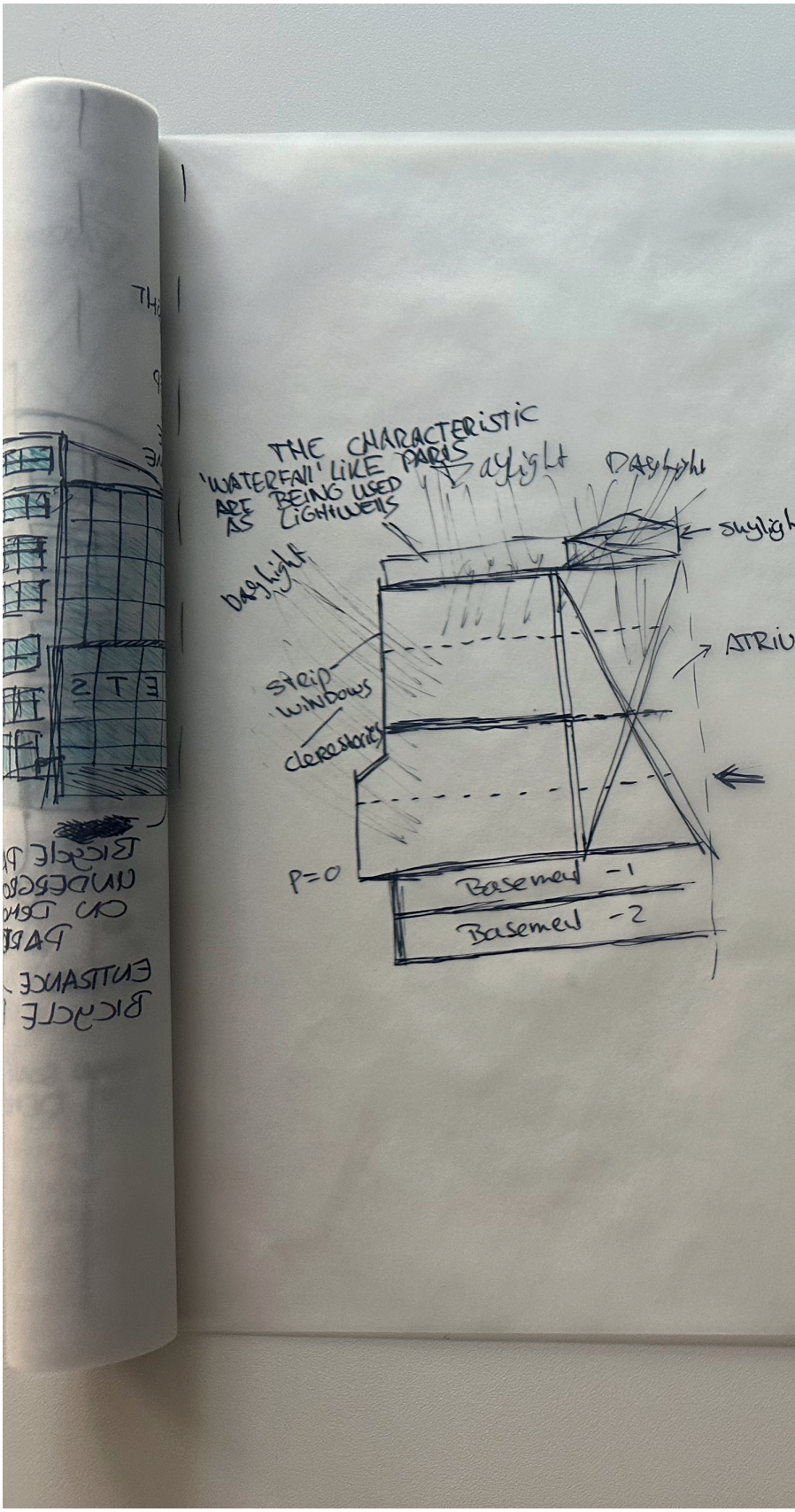
Façade Composition

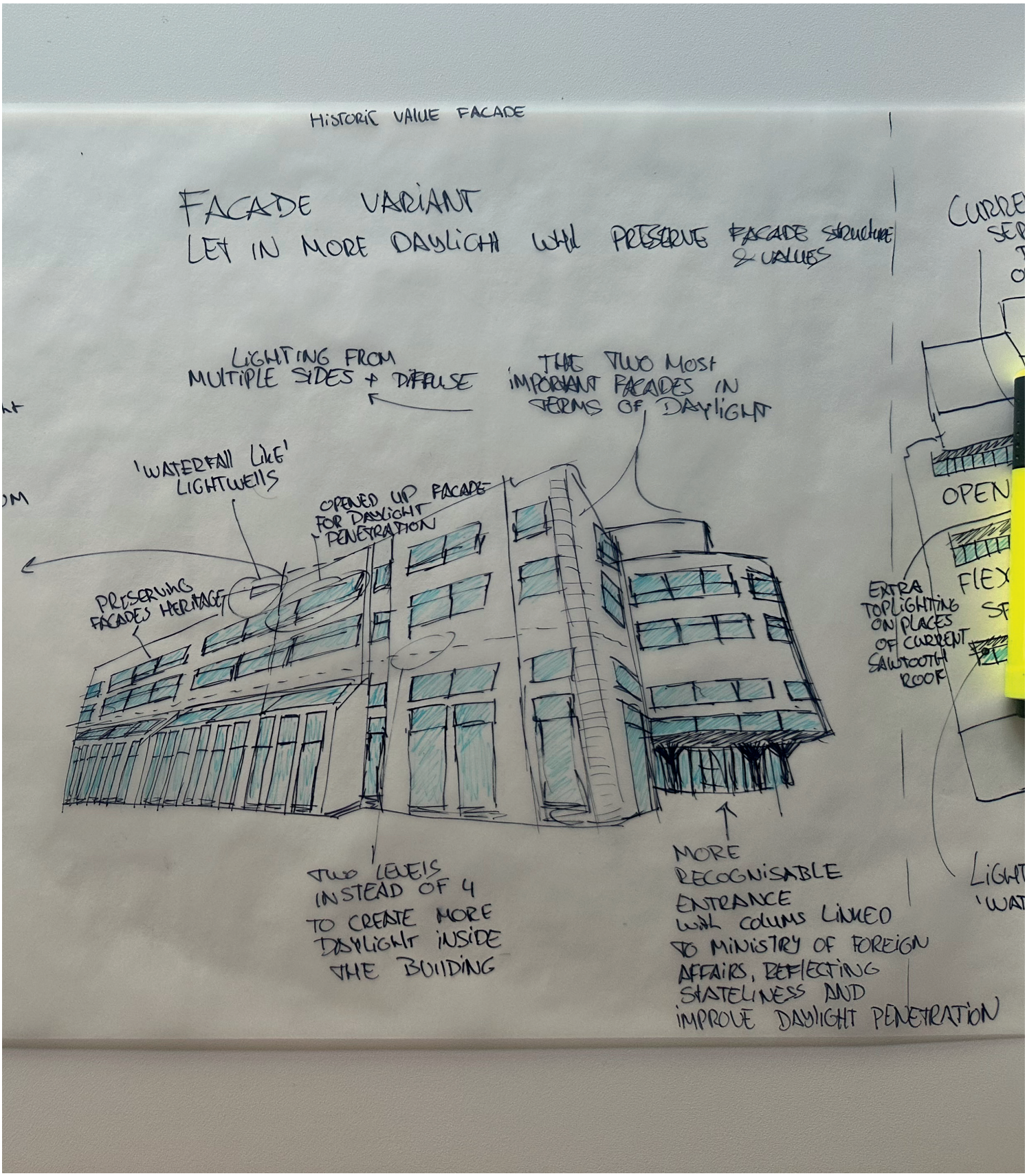

VALUES: STATELINESS / HISTORIC VALUE FACADE
URBAN CONTEXT
& IMPORTAN FACADE
→ CREATE UNIFORM LIGHTING
N
BEBOUWDENHOUT
FUTURE GREEN CANOPY
FUTURE GREEN CANOPY
OBSTRUCTION
OBSTRUCTION
PRESERVE PART OF STRUCTURE?
OBSTRUCTION
PERFECT PLACE FOR ENTRANCE
IMPORTANT FACADE IN TERMS OF HERITAGE VALUES + UNIFORM LIGHTING
OBSTRUCTION
OBSTRUCTION
SUNPATH
CENTRAL STATION

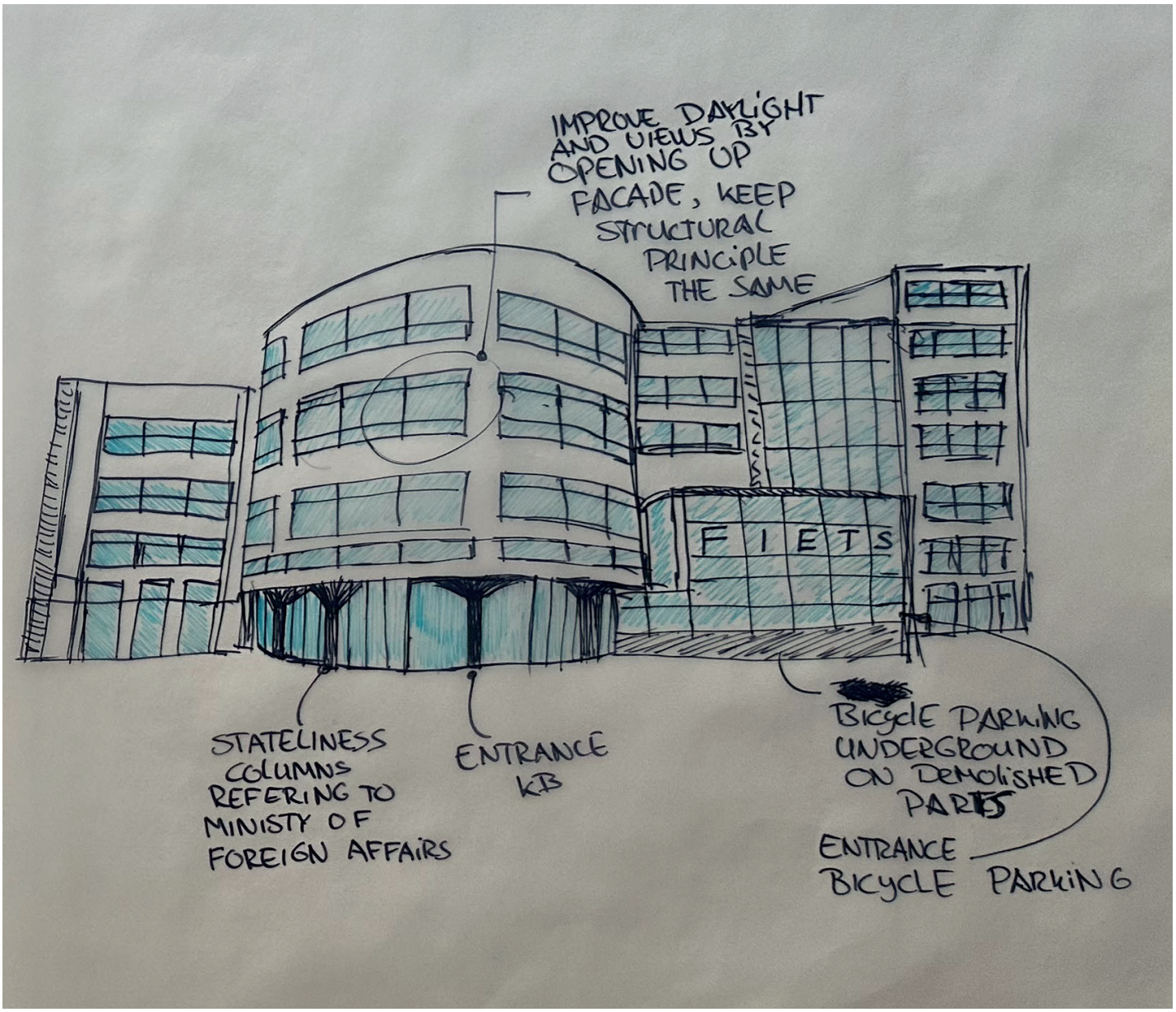

INNER COURTYARDS VARIANTS
CURRENT IMPORTANT SEPARATION IN BUILDING BETWEEN OPEN FLEXIBLE SPACES & MORE CLOSED OFF SMALL ROOMS
INNER COURTYARDS CREATING INTIMATE WORKSPACES WITH GOOD VIEWS TO NATURE
MORE CONCENTRATED SPACES VIEW TO THE HAGUE SKYLINE + COURTYARDS
OPEN
FLEXIBLE SPACES
EXTRA OPLIGHTING ON PLACES OF CURRENT SAWTOOTH ROOF
ENTRANCE BICYCLE PARKING (UNDERGROUND)
MAIN ENTRANCE
LIGHTWELLS WITH 'WATERFALL LIKE' STRUCTURE

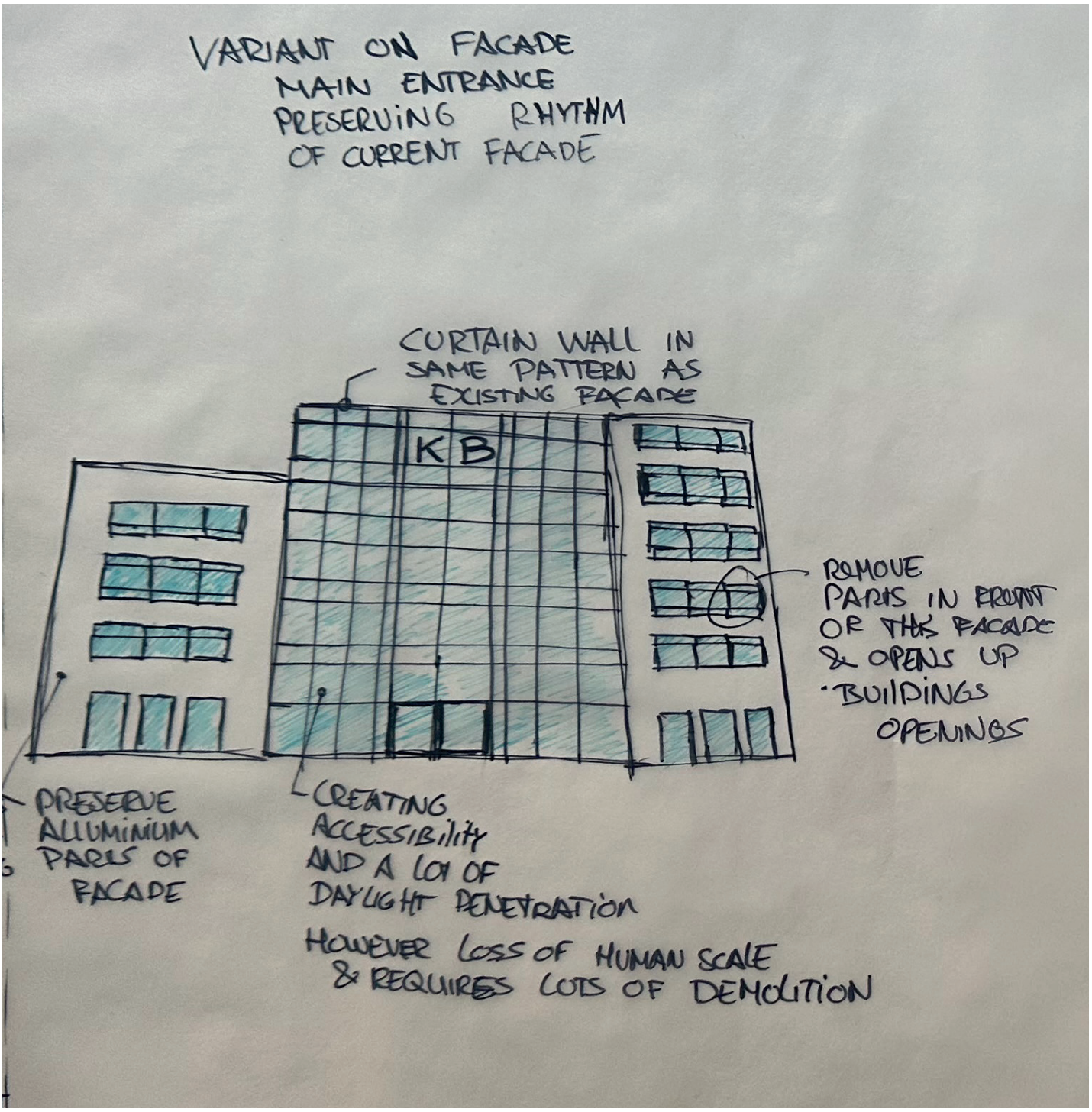

VALUES: - ACCESSIBILITY
- GOOD VIEW TO OUTSIDE
OPTIMIZE VIEWS
N
GRAND PUBLIC GREEN SPACE
OBSTRUCTION
VIEW
OBSTRUCTION
VIEW
OBSTRUCTIONS
VIEW
VIEW
OPENING UP EXITS BEZUIDENHOUT CENTRAL STATION
OBSTRUCTION
VIEW
PRO'S: + MAKE SPACE IN OVERCROWDED BUILDING SITE FOR BETTER VIEWS + DAYLIGHT
* AXIS CS - BEZUIDENHOUT
CONS: * VERY LARGE PUBLIC SPACE CREATED, HOW TO FILL IN?

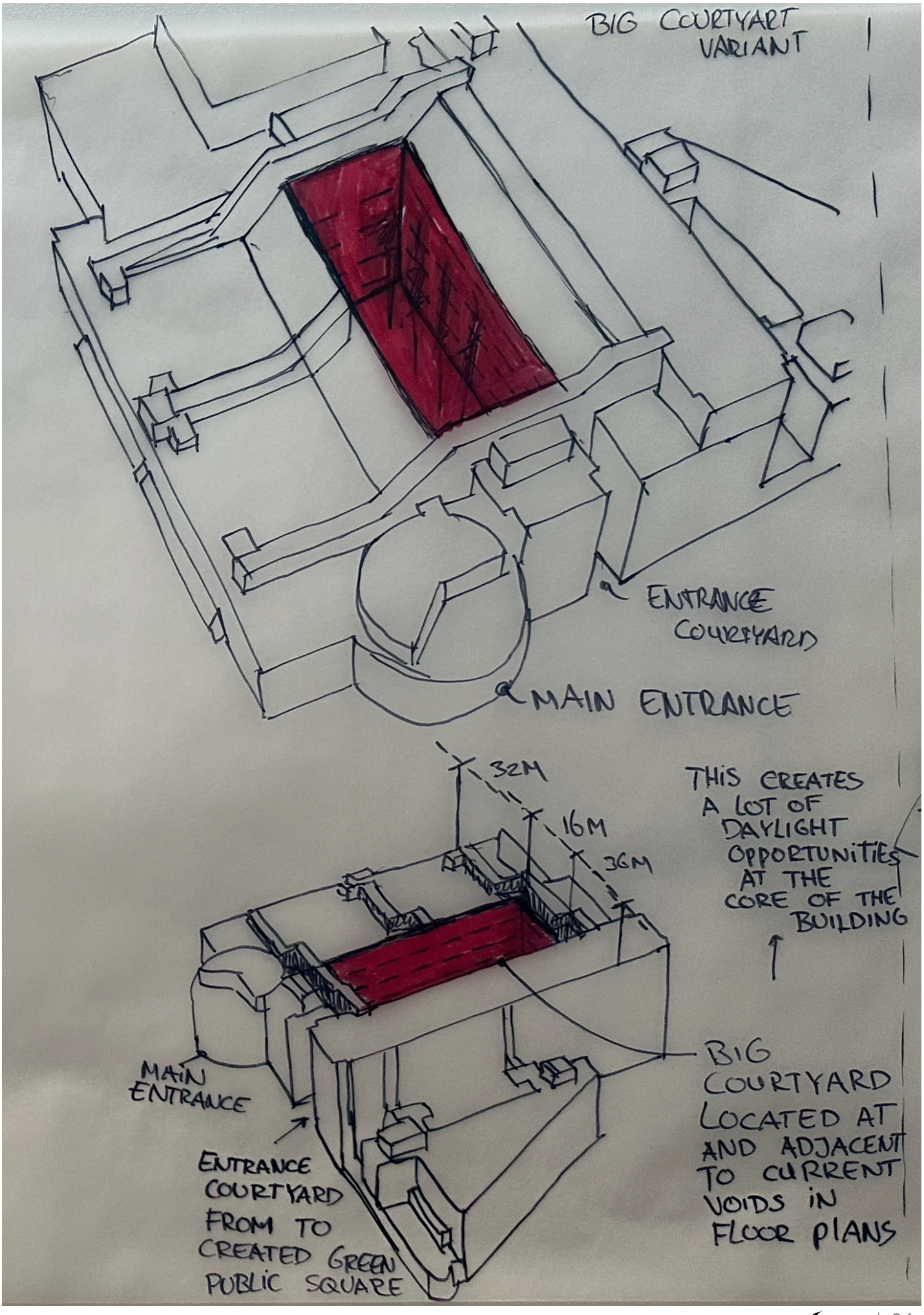

VALUES:
- ACCESSIBILITY
- DAYLIGHT PENETRATION
- Good View to NATURE
CREATION OF AN CONNECTION BETWEEN Block A&B
N
MAIN ENTRANCE?
Block A
Block B
Glass Atrium with Green Space inside
BIG PUBLIC SPACE (GREEN)
Separate entrance For BUILDING Block B
PASSAGE BEZUIDENHOUT AND CENTRAL STATION
PRO's :- CREATES BETTER CONNECTION BETWEEN Block A +B
- IMPROVES PASSAGE BEZUIDENHOUT - CS
- CREATION OF INTERIOR GREEN SPACE AND SO BETTER VIEW
- IMPROVES Lighting POSSABILITIES
CONS: HEATING ISSUES IF NOT IMPLEMENTED CORRECTLY

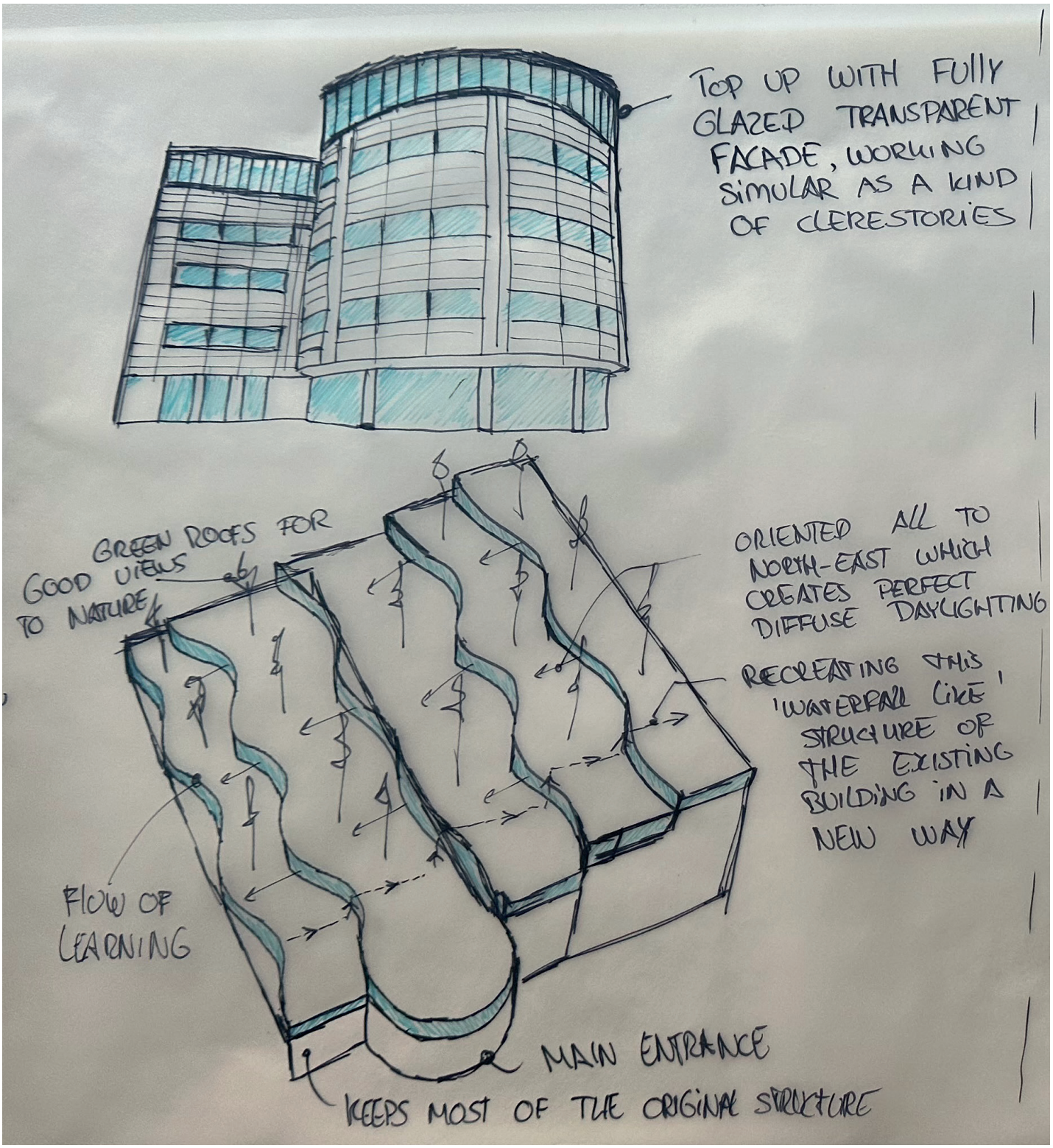

THE CHARACTERISTIC
'WATERFALL' LIKE PARTS
ARE BEING USED
AS LIGHTWELLS
Daylight
Daylight
Daylight
Daylight
strip windows
clerestories
P=0
Basement -1
Basement -2

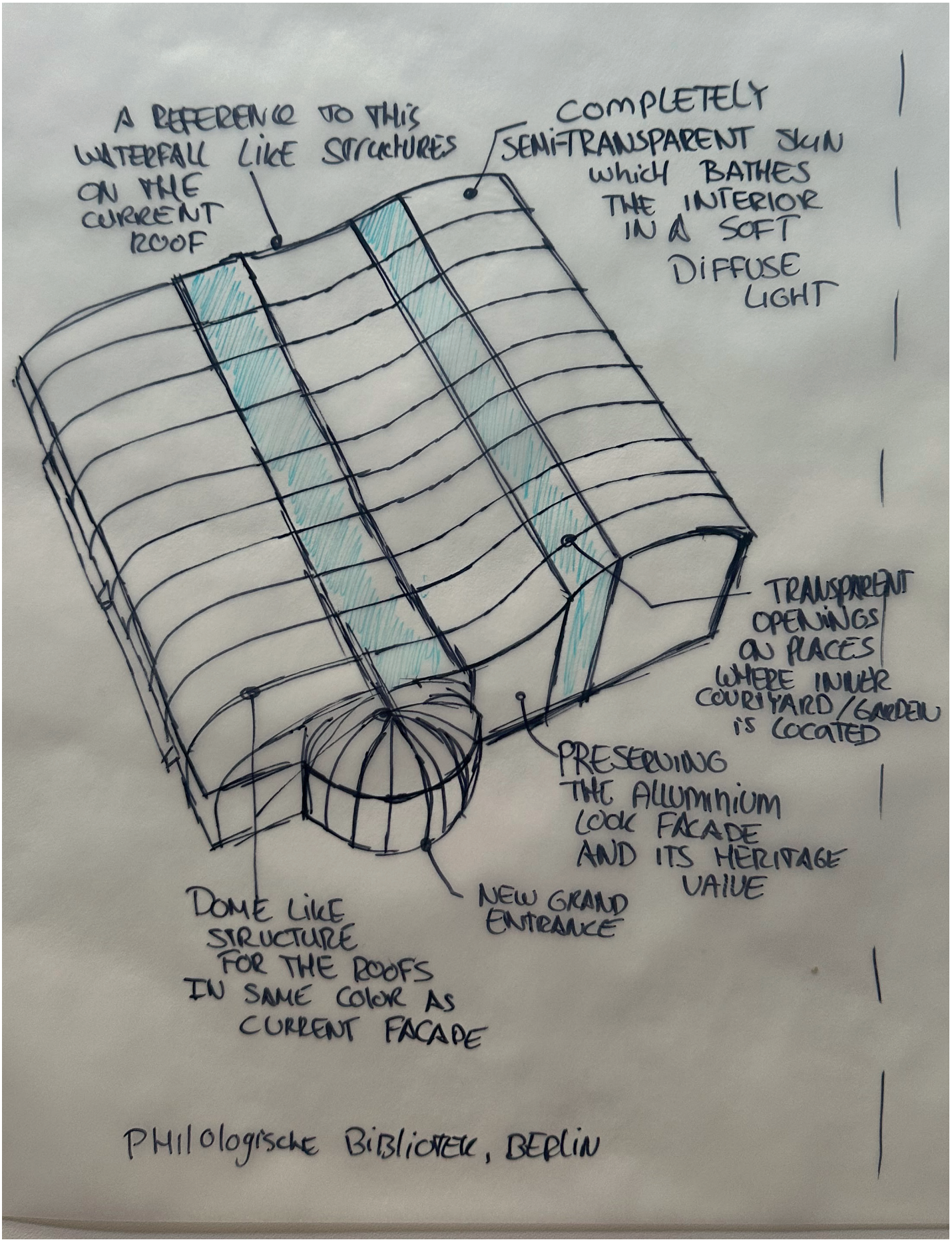

HISTORIC VALUE FACADE
FACADE VARIANT
LET IN MORE DAYLIGHT WHILE PRESERVE FACADE STRUCTURE & VALUES
LIGHTING FROM MULTIPLE SIDES + DIFFUSE
THE TWO MOST IMPORTANT FACADES IN TERMS OF DAYLIGHT
'WATERFALL LIKE' LIGHTWELLS
OPENED UP FACADE FOR DAYLIGHT PENETRATION
PRESERVING FACADES HERITAGE
EXTRA TOPLIGHTING ON PLACES OF CURRENT SAWTOOTH ROOF
OPEN
FLEX
TWO LEVELS INSTEAD OF 4 TO CREATE MORE DAYLIGHT INSIDE THE BUILDING
MORE RECOGNISABLE ENTRANCE WITH COLUMS LINKED TO MINISTRY OF FOREIGN AFFAIRS, REFLECTING STATELINESS AND IMPROVE DAYLIGHT PENETRATION

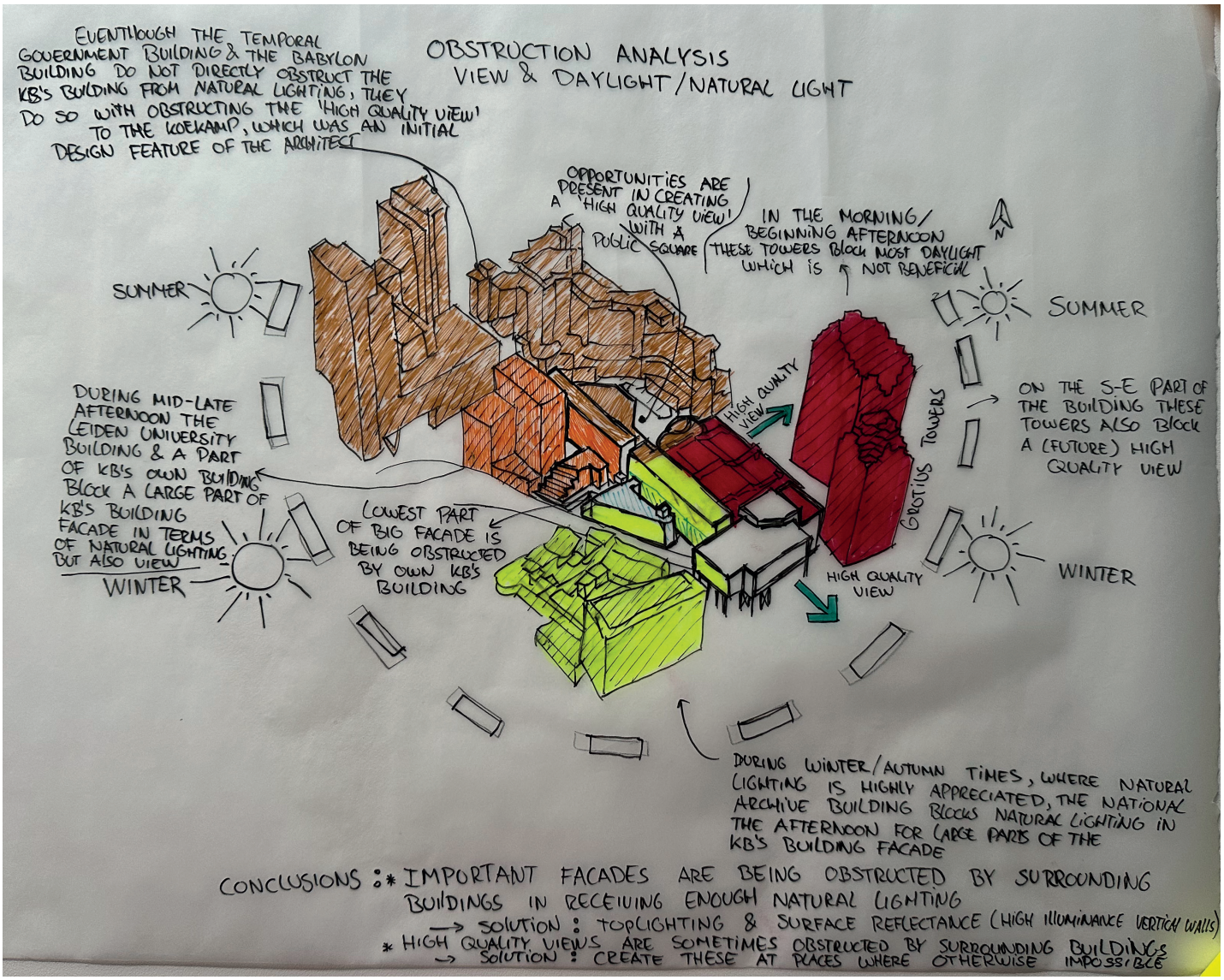

IMPROVE DAYLIGHT AND VIEWS BY OPENING UP FACADE, KEEP STRUCTURAL PRINCIPLE THE SAME
F I E T S
STATELINESS COLUMNS REFERING TO MINISTY OF FOREIGN AFFAIRS
ENTRANCE KB
BICYCLE PARKING UNDERGROUND ON DEMOLISHED PARTS
ENTRANCE BICYCLE PARKING

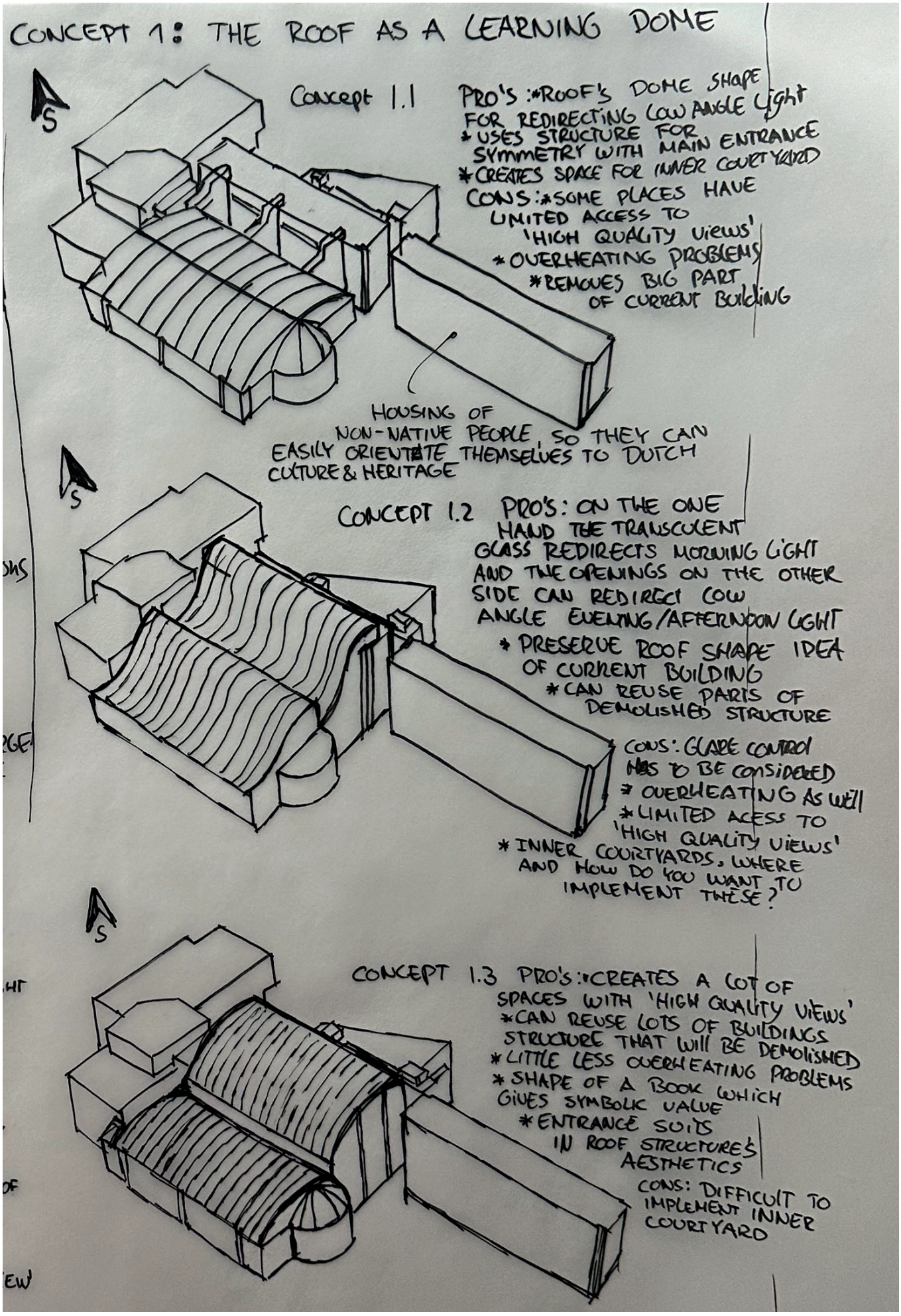

VARIANT ON FACADE
MAIN ENTRANCE
PRESERVING RHYTHM
OF CURRENT FACADE
CURTAIN WALL IN
SAME PATTERN AS
EXISTING FACADE
KB
REMOVE
PARTS IN FRONT
OF THE FACADE
& OPENS UP
BUILDINGS
OPENINGS
PRESERVE
ALLUMINIUM
PARTS OF
FACADE
CREATING
ACCESSIBILITY
AND A LOT OF
DAYLIGHT PENETRATION
HOWEVER LOSS OF HUMAN SCALE
& REQUIRES LOTS OF DEMOLITION


BIG COURTYART
VARIANT
ENTRANCE
COURTYARD
MAIN ENTRANCE
32M
16M
3GM
THIS CREATES
A LOT OF
DAYLIGHT
OPPORTUNITIES
AT THE
CORE OF THE
BUILDING
MAIN
ENTRANCE
ENTRANCE
COURTYARD
FROM TO
CREATED GREEN
PUBLIC SQUARE
BIG
COURTYARD
LOCATED AT
AND ADJACENT
TO CURRENT
VOIDS IN
FLOOR PLANS


TOP UP WITH FULLY GLAZED TRANSPARENT FACADE, WORKING SIMULAR AS A KIND OF CLERESTORIES
GREEN ROOFS FOR GOOD VIEWS TO NATURE
ORIENTED ALL TO NORTH-EAST WHICH CREATES PERFECT DIFFUSE DAYLIGHTING
RECREATING THIS 'WATERFALL LIKE' STRUCTURE OF THE EXISTING BUILDING IN A NEW WAY
FLOW OF LEARNING
MAIN ENTRANCE
KEEPS MOST OF THE ORIGINAL STRUCTURE

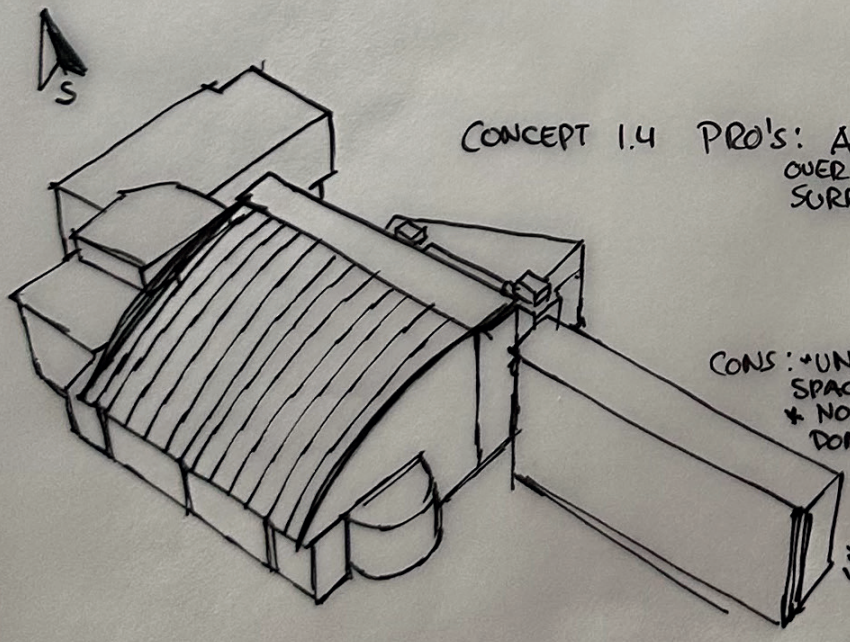

A REFERENCE TO THIS WATERFALL LIKE STRUCTURES ON THE CURRENT ROOF
COMPLETELY SEMI-TRANSPARENT SKIN WHICH BATHES THE INTERIOR IN A SOFT DIFFUSE LIGHT
TRANSPARENT OPENINGS ON PLACES WHERE INNER COURTYARD / GARDEN IS LOCATED
PRESERVING THE ALUMINIUM LOCK FACADE AND ITS HERITAGE VALUE
NEW GRAND ENTRANCE
DOME LIKE STRUCTURE FOR THE ROOFS IN SAME COLOR AS CURRENT FACADE
PHILOLOGISCHE BIBLIOTEK, BERLIN


OBSTRUCTION ANALYSIS
VIEW & DAYLIGHT/NATURAL LIGHT
EVENTHOUGH THE TEMPORAL GOUERNMENT BUILDING & THE BABYLON BUILDING DO NOT DIRECTLY OBSTRUCT THE KB'S BUILDING FROM NATURAL LIGHTING, THEY DO SO WITH OBSTRUCTING THE 'HIGH QUALITY VIEW' TO THE KOEKAMP, WHICH WAS AN INITIAL DESIGN FEATURE OF THE ARCHITECT
OPPORTUNITIES ARE PRESENT IN CREATING A 'HIGH QUALITY VIEW' WITH A PUBLIC SQUARE
IN THE MORNING/ BEGINNING AFTERNOON THESE TOWERS BLOCK MOST DAYLIGHT WHICH IS NOT BENEFICIAL
N
SUMMER
SUMMER
HIGH QUALITY VIEW
GROTIUS TOWERS
ON THE S-E PART OF THE BUILDING THESE TOWERS ALSO BLOCK A (FUTURE) HIGH QUALITY VIEW
DURING MID-LATE AFTERNOON THE LEIDEN UNIVERSITY BUILDING & A PART OF KB'S OWN BUILDING BLOCK A LARGE PART OF KB'S BUILDING FACADE IN TERMS OF NATURAL LIGHTING BUT ALSO VIEW
WINTER
LOWEST PART OF BIG FACADE IS BEING OBSTRUCTED BY OWN KB'S BUILDING
HIGH QUALITY VIEW
WINTER
DURING WINTER/AUTUMN TIMES, WHERE NATURAL LIGHTING IS HIGHLY APPRECIATED, THE NATIONAL ARCHIVE BUILDING BLOCKS NATURAL LIGHTING IN THE AFTERNOON FOR LARGE PARTS OF THE KB'S BUILDING FACADE
CONCLUSIONS :* IMPORTANT FACADES ARE BEING OBSTRUCTED BY SURROUNDING BUILDINGS IN RECEIVING ENOUGH NATURAL LIGHTING
→ SOLUTION : TOPLIGHTING & SURFACE REFLECTANCE (HIGH ILLUMINANCE VERTICAL WALLS)
* HIGH QUALITY VIEWS ARE SOMETIMES OBSTRUCTED BY SURROUNDING BUILDINGS
→ SOLUTION : CREATE THESE AT PLACES WHERE OTHERWISE IMPOSSIBLE


CONCEPT 1: THE ROOF AS A LEARNING DOME
Concept 1.1
PRO'S: *ROOF'S DOME SHAPE FOR REDIRECTING LOW ANGLE LIGHT
* USES STRUCTURE FOR SYMMETRY WITH MAIN ENTRANCE
*CREATES SPACE FOR INNER COURTYARD
CONS: *SOME PLACES HAVE LIMITED ACCESS TO 'HIGH QUALITY VIEWS'
*OVERHEATING PROBLEMS
*REMOVES BIG PART OF CURRENT BUILDING
HOUSING OF NON-NATIVE PEOPLE, SO THEY CAN EASILY ORIENTATE THEMSELVES TO DUTCH CULTURE & HERITAGE
CONCEPT 1.2
PRO'S: ON THE ONE HAND THE TRANSCULENT GLASS REDIRECTS MORNING LIGHT AND THE OPENINGS ON THE OTHER SIDE CAN REDIRECT LOW ANGLE EVENING/AFTERNOON LIGHT
* PRESERVE ROOF SHAPE IDEA OF CURRENT BUILDING
*CAN REUSE PARTS OF DEMOLISHED STRUCTURE
CONS: GLARE CONTROL HAS TO BE CONSIDERED
* OVERHEATING AS WELL
*LIMITED ACCESS TO 'HIGH QUALITY VIEWS'
* INNER COURTYARDS, WHERE AND HOW DO YOU WANT TO IMPLEMENT THESE?
CONCEPT 1.3 PRO'S: *CREATES A LOT OF SPACES WITH 'HIGH QUALITY VIEWS'
*CAN REUSE LOTS OF BUILDINGS STRUCTURE THAT WILL BE DEMOLISHED
*LITTLE LESS OVERHEATING PROBLEMS
* SHAPE OF A BOOK WHICH GIVES SYMBOLIC VALUE
*ENTRANCE SUITS IN ROOF STRUCTURE'S AESTHETICS
CONS: DIFFICULT TO IMPLEMENT INNER COURTYARD

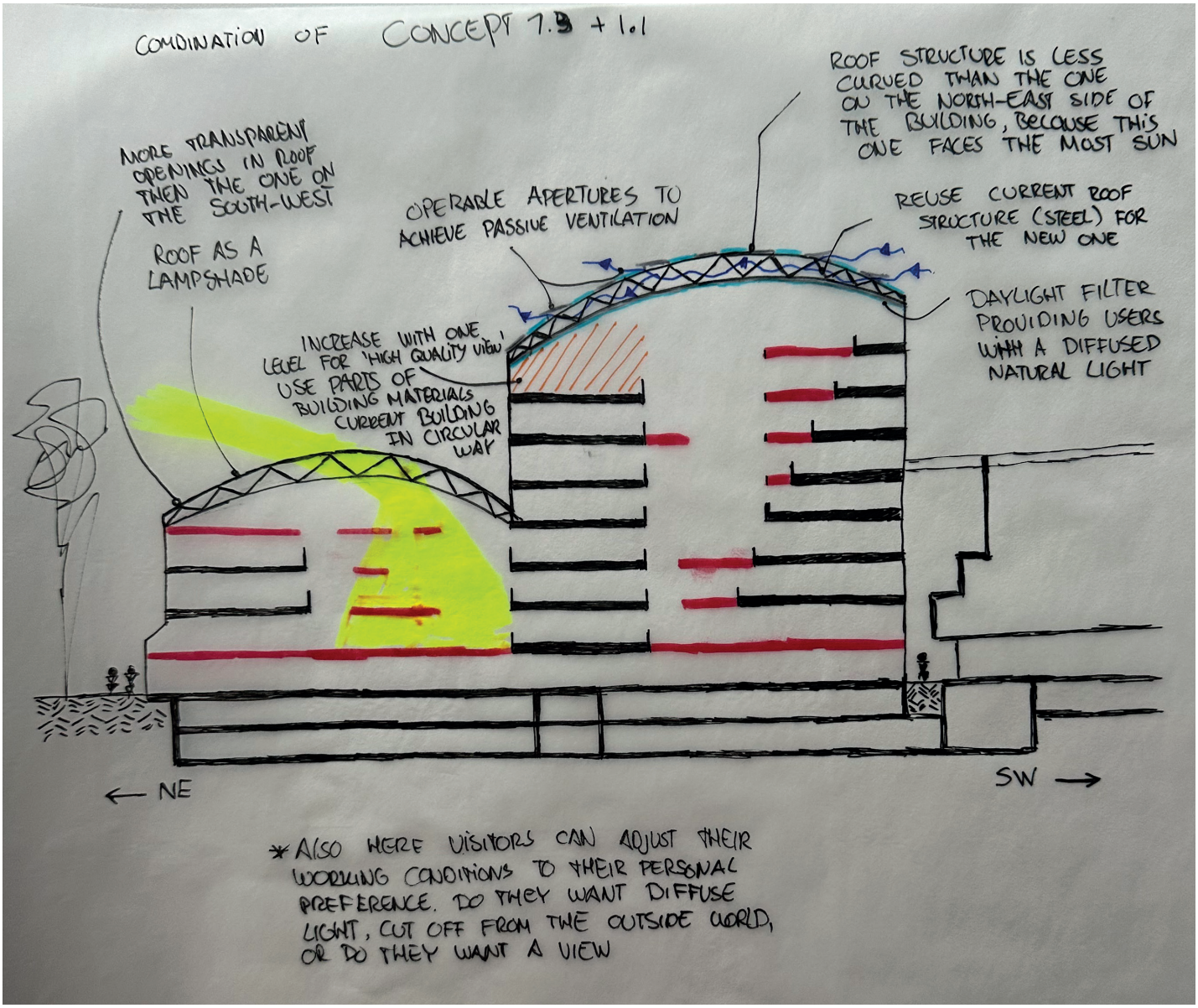
*BEST WAY TO ILLUMINATE A BUILDING WITH THESE KIND OF DEEP-PLAN LAYOUTS, SUCH AN CLIMATE (MAINLY OVERCAST), AND THESE OBSTRUCTIONS IS VIA TOPLIGHTING/ OVERHEAD SURFACES. WHY NOT MAKE THE WHOLE CONCEPT TURN AROUND THIS PRINCIPLE?

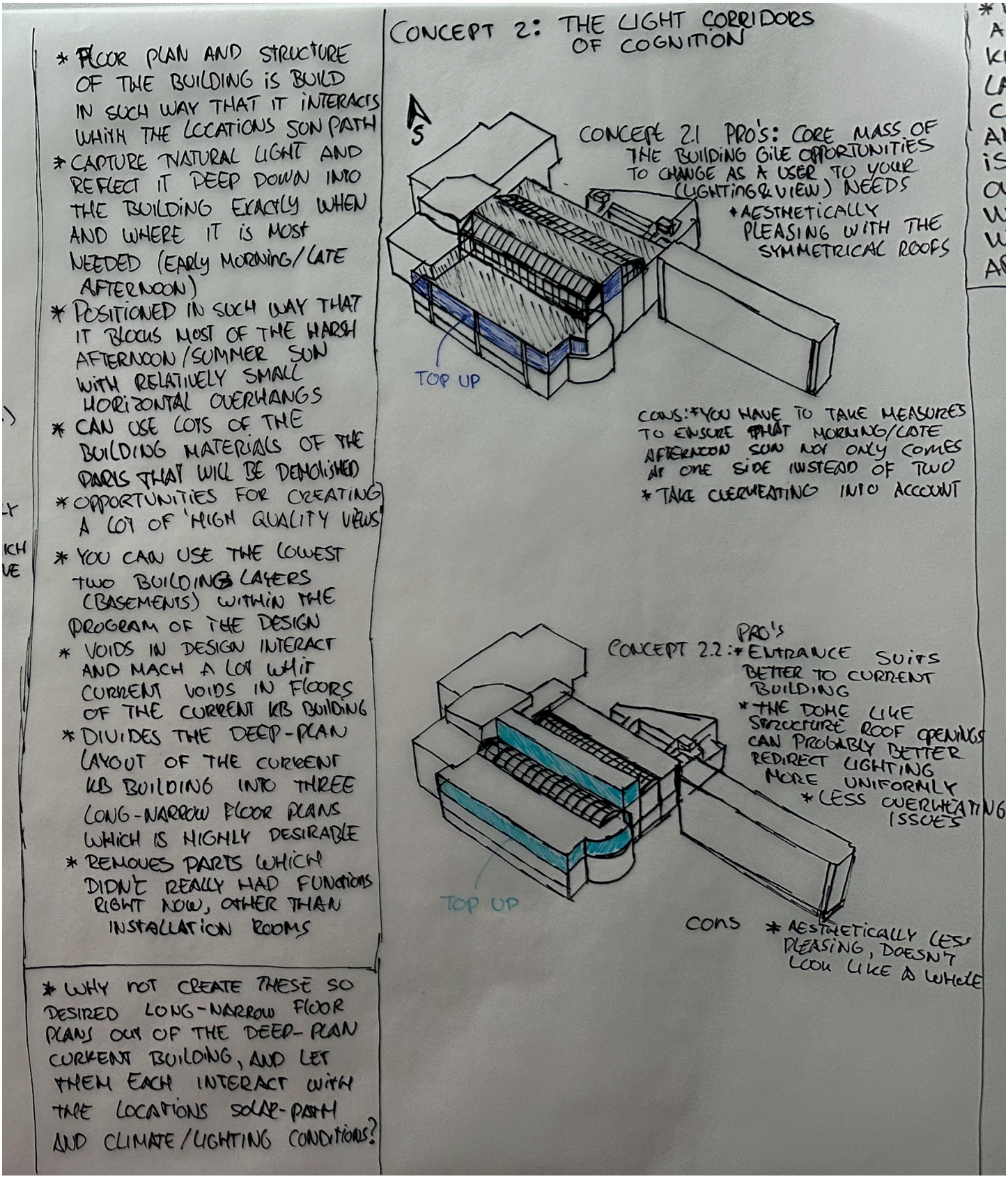
*PRESERVE THE HIGH VALUEABLE PARTS WITH LONG-NARROW FLOOR PLAN
*TRANSCCLENT Glass WHICH CREATES AMBIENT LIGHT, MORE DISTRIBUTED UNIFORMLY WHICH IS HIGHLY DESIRED IN LIBRARY SPACES
*THE DOME LIKE SHAPE CAN STILL MANAGE TO REDIRECT LIGHT TO PLACES WHICH WERE OTHERWISE OBSTRUCTED FROM NATURAL LIGHTING BY ITS SURROUNDING BUILDINGS
*ALUMINIUM CLADDING IS HIGHLY VALUED AND PLAYS A BIG ROLE IN THE BUILDINGS HERITAGE, THIS will BE PRESERVED AND IN TERMS OF AESTHETICS AND MATERIALS, THE CURRENT CLADDING SUITS WIDH THE TRANSCULENT GLASS ROOF
*GLARE IS BEING REDUCED WHILE STILL IMPROVE THE LIGHTING CONDITIONS
*EASY DISTINCTION BETWEEN THE MORE PUBLIC AND THE PRIVATE SPACES ARE POSSIBLE
*CREATES MORE SPACE FOR THE COURTYARD IN FRONT OF THE MAIN ENTRANCE, WHILE PRESERVING A LARGE PART OF CURREN CHILDRENS BOOK MUSEUM BUILDING

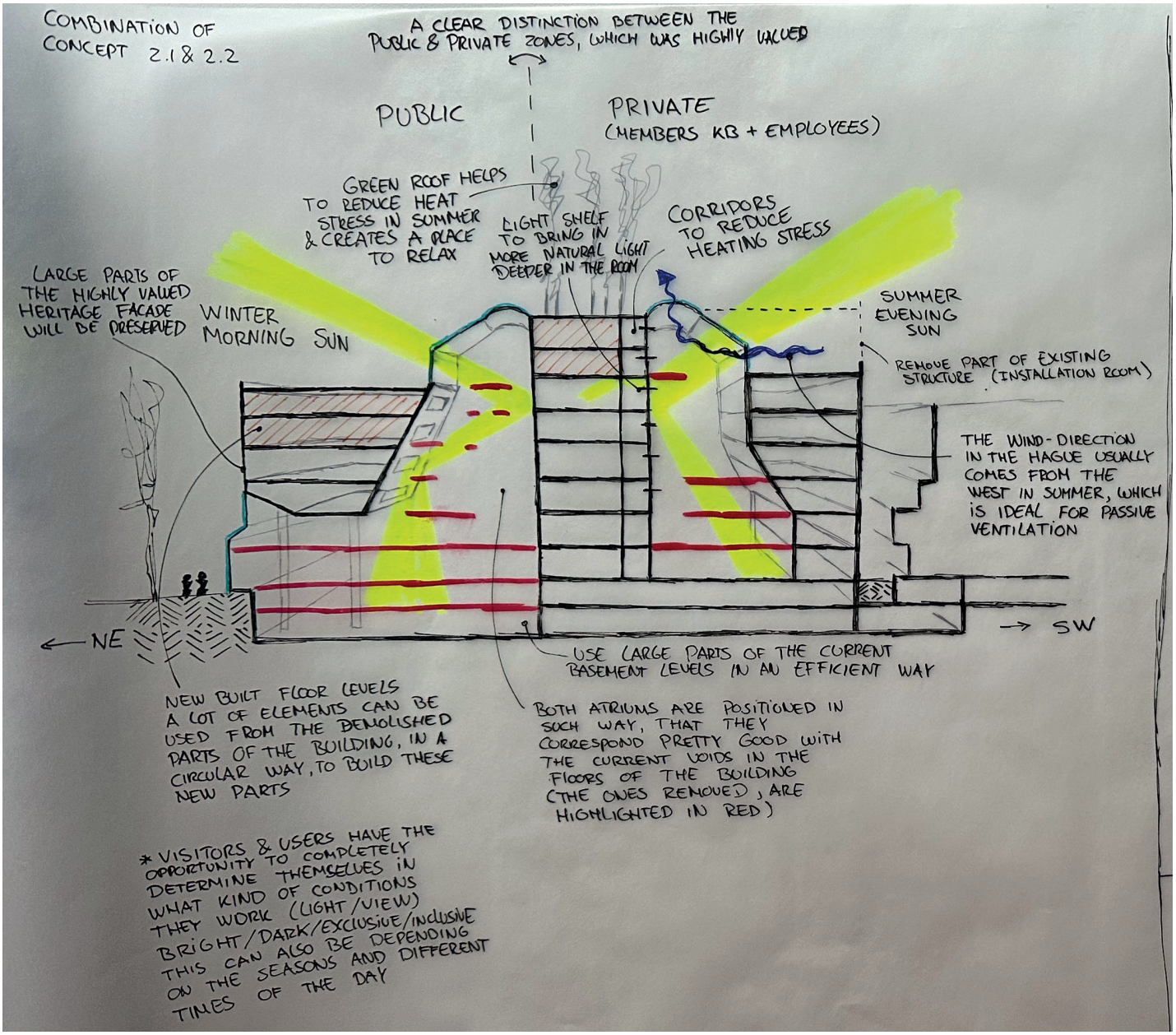


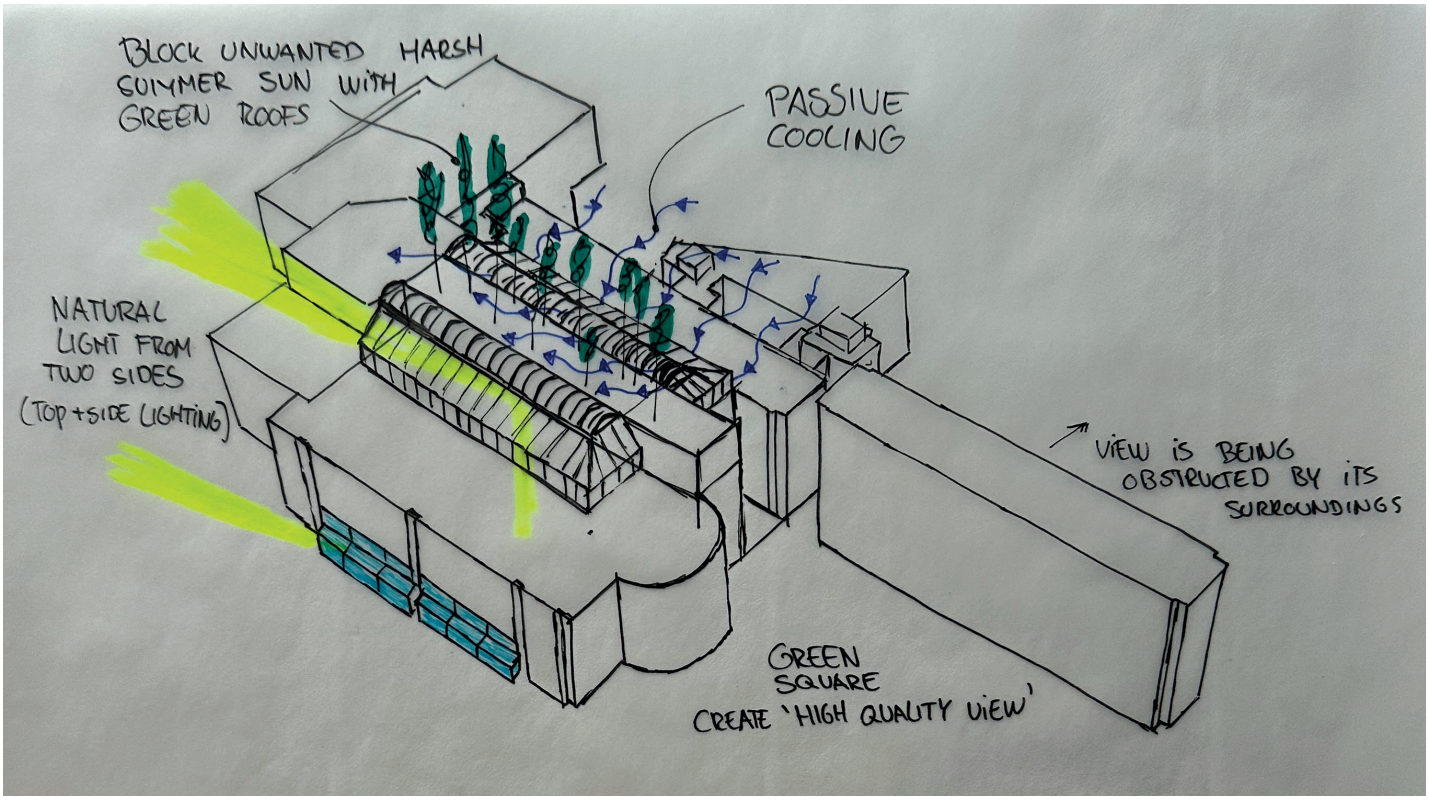
CONCEPT 1.4 PRO's: A lOT OF DAYLIGHT OVER THE WOLE ROOF'S SURFACE

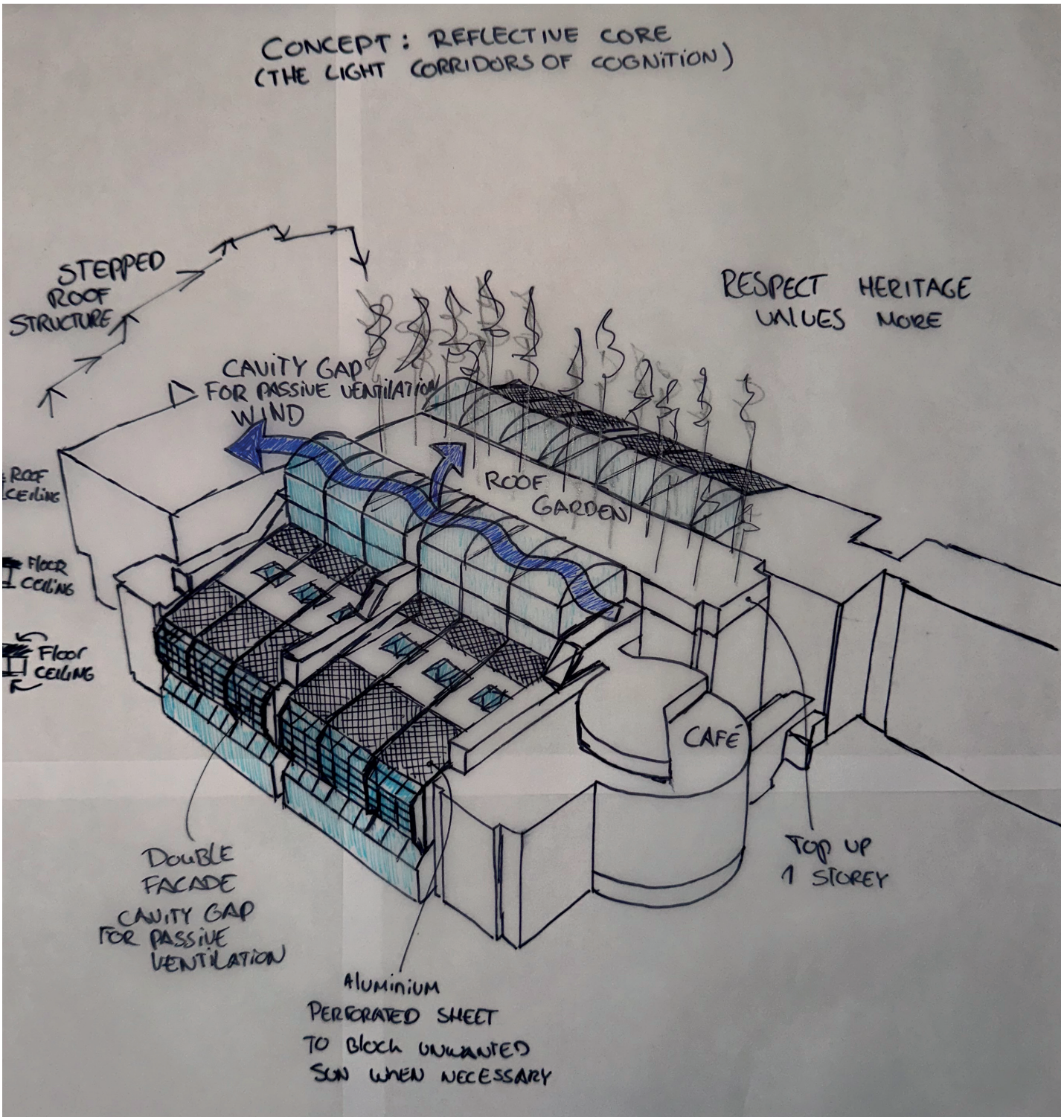
CONS: *UNNECESSARY BIG SPACE CREATED
* NOT SPECIFICALLY DOME STRUCTURE ROOF
*TO MUCH OVERHEATING PROBLEMS
*LIMITED 'HIGH QUALITY VIEW' POSSIBILITIES

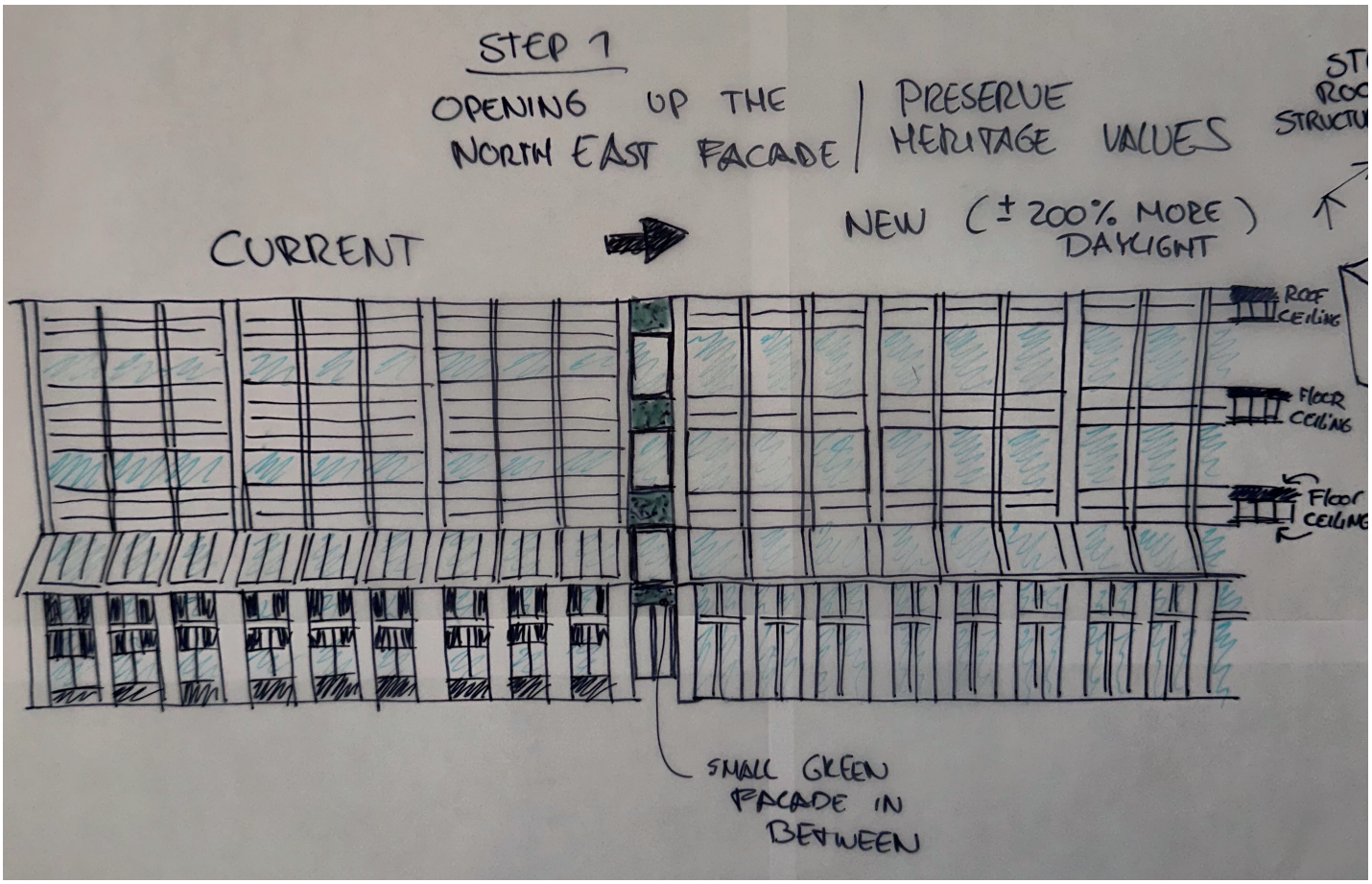

COMBINATION OF CONCEPT 1.3 + 1.1
MORE TRANSPARENT OPENINGS IN ROOF THEN THE ONE ON THE SOUTH-WEST
ROOF AS A LAMPSHADE
OPERABLE APERTURES TO ACHIEVE PASSIVE VENTILATION
ROOF STRUCTURE IS LESS CURVED THAN THE ONE ON THE NORTH-EAST SIDE OF THE BUILDING, BECOUSE THIS ONE FACES THE MOST SUN
REUSE CURRENT ROOF STRUCTURE (STEEL) FOR THE NEW ONE
DAYLIGHT FILTER PROVIDING USERS WITH A DIFFUSED NATURAL LIGHT
INCREASE WITH ONE LEVEL FOR 'HIGH QUALITY VIEW'
USE PARTS OF BUILDING MATERIALS CURRENT BUILDING IN CIRCULAR WAY
← NE
SW →
*ALSO WHERE VISITORS CAN ADJUST THEIR WORKING CONDITIONS TO THEIR PERSONAL PREFERENCE. DO THEY WANT DIFFUSE LIGHT, CUT OFF FROM THE OUTSIDE WORLD, OR DO THEY WANT A VIEW

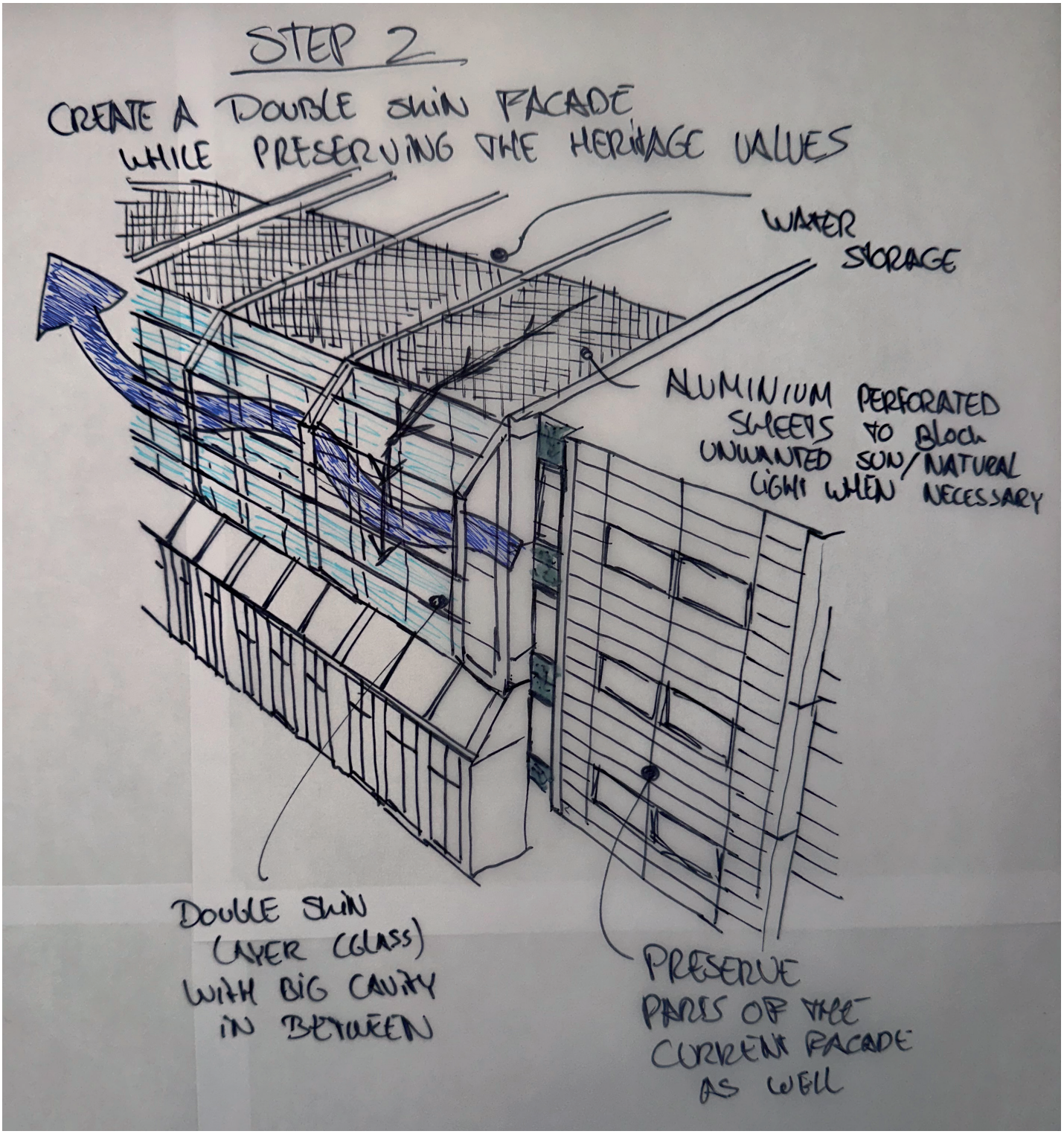

* FLOOR PLAN AND STRUCTURE OF THE BUILDING IS BUILD IN SUCH WAY THAT IT INTERACTS WHITH THE LOCATIONS SUN PATH
* CAPTURE NATURAL LIGHT AND REFLECT IT DEEP DOWN INTO THE BUILDING EXACTLY WHEN AND WHERE IT IS MOST NEEDED (EARLY MORNING/LATE AFTERNOON)
* POSITIONED IN SUCH WAY THAT IT BLOCKS MOST OF THE HARSH AFTERNOON/SUMMER SUN WITH RELATIVELY SMALL HORIZONTAL OVERHANGS
* CAN USE LOTS OF THE BUILDING MATERIALS OF THE PARTS THAT WILL BE DEMOLISHED
* OPPORTUNITIES FOR CREATING A LOT OF 'HIGH QUALITY VIEWS'
* YOU CAN USE THE LOWEST TWO BUILDING LAYERS (BASEMENTS) WITHIN THE PROGRAM OF THE DESIGN
* VOIDS IN DESIGN INTERACT AND MACH A LOT WHIT CURRENT VOIDS IN FLOORS OF THE CURRENT KB BUILDING
* DIVIDES THE DEEP-PLAN LAYOUT OF THE CURRENT KB BUILDING INTO THREE LONG-NARROW FLOOR PLANS WHICH IS HIGHLY DESIRABLE
* REMOVES PARTS WHICH DIDN'T REALLY HAD FUNCTIONS RIGHT NOW, OTHER THAN INSTALLATION ROOMS
* WHY NOT CREATE THESE SO DESIRED LONG-NARROW FLOOR PLANS OUT OF THE DEEP-PLAN CURRENT BUILDING, AND LET THEM EACH INTERACT WITH THE LOCATIONS SOLAR-PATH AND CLIMATE/LIGHTING CONDITIONS?
CONCEPT 2: THE LIGHT CORRIDORS OF COGNITION
S
CONCEPT 2.1 PRO's: CORE MASS OF THE BUILDING GIVE OPPORTUNITIES TO CHANGE AS A USER TO YOUR (LIGHTING&VIEW) NEEDS
* AESTHETICALLY PLEASING WITH THE SYMMETRICAL ROOFS
TOP UP
CONS: * YOU HAVE TO TAKE MEASURES TO ENSURE THAT MORNING/LATE AFTERNOON SUN NOT ONLY COMES AT ONE SIDE INSTEAD OF TWO
* TAKE OVERHEATING INTO ACCOUNT
CONCEPT 2.2: PRO's
* ENTRANCE SUITS BETTER TO CURRENT BUILDING
* THE DOME LIKE STRUCTURE ROOF OPENINGS CAN PROBABLY BETTER REDIRECT LIGHTING MORE UNIFORMLY
* LESS OVERHEATING ISSUES
TOP UP
CONS * AESTHETICALLY LESS PLEASING, DOESN'T LOOK LIKE A WHOLE

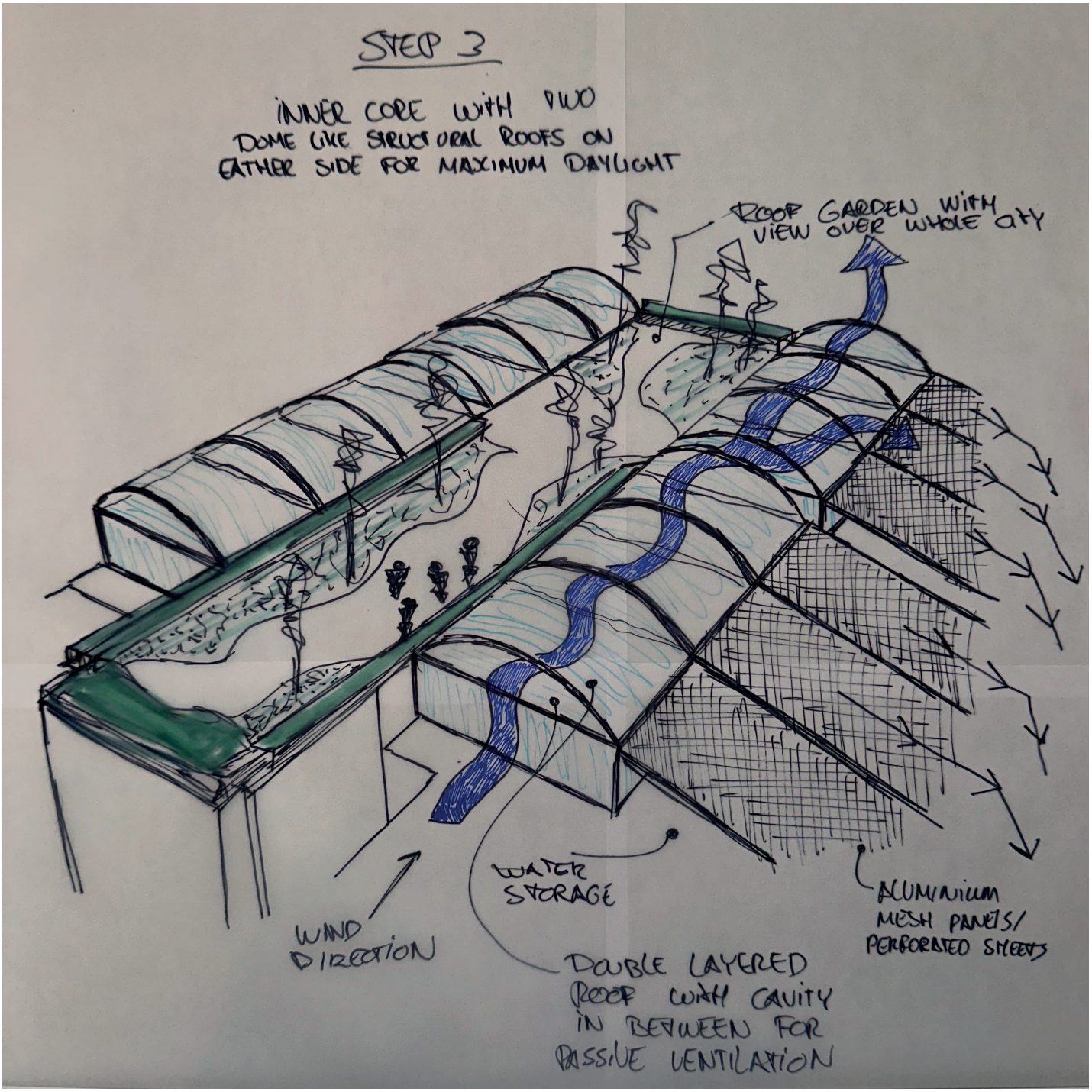

COMBINATION OF CONCEPT 2.1 & 2.2
A CLEAR DISTINCTION BETWEEN THE PUBLIC & PRIVATE ZONES, WHICH WAS HIGHLY VALUED
PUBLIC
PRIVATE (MEMBERS KB + EMPLOYEES)
GREEN ROOF HELPS TO REDUCE HEAT STRESS IN SUMMER & CREATES A PLACE TO RELAX
LIGHT SHELF TO BRING IN MORE NATURAL LIGHT DEEPER IN THE ROOM
CORRIDORS TO REDUCE HEATING STRESS
LARGE PARTS OF THE HIGHLY VALUED HERITAGE FACADE WILL BE PRESERVED
WINTER MORNING SUN
SUMMER EVENING SUN
REMOVE PART OF EXISTING STRUCTURE (INSTALLATION ROOM)
THE WIND-DIRECTION IN THE HAGUE USUALLY COMES FROM THE WEST IN SUMMER, WHICH IS IDEAL FOR PASSIVE VENTILATION
NE
SW
USE LARGE PARTS OF THE CURRENT BASEMENT LEVELS IN AN EFFICIENT WAY
NEW BUILT FLOOR LEVELS A LOT OF ELEMENTS CAN BE USED FROM THE DEMOLISHED PARTS OF THE BUILDING, IN A CIRCULAR WAY, TO BUILD THESE NEW PARTS
BOTH ATRIUMS ARE POSITIONED IN SUCH WAY, THAT THEY CORRESPOND PRETTY GOOD WITH THE CURRENT VOIDS IN THE FLOORS OF THE BUILDING (THE ONES REMOVED, ARE HIGHLIGHTED IN RED)
* VISITORS & USERS HAVE THE OPPORTUNITY TO COMPLETELY DETERMINE THEMSELVES IN WHAT KIND OF CONDITIONS THEY WORK (LIGHT/VIEW) BRIGHT/DARK/EXCLUSIVE/INCLUSIVE THIS CAN ALSO BE DEPENDING ON THE SEASONS AND DIFFERENT TIMES OF THE DAY

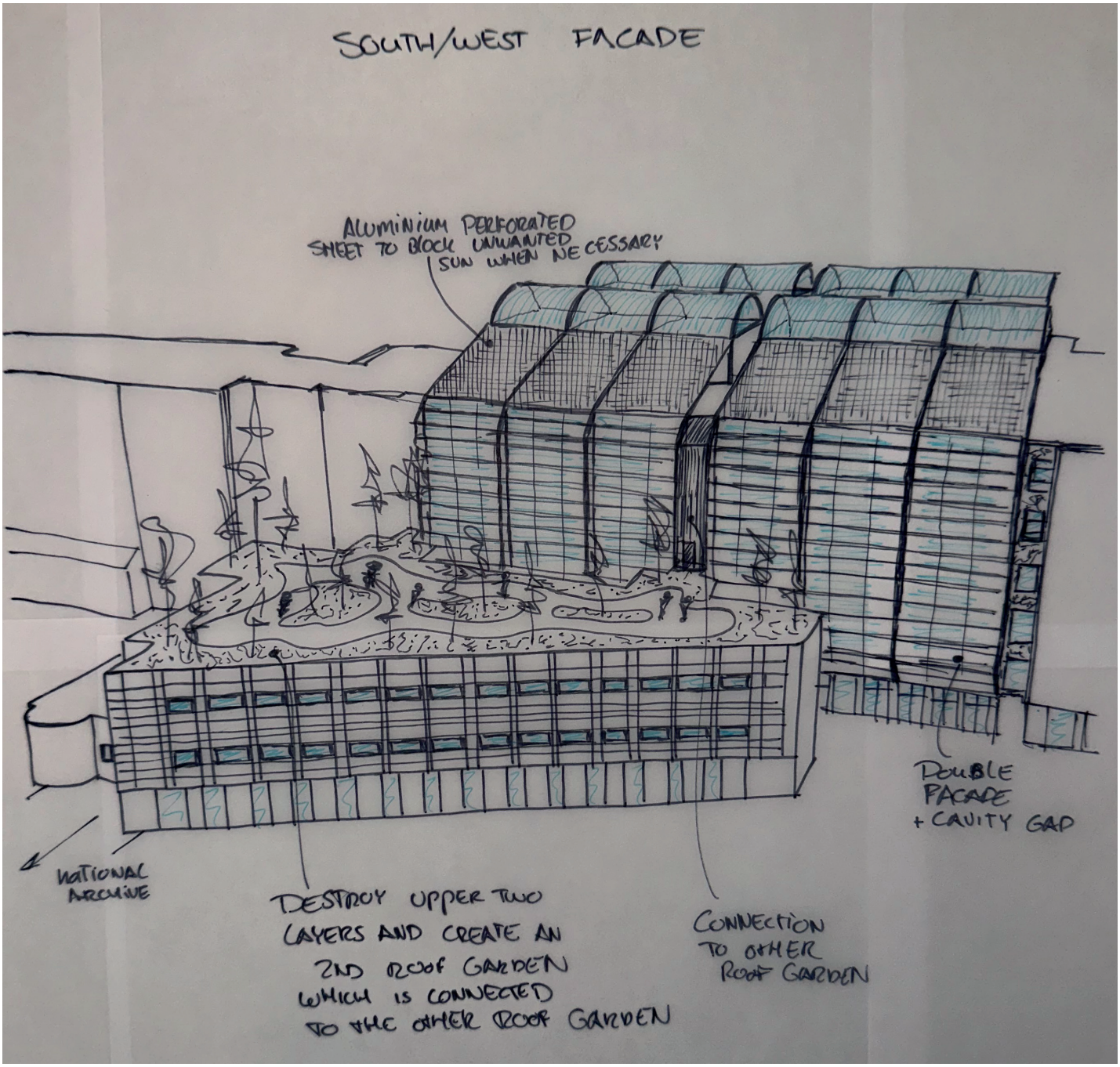

BLOCK UNWANTED HARSH SUMMER SUN WITH GREEN ROOFS
PASSIVE COOLING
NATURAL LIGHT FROM TWO SIDES (TOP + SIDE LIGHTING)
VIEW IS BEING OBSTRUCTED BY ITS SURROUNDINGS
GREEN SQUARE CREATE 'HIGH QUALITY VIEW'

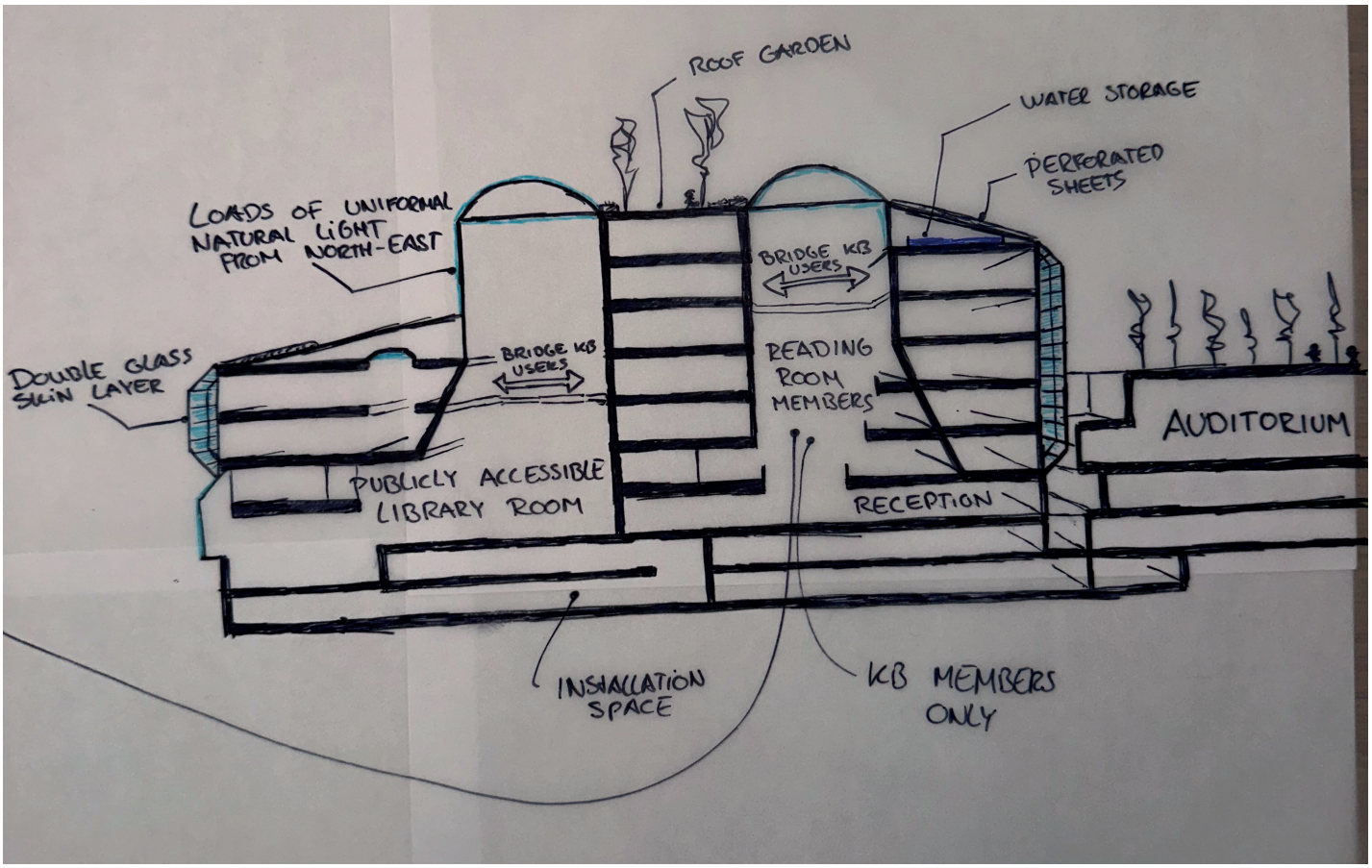

CONCEPT : REFLECTIVE CORE
(THE LIGHT CORRIDORS OF COGNITION)
STEPPED ROOF STRUCTURE
RESPECT HERITAGE VALUES MORE
CAVITY GAP FOR PASSIVE VENTILATION
WIND
ROOF GARDEN
ROOF CEILING
FLOOR CEILING
Floor CEILING
CAFÉ
DOUBLE FACADE CAVITY GAP FOR PASSIVE VENTILATION
TOP UP 1 STOREY
Aluminium PERFORATED SHEET TO BLOCK UNWANTED SUN WHEN NECESSARY

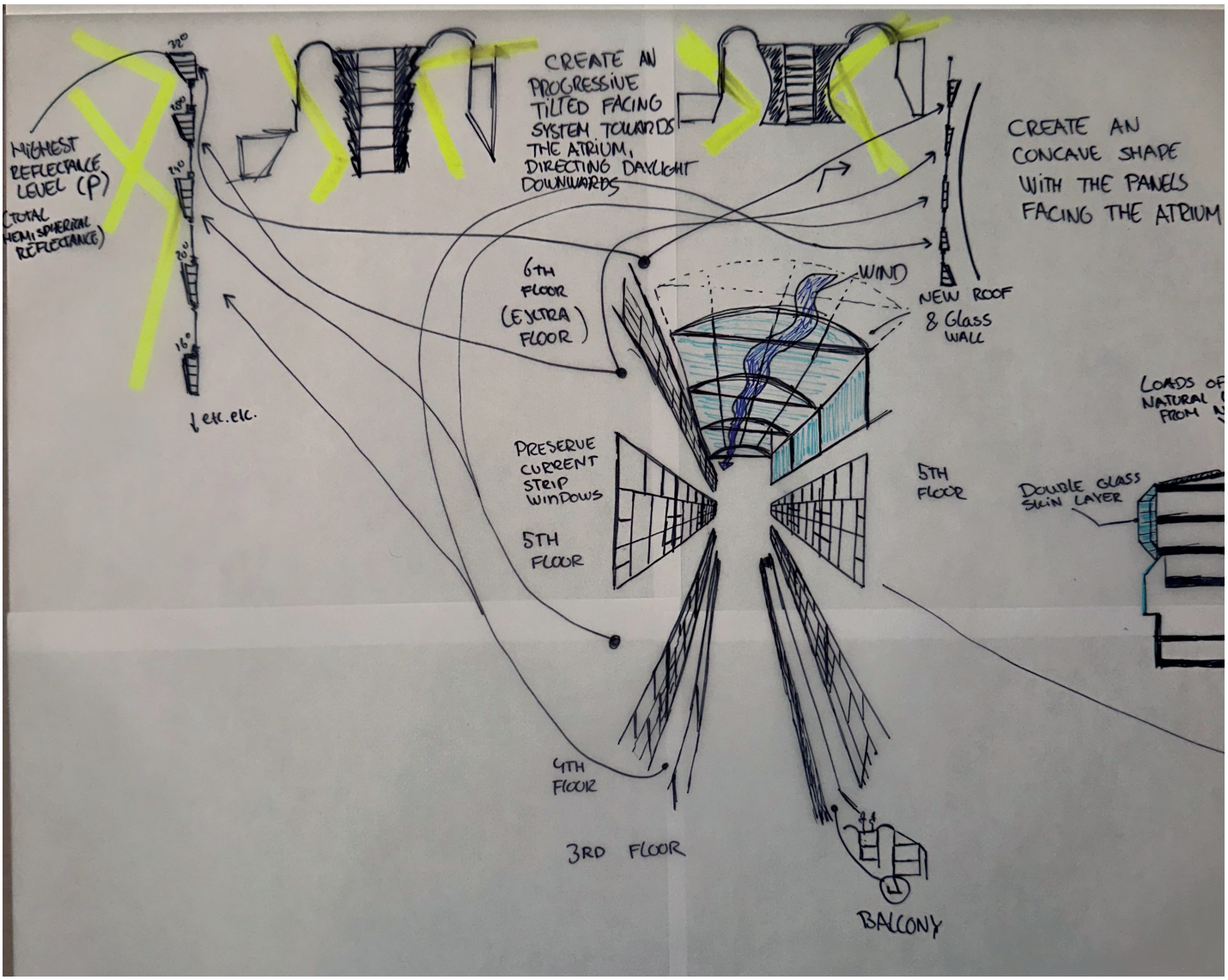

STEP 1
OPENING UP THE NORTH EAST FACADE
PRESERVE HERITAGE VALUES
CURRENT
NEW (± 200% MORE DAYLIGHT)
ROOF CEILING
FLOOR CEILING
FLOOR CEILING
SMALL GREEN FACADE IN BETWEEN

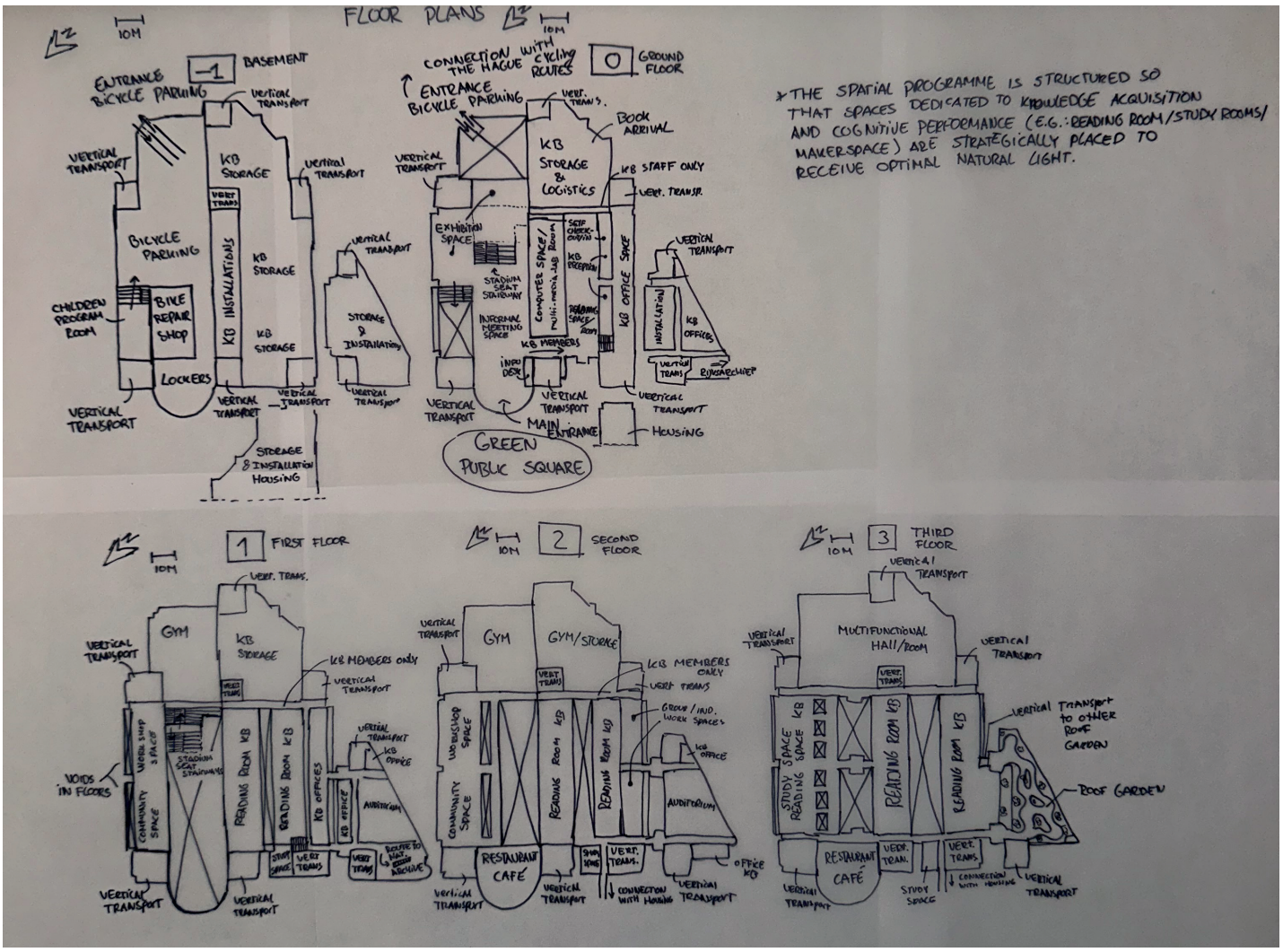

STEP 2
CREATE A DOUBLE SKIN FACADE WHILE PRESERVING THE HERITAGE VALUES
WATER STORAGE
ALUMINIUM PERFORATED SHEETS TO BLOCK UNWANTED SUN/NATURAL LIGHT WHEN NECESSARY
DOUBLE SKIN LAYER (GLASS) WITH BIG CAVITY IN BETWEEN
PRESERVE PARTS OF THE CURRENT FACADE AS WELL

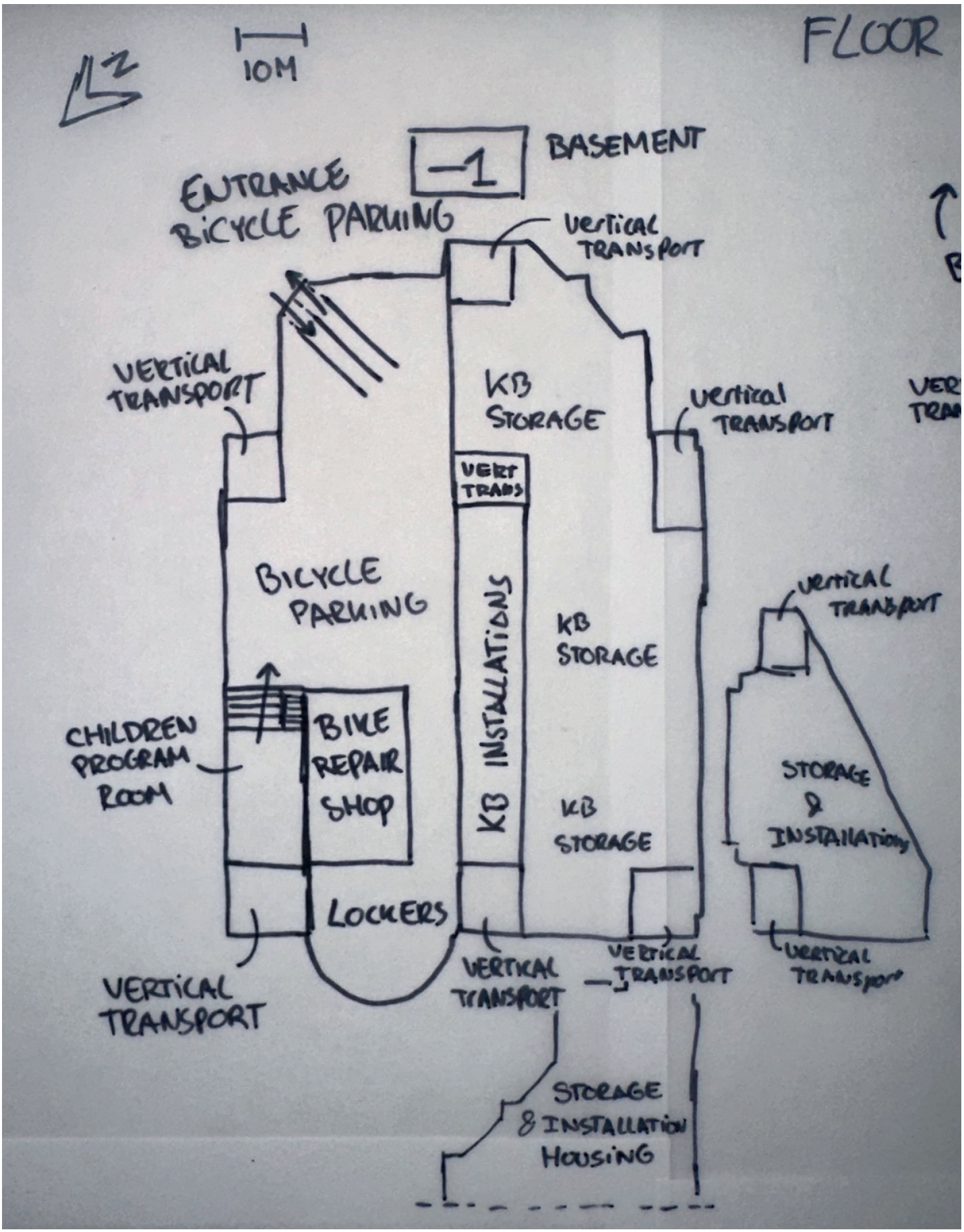

STEP 3
INNER CORE WITH TWO DOME LIKE STRUCTURAL ROOFS ON EATHER SIDE FOR MAXIMUM DAYLIGHT
ROOF GARDEN WITH VIEW OVER WHOLE CITY
WATER STORAGE
ALUMINIUM MESH PANELS/ PERFORATED SHEETS
WIND DIRECTION
DOUBLE LAYERED ROOF WITH CAVITY IN BETWEEN FOR PASSIVE VENTILATION

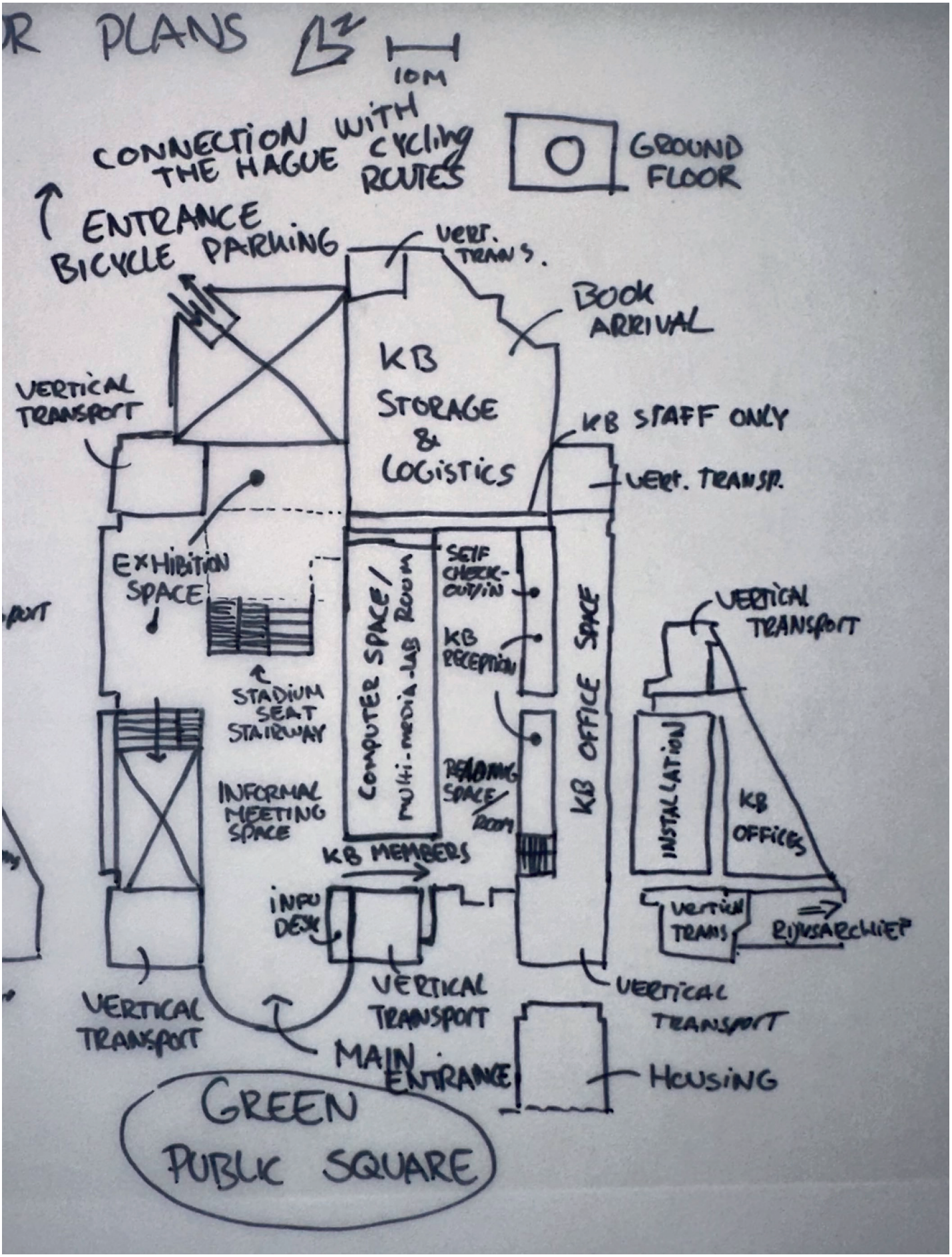

SOUTH/WEST FACADE
ALUMINIUM PERFORATED SHEET TO BLOCK UNWANTED SUN WHEN NECESSARY
DOUBLE FACADE + CAVITY GAP
NATIONAL ARCHIVE
DESTROY UPPER TWO LAYERS AND CREATE AN 2ND ROOF GARDEN WHICH IS CONNECTED TO THE OTHER ROOF GARDEN
CONNECTION TO OTHER ROOF GARDEN

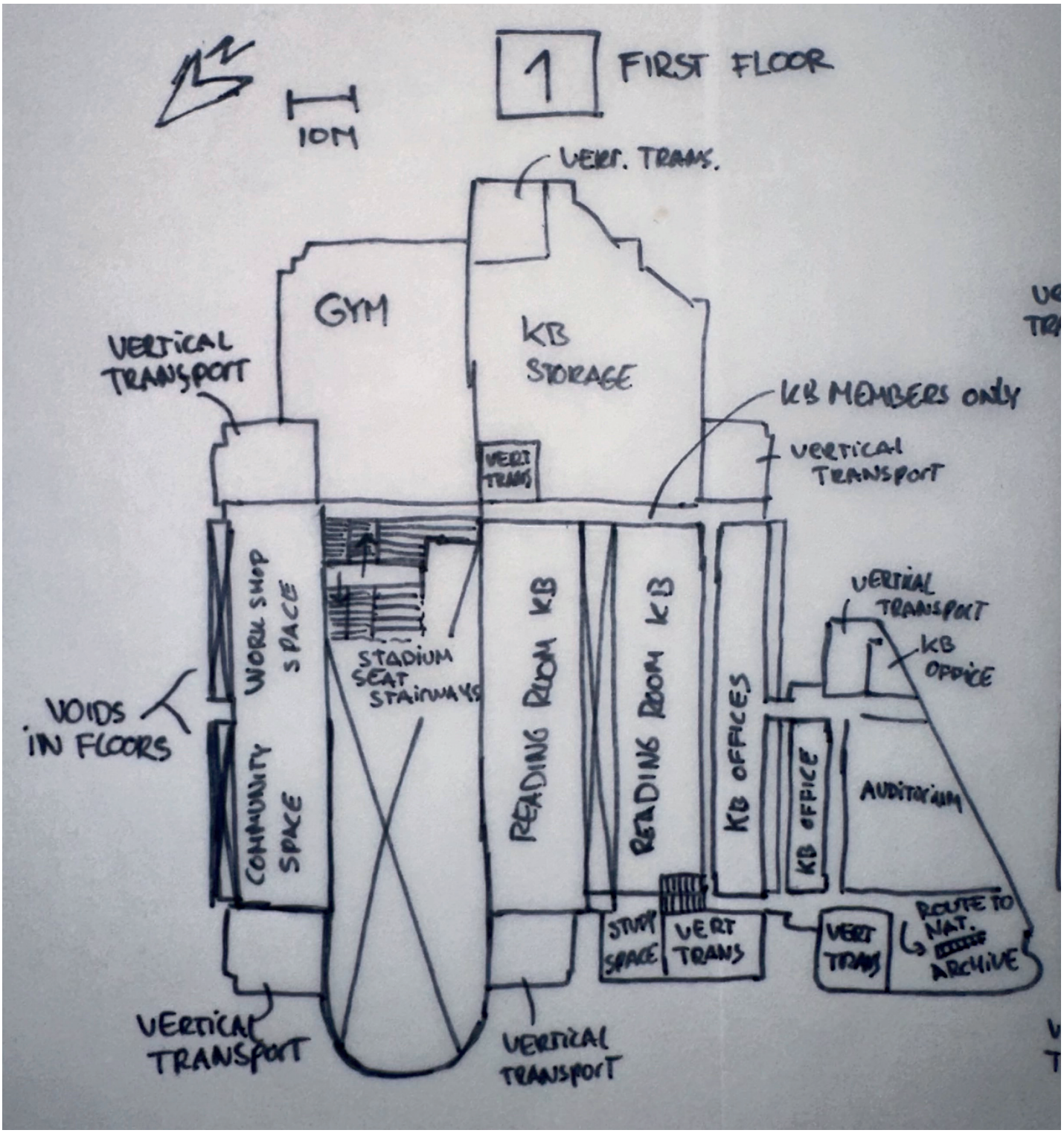

ROOF GARDEN
WATER STORAGE
PERFORATED SHEETS
LOADS OF UNIFORMAL NATURAL LIGHT FROM NORTH-EAST
BRIDGE KB USERS
DOUBLE GLASS SKIN LAYER
BRIDGE KB USERS
READING ROOM MEMBERS
AUDITORIUM
PUBLICLY ACCESSIBLE LIBRARY ROOM
RECEPTION
INSTALLATION SPACE
KB MEMBERS ONLY

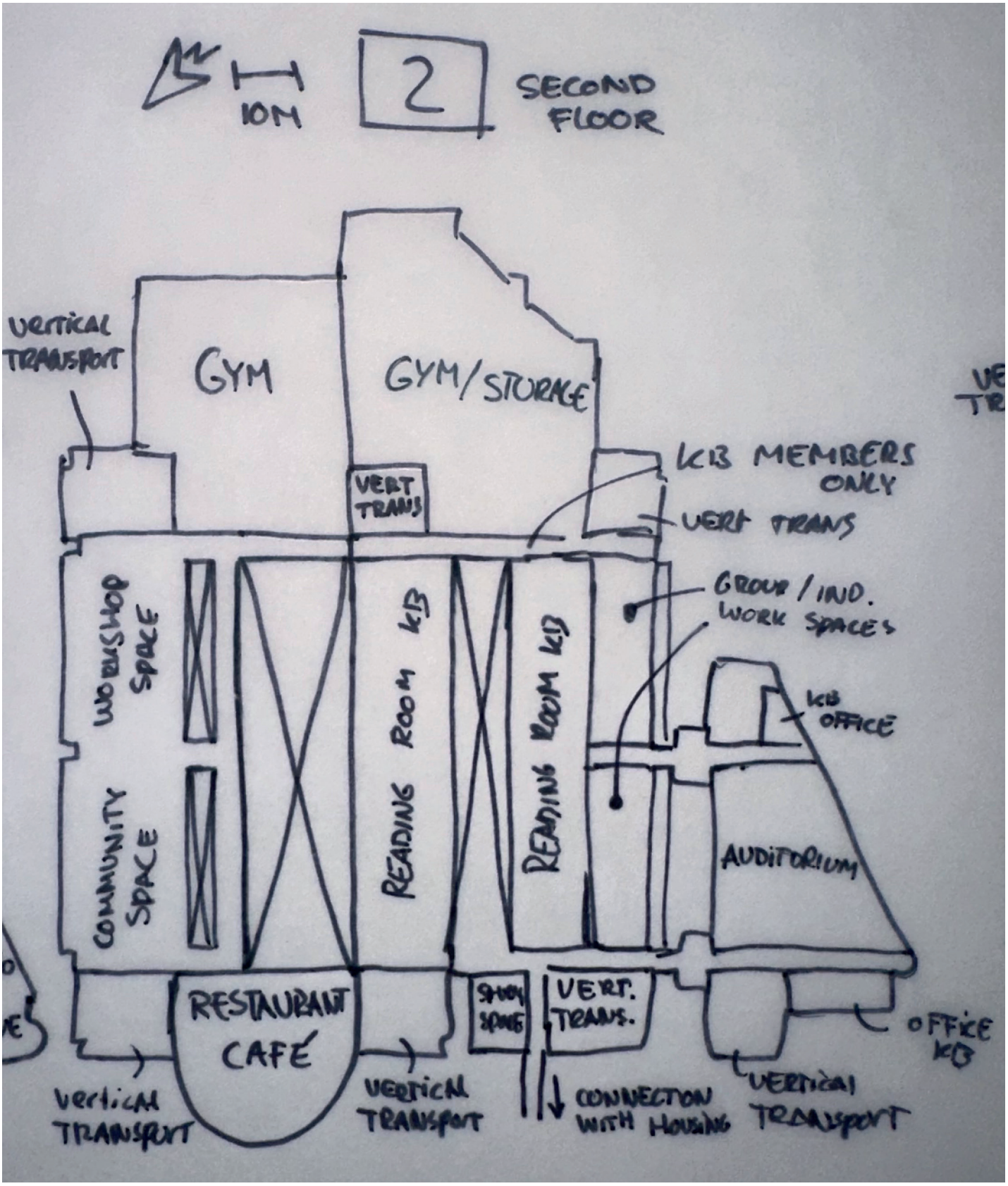

HIGHEST REFLECTANCE LEVEL (ρ)
(TOTAL HEMISPHERICAL REFLECTANCE)
22°
18°
14°
20°
16°
etc. etc.
CREATE AN PROGRESSIVE TILTED FACING SYSTEM TOWARDS THE ATRIUM, DIRECTING DAYLIGHT DOWNWARDS
CREATE AN CONCAVE SHAPE WITH THE PANELS FACING THE ATRIUM
6TH FLOOR (EXTRA FLOOR)
WIND
NEW ROOF & Glass WALL
LOADS OF NATURAL
FROM
PRESERVE CURRENT STRIP WINDOWS
5TH FLOOR
5TH FLOOR
DOUBLE GLASS SKIN LAYER
4TH FLOOR
3RD FLOOR
BALCONY

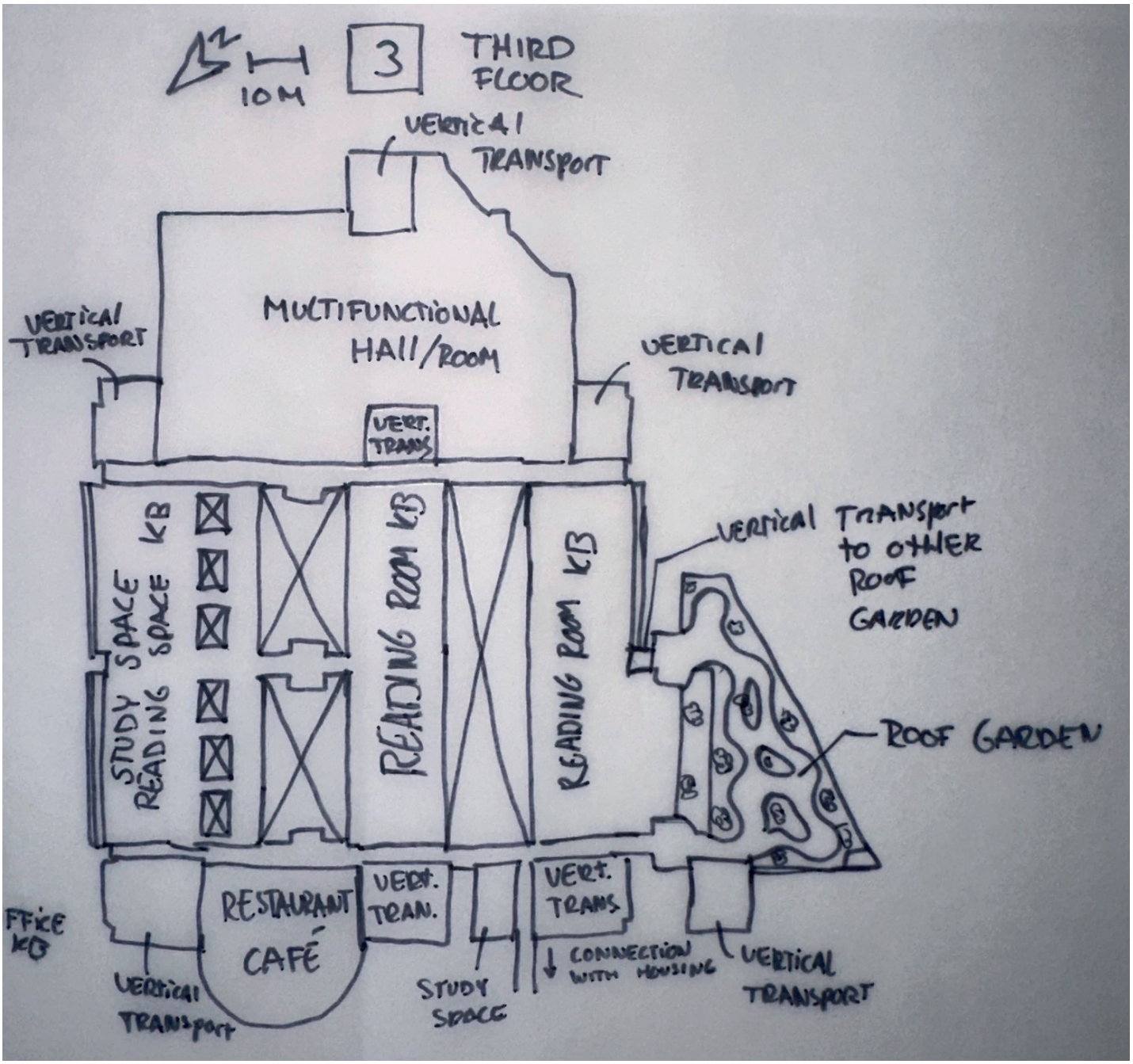

FLOOR PLANS
-1 BASEMENT
ENTRANCE BICYCLE PARKING
VERTICAL TRANSPORT
KB STORAGE
BICYCLE PARKING
KB INSTALLATIONS
BIKE REPAIR SHOP
CHILDREN PROGRAM ROOM
LOCKERS
STORAGE & INSTALLATION HOUSING
CONNECTION WITH THE HAGUE CYCLING ROUTES
0 GROUND FLOOR
ENTRANCE BICYCLE PARKING
BOOK ARRIVAL
KB STORAGE & LOGISTICS
KB STAFF ONLY
EXHIBITION SPACE
COMPUTER SPACE/ MULTI-MEDIA LAB ROOM
KB RECEPTION
KB OFFICE SPACE
INFORMAL MEETING SPACE
KB MEMBERS
MAIN ENTRANCE
HOUSING
GREEN PUBLIC SQUARE
*THE SPATIAL PROGRAMME IS STRUCTURED SO THAT SPACES DEDICATED TO KNOWLEDGE ACQUISITION AND COGNITIVE PERFORMANCE (E.G.: READING ROOM/STUDY ROOMS/ MAKERSPACE) ARE STRATEGICALLY PLACED TO RECEIVE OPTIMAL NATURAL LIGHT.
1 FIRST FLOOR
GYM
KB STORAGE
KB MEMBERS ONLY
READING ROOM KB
KB OFFICES
AUDITORIUM
COMMUNITY SPACE
VOIDS IN FLOORS
2 SECOND FLOOR
GYM
GYM/STORAGE
WORKSHOP SPACE
READING ROOM KB
GROUP / IND. WORK SPACES
KB OFFICE
AUDITORIUM
RESTAURANT CAFÉ
OFFICE KB
3 THIRD FLOOR
MULTIFUNCTIONAL HALL/ROOM
STUDY SPACE
READING ROOM KB
Vertical Transport to other Roof Garden
ROOF GARDEN
RESTAURANT CAFÉ
STUDY SPACE

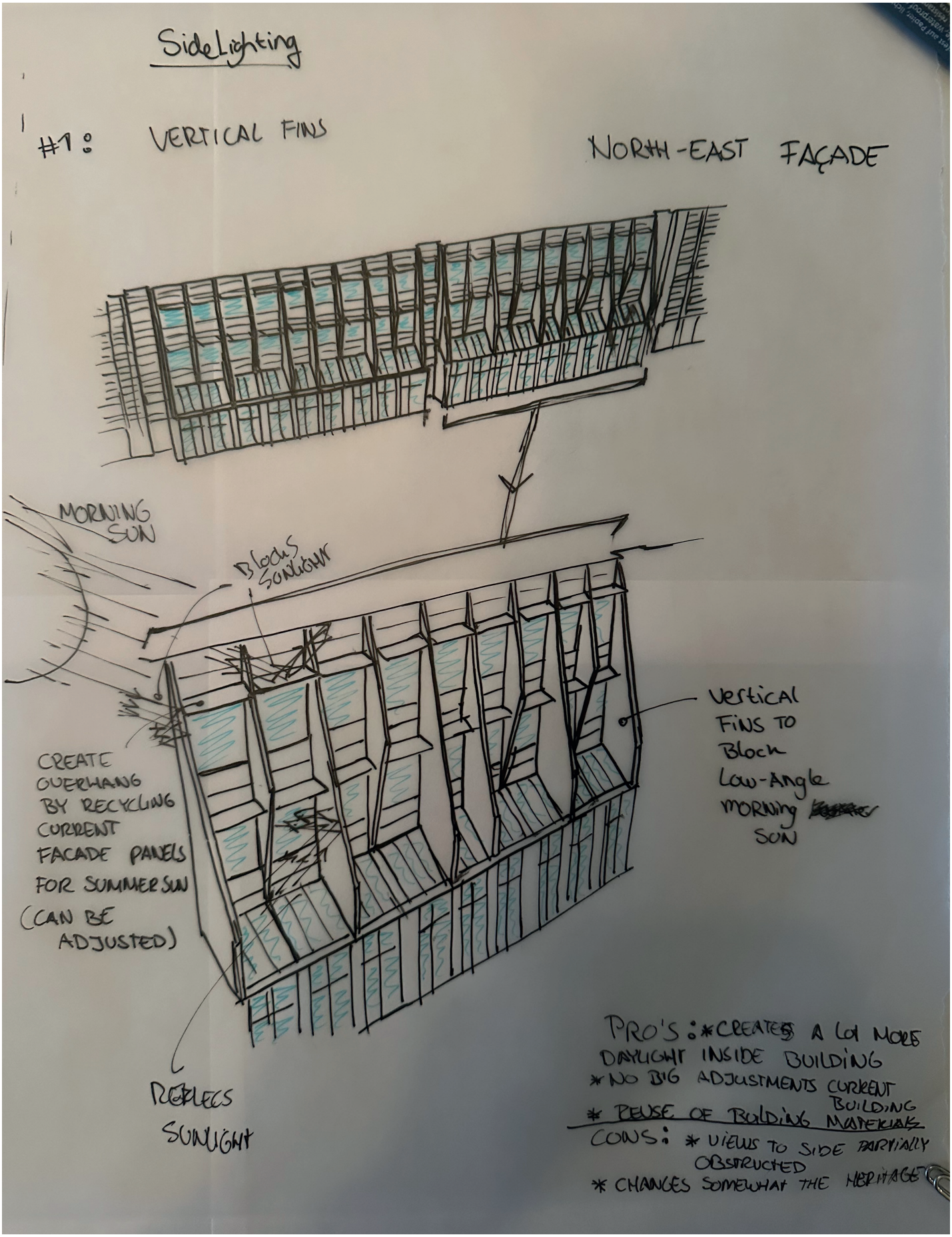

FLOOR
10M
-1
BASEMENT
ENTRANCE
BICYCLE PARKING
VERTICAL TRANSPORT
VERTICAL TRANSPORT
KB STORAGE
VERTICAL TRANSPORT
VERT TRANS
BICYCLE PARKING
KB INSTALLATIONS
KB STORAGE
VERTICAL TRANSPORT
CHILDREN PROGRAM ROOM
BIKE REPAIR SHOP
KB STORAGE
STORAGE & INSTALLATION
LOCKERS
VERTICAL TRANSPORT
VERTICAL TRANSPORT
VERTICAL TRANSPORT
VERTICAL TRANSPORT
STORAGE & INSTALLATION HOUSING

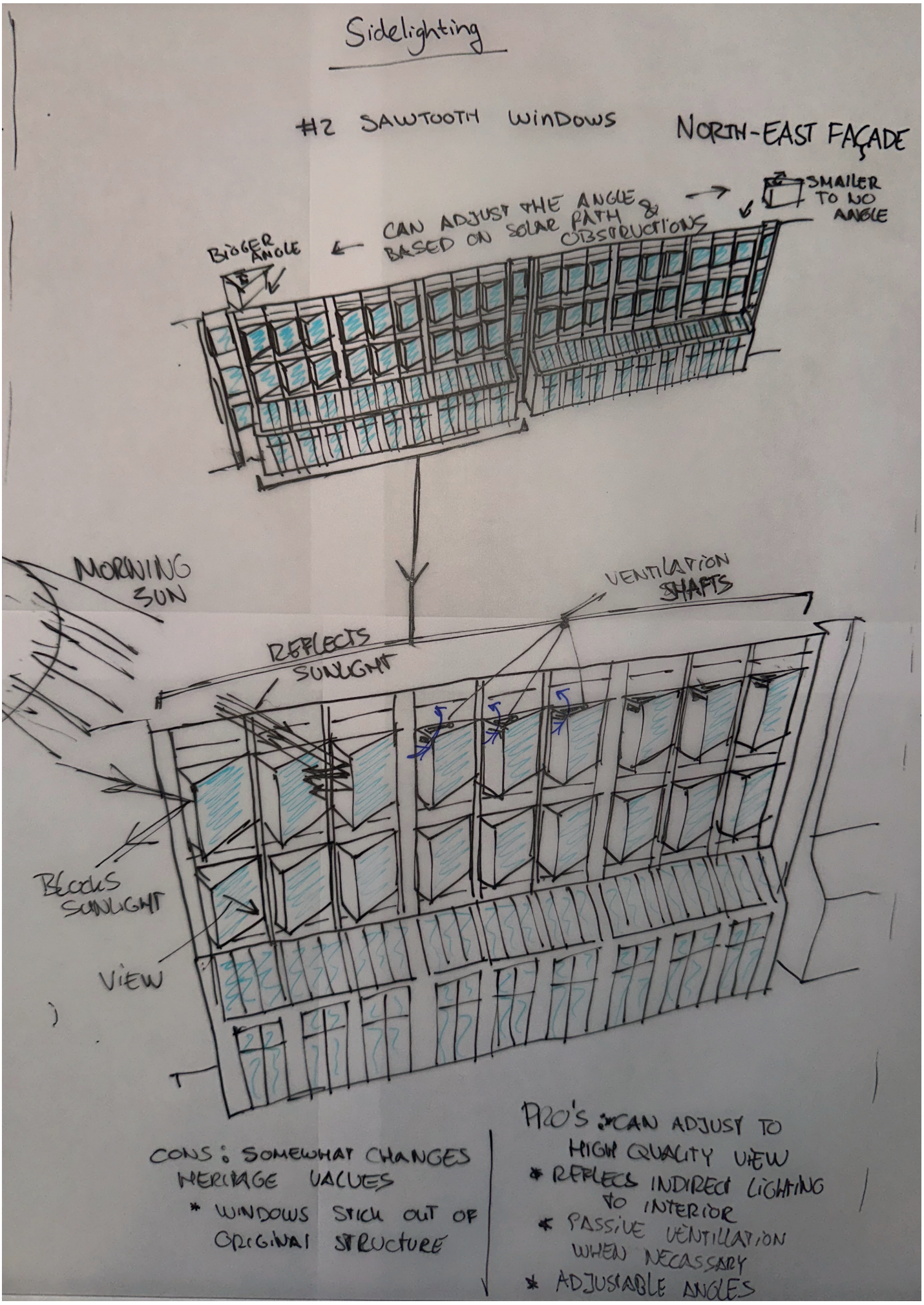

R PLANS
10M
CONNECTION WITH CYCLING ROUTES THE HAGUE
GROUND FLOOR
ENTRANCE BICYCLE PARKING
VERT. TRANS.
BOOK ARRIVAL
KB STORAGE & LOGISTICS
VERTICAL TRANSPORT
KB STAFF ONLY
VERT. TRANSP.
EXHIBITION SPACE
SELF CHECK-OUT/IN
COMPUTER SPACE/ MULTI-MEDIA-LAB ROOM
KB RECEPTION
KB OFFICE SPACE
VERTICAL TRANSPORT
STADIUM SEAT STAIRWAY
INFORMAL MEETING SPACE
READING SPACE/ ROOM
INSTALLATION
KB OFFICES
KB MEMBERS
INFO DESK
VERTICAL TRANSPORT
RIJKSARCHIEF
VERTICAL TRANSPORT
VERTICAL TRANSPORT
MAIN ENTRANCE
HOUSING
GREEN PUBLIC SQUARE

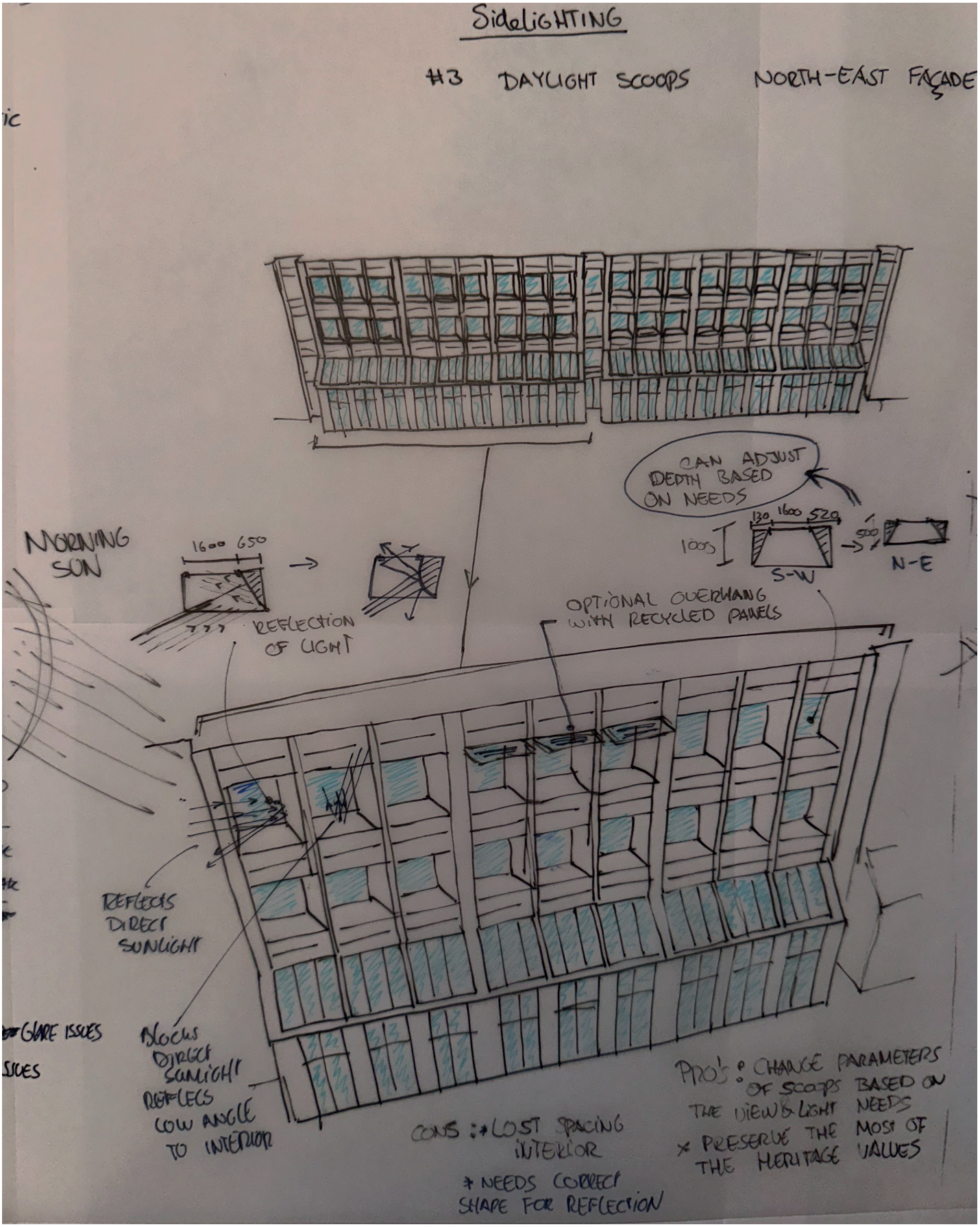

1
FIRST FLOOR
10M
VERT. TRANS.
GYM
KB STORAGE
VERTICAL TRANSPORT
KB MEMBERS ONLY
VERT TRANS
VERTICAL TRANSPORT
WORK SHOP SPACE
COMMUNITY SPACE
STADIUM SEAT STAIRWAYS
READING ROOM KB
READING ROOM KB
KB OFFICES
VERTICAL TRANSPORT
KB OFFICE
KB OFFICE
AUDITORIUM
VOIDS IN FLOORS
STUFF SPACE
VERT TRANS
VERT TRANS
ROUTE TO NAT. ARCHIVE
VERTICAL TRANSPORT
VERTICAL TRANSPORT

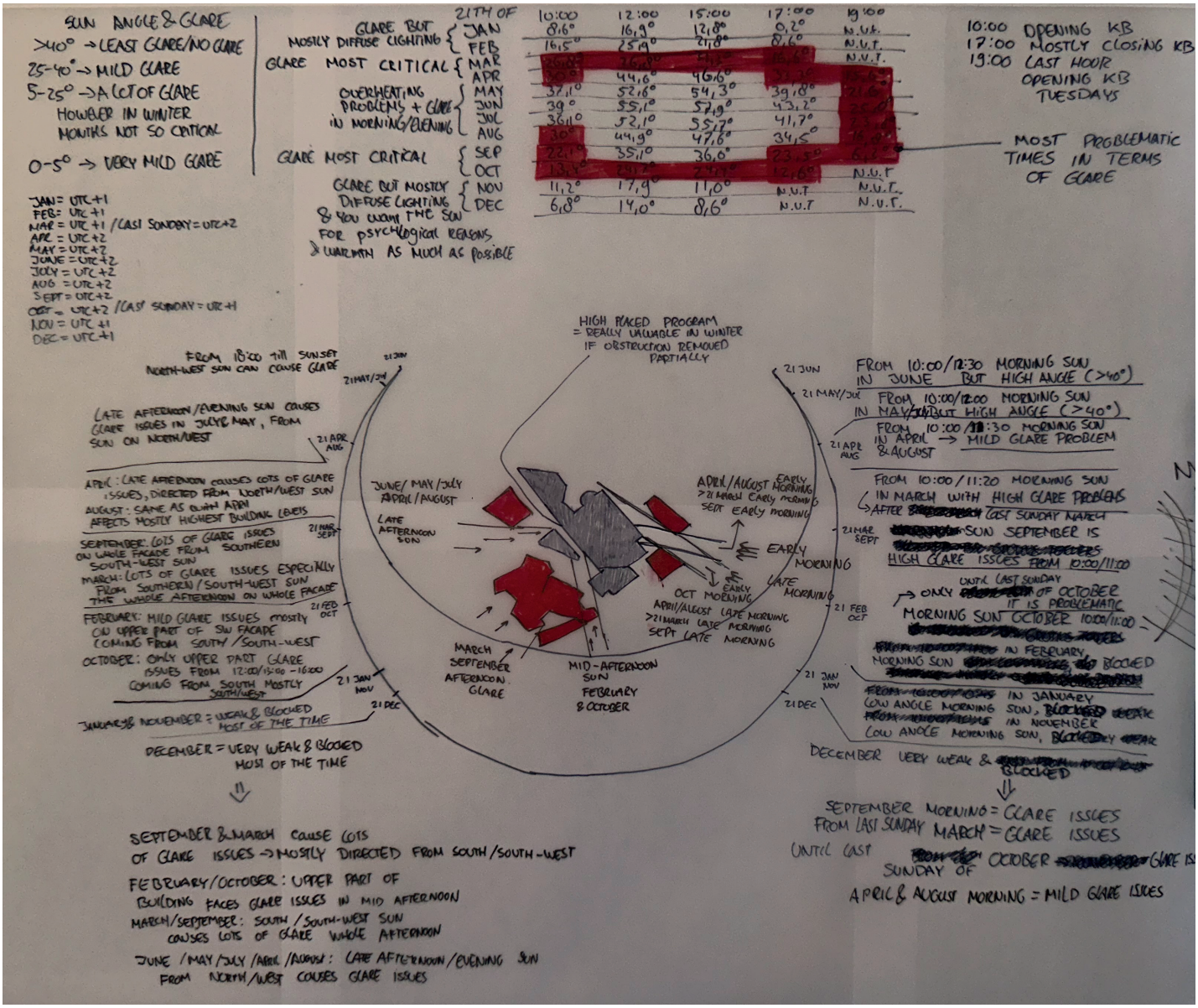

10M
2
SECOND FLOOR
VERTICAL TRANSPORT
GYM
GYM/STORAGE
VERT TRANS
KCB MEMBERS ONLY
VERT TRANS
GROUP / IND. WORK SPACES
KCB OFFICE
WORKSHOP SPACE
COMMUNITY SPACE
READING ROOM KCB
READING ROOM KCB
AUDITORIUM
RESTAURANT CAFÉ
VERT. TRANS.
OFFICE KCB
VERTICAL TRANSPORT
VERTICAL TRANSPORT
CONNECTION WITH HOUSING
VERTICAL TRANSPORT

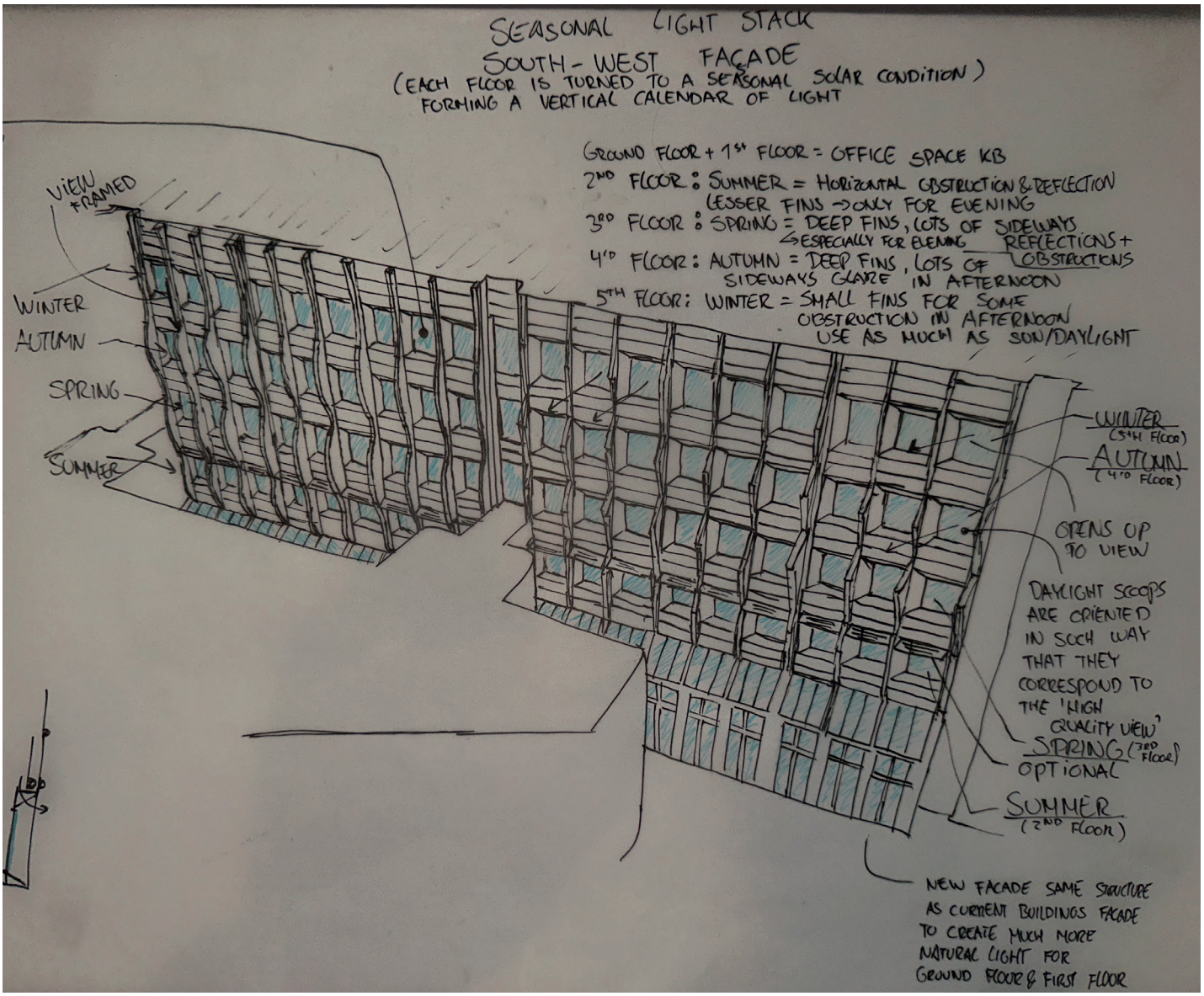

10M
3
THIRD FLOOR
VERTICAL TRANSPORT
MULTIFUNCTIONAL HALL/ROOM
VERTICAL TRANSPORT
VERTICAL TRANSPORT
VERT. TRANS
STUDY SPACE READING SPACE KB
READING ROOM KB
READING ROOM KB
VERTICAL TRANSPORT to OTHER ROOF GARDEN
ROOF GARDEN
FFICE KB
RESTAURANT CAFÉ
VERT. TRAN.
VERT. TRANS
CONNECTION WITH HOUSING
VERTICAL TRANSPORT
VERTICAL TRANSPORT
STUDY SPACE

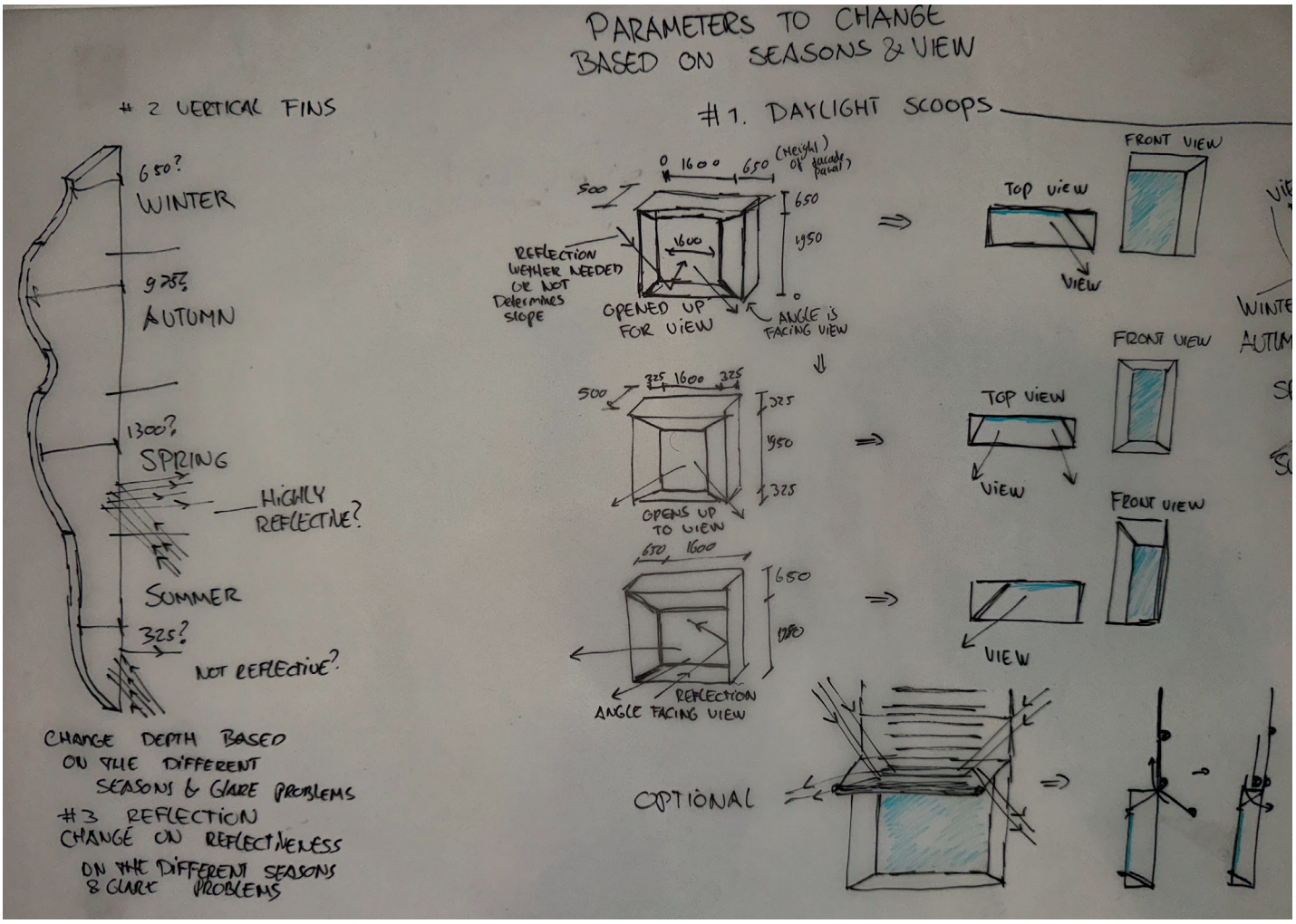

SideLighting
#1: VERTICAL FINS
NORTH-EAST FAÇADE
MORNING SUN
Blocks Sunlight
Vertical Fins to Block Low-Angle morning sun
CREATE OVERHANG BY RECYCLING CURRENT FACADE PANELS FOR SUMMER SUN (CAN BE ADJUSTED)
REFLECTS SUNLIGHT
PRO'S: * CREATES A LOT MORE DAYLIGHT INSIDE BUILDING
* NO BIG ADJUSTMENTS CURRENT BUILDING
* REUSE OF BUILDING MATERIALS
CONS: * VIEWS TO SIDE PARTIALLY OBSTRUCTED
* CHANGES SOMEWHAT THE HERITAGE

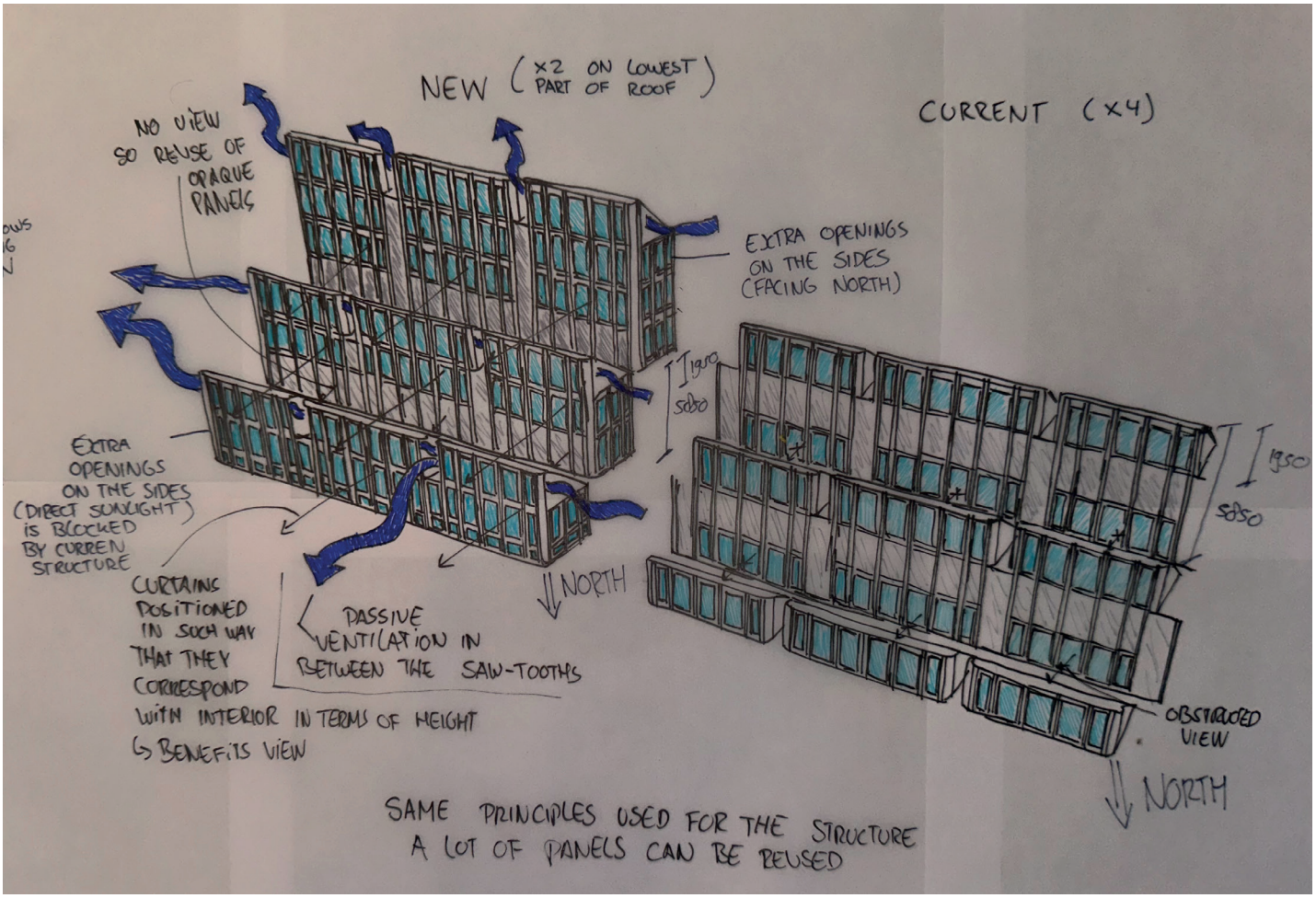

Sidelighting
#2 SAWTOOTH WINDOWS
NORTH-EAST FAÇADE
SMALLER TO NO ANGLE
CAN ADJUST THE ANGLE BASED ON SOLAR PATH & OBSTRUCTIONS
BIGGER ANGLE
MORNING SUN
VENTILATION SHAFTS
REFLECTS SUNLIGHT
BLOCKS SUNLIGHT
VIEW
CONS: SOMEWHAT CHANGES HERITAGE VALUES
* WINDOWS STICK OUT OF ORIGINAL STRUCTURE
PRO'S: CAN ADJUST TO HIGH QUALITY VIEW
* REFLECS INDIRECT LIGHTING TO INTERIOR
* PASSIVE VENTILATION WHEN NECASSARY
* ADJUSTABLE ANGLES

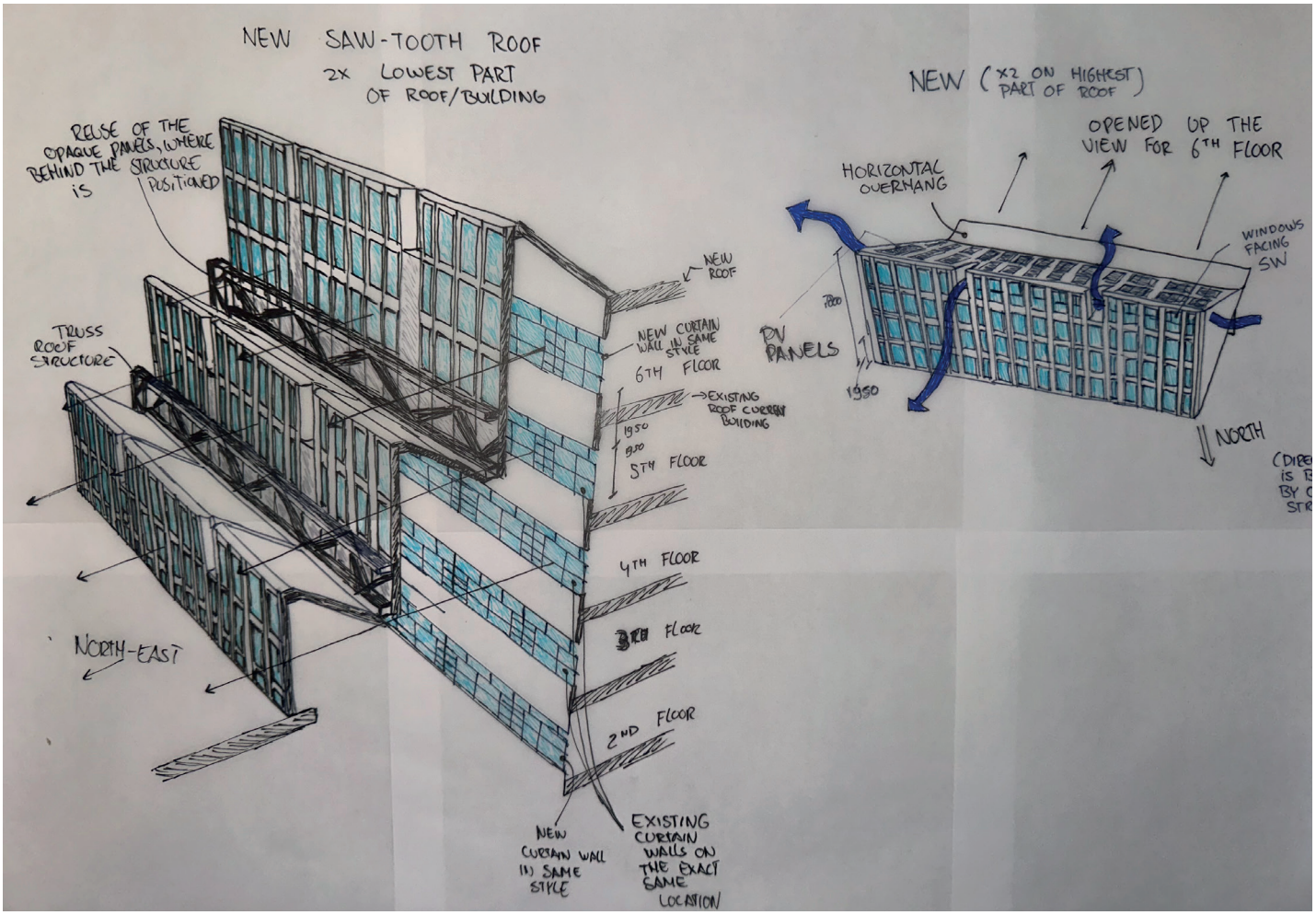

SIDELIGHTING
#3 DAYLIGHT SCOOPS
NORTH-EAST FAÇADE
CAN ADJUST DEPTH BASED ON NEEDS
MORNING SUN
1600 650
REFLECTION OF LIGHT
1600 520
1005
S-W
N-E
OPTIONAL OVERHANG WITH RECYCLED PANELS
REFLECTS DIRECT SUNLIGHT
GLARE ISSUES
ISSUES
BLOCKS DIRECT SUNLIGHT REFLECTS LOW ANGLE TO INTERIOR
CONS: LOST SPACING INTERIOR
* NEEDS CORRECT SHAPE FOR REFLECTION
PRO'S: CHANGE PARAMETERS OF SCOOPS BASED ON THE VIEW & LIGHT NEEDS
* PRESERVE THE MOST OF THE HERITAGE VALUES

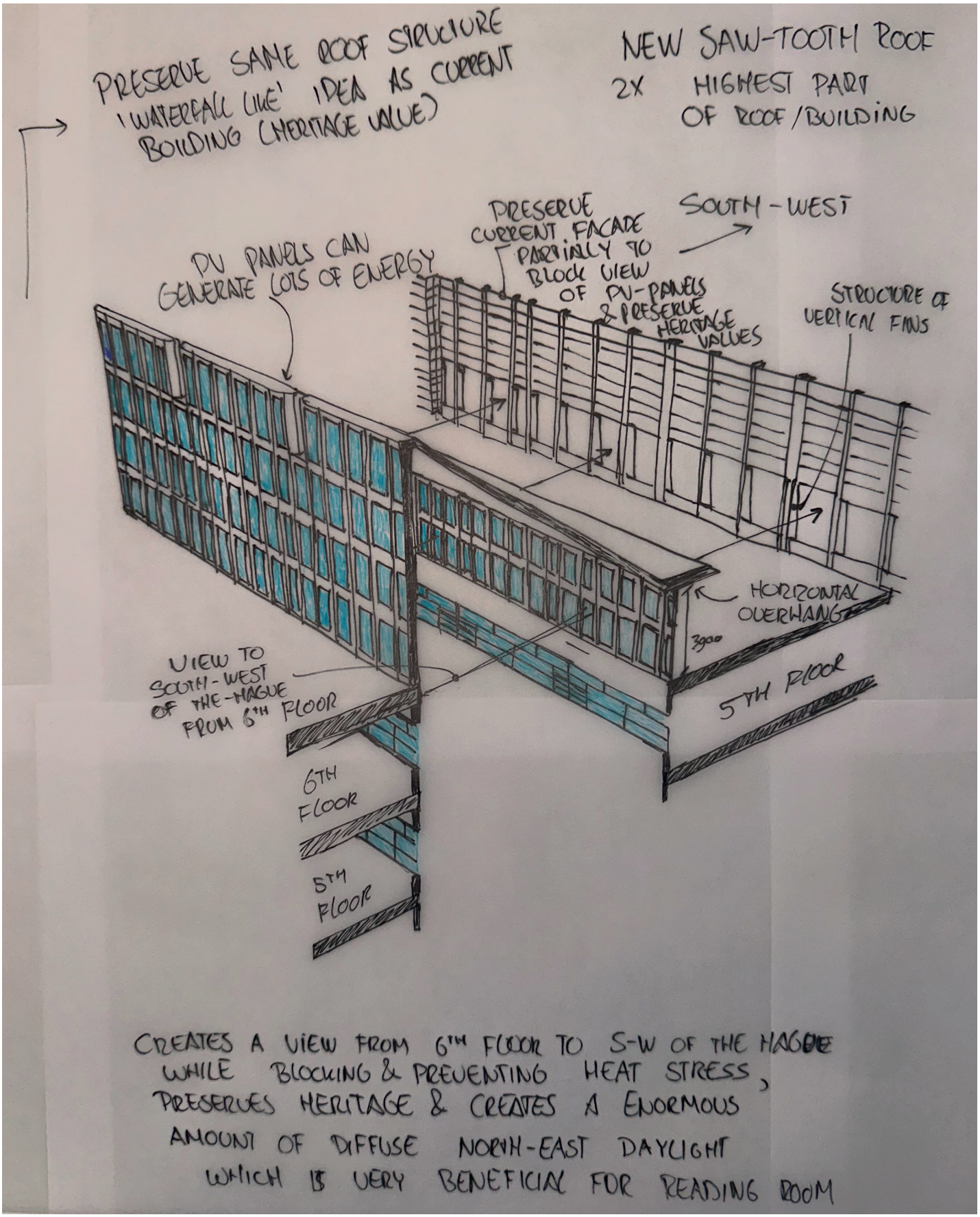

SUN ANGLE & GLARE
>40° → LEAST GLARE/NO GLARE
25-40° → MILD GLARE
5-25° → A LOT OF GLARE
HOWEVER IN WINTER MONTHS NOT SO CRITICAL
0-5° → VERY MILD GLARE
GLARE BUT MOSTLY DIFFUSE LIGHTING
GLARE MOST CRITICAL
OVERHEATING PROBLEMS + GLARE IN MORNING/EVENING
GLARE MOST CRITICAL
GLARE BUT MOSTLY DIFFUSE LIGHTING
& YOU WANT THE SUN FOR PSYCHOLOGICAL REASONS & WARMTH AS MUCH AS POSSIBLE
21TH OF JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
10:00 12:00 15:00 17:00 19:00
10:00 OPENING KB
17:00 MOSTLY CLOSING KB
19:00 LAST HOUR OPENING KB TUESDAYS
MOST PROBLEMATIC TIMES IN TERMS OF GLARE
JAN= UTC+1
FEB= UTC+1
MAR = UTC+1 /LAST SUNDAY = UTC+2
APR = UTC+2
MAY = UTC+2
JUNE = UTC+2
JULY = UTC+2
AUG = UTC+2
SEPT = UTC+2
OCT = UTC+2 /LAST SUNDAY = UTC+1
NOV = UTC+1
DEC = UTC+1
HIGH PLACED PROGRAM = REALLY UNLIKELY IN WINTER IF OBSTRUCTION REMOVED PARTIALLY
FROM 18:00 TILL SUNSET NORTH-WEST SUN CAN CAUSE GLARE
LATE AFTERNOON/EVENING SUN CAUSES GLARE ISSUES IN JUNE, MAY, FROM SUN ON NORTH/WEST
APRIL: LATE AFTERNOON CAUSES LOTS OF GLARE ISSUES, DIRECTED FROM NORTH/WEST SUN
AUGUST: SAME AS WITH APRIL AFFECTS MOSTLY HIGHEST BUILDING LEVELS
SEPTEMBER: LOTS OF GLARE ISSUES ON WHOLE FACADE FROM SOUTHERN SOUTH-WEST SUN
MARCH: LOTS OF GLARE ISSUES ESPECIALLY FROM SOUTHERN/SOUTH-WEST SUN THE WHOLE AFTERNOON ON WHOLE FACADE
FEBRUARY: MILD GLARE ISSUES MOSTLY ON UPPER PART OF SW FACADE COMING FROM SOUTH/SOUTH-WEST
OCTOBER: ONLY UPPER PART GLARE ISSUES FROM 12:00/13:00 -16:00 COMING FROM SOUTH MOSTLY SOUTH/WEST
JANUARY& NOVEMBER = WEAK & BLOCKED MOST OF THE TIME
DECEMBER = VERY WEAK & BLOCKED MOST OF THE TIME
21 JAN NOV
21 FEB OCT
21 MAR SEPT
21 APR AUG
21 MAY/JUL
21 JUN
21 DEC
JUNE/MAY/JULY APRIL/AUGUST LATE AFTERNOON SUN
APRIL/AUGUST EARLY MORNING >21 MARCH EARLY MORNING SEPT EARLY MORNING
EARLY MORNING
LATE MORNING
OCT MORNING
APRIL/AUGUST LATE MORNING >21 MARCH LATE MORNING SEPT LATE MORNING
MARCH SEPTEMBER AFTERNOON GLARE
MID-AFTERNOON SUN FEBRUARY & OCTOBER
SEPTEMBER & MARCH CAUSE LOTS OF GLARE ISSUES → MOSTLY DIRECTED FROM SOUTH/SOUTH-WEST
FEBRUARY/OCTOBER: UPPER PART OF BUILDING FACES GLARE ISSUES IN MID AFTERNOON
MARCH/SEPTEMBER: SOUTH/SOUTH-WEST SUN CAUSES LOTS OF GLARE WHOLE AFTERNOON
JUNE/MAY/JULY/APRIL/AUGUST: LATE AFTERNOON/EVENING SUN FROM NORTH/WEST CAUSES GLARE ISSUES
FROM 10:00/12:30 MORNING SUN IN JUNE BUT HIGH ANGLE (>40°)
FROM 10:00/12:00 MORNING SUN IN MAY/JUNE BUT HIGH ANGLE (>40°)
FROM 10:00/11:30 MORNING SUN IN APRIL → MILD GLARE PROBLEM & AUGUST
FROM 10:00/11:20 MORNING SUN IN MARCH WITH HIGH GLARE PROBLEMS
AFTER [redacted] LAST SUNDAY MARCH
[redacted] SUN SEPTEMBER IS HIGH GLARE ISSUES FROM 10:00/11:00
UNTIL LAST SUNDAY
→ ONLY [redacted] OF OCTOBER IT IS PROBLEMATIC
MORNING SUN OCTOBER 10:00/11:00
[redacted] IN FEBRUARY MORNING SUN [redacted] BLOCKED
IN JANUARY LOW ANGLE MORNING SUN, BLOCKED WEAK
IN NOVEMBER LOW ANGLE MORNING SUN, BLOCKED WEAK
DECEMBER VERY WEAK & BLOCKED
SEPTEMBER MORNING = GLARE ISSUES
FROM LAST SUNDAY MARCH = GLARE ISSUES
UNTIL LAST [redacted] SUNDAY OF OCTOBER [redacted] GLARE ISSUES
APRIL & AUGUST MORNING = MILD GLARE ISSUES


SEASONAL LIGHT STACK
SOUTH-WEST FAÇADE
(EACH FLOOR IS TURNED TO A SEASONAL SOLAR CONDITION)
FORMING A VERTICAL CALENDAR OF LIGHT
GROUND FLOOR + 1ST FLOOR = OFFICE SPACE KB
2ND FLOOR: SUMMER = HORIZONTAL OBSTRUCTION & REFLECTION
LESSER FINS → ONLY FOR EVENING
3RD FLOOR: SPRING = DEEP FINS, LOTS OF SIDEWAYS
↳ESPECIALLY FOR EVENING REFLECTIONS + OBSTRUCTIONS
4TH FLOOR: AUTUMN = DEEP FINS, LOTS OF
SIDEWAYS GLARE IN AFTERNOON
5TH FLOOR: WINTER = SMALL FINS FOR SOME
OBSTRUCTION IN AFTERNOON
USE AS MUCH AS SUN/DAYLIGHT
VIEW FRAMED
WINTER
AUTUMN
SPRING
SUMMER
WINTER (5TH FLOOR)
AUTUMN (4TH FLOOR)
OPENS UP TO VIEW
DAYLIGHT SCOOPS ARE ORIENTED IN SOCH WAY THAT THEY CORRESPOND TO THE 'HIGH QUALITY VIEW'
SPRING (3RD FLOOR)
OPTIONAL
SUMMER (2ND FLOOR)
NEW FACADE SAME STRUCTURE AS CURRENT BUILDINGS FACADE TO CREATE MUCH MORE NATURAL LIGHT FOR GROUND FLOOR & FIRST FLOOR


PARAMETERS TO CHANGE
BASED ON SEASONS & VIEW
#1. DAYLIGHT SCOOPS
2 VERTICAL FINS
650?
WINTER
925?
AUTUMN
1300?
SPRING
HIGHLY REFLECTIVE?
SUMMER
325?
NOT REFLECTIVE?
CHANGE DEPTH BASED ON THE DIFFERENT SEASONS & GLARE PROBLEMS
#3 REFLECTION CHANGE ON REFLECTIVENESS ON THE DIFFERENT SEASONS & GLARE PROBLEMS
0 1600 650 (Height of facade panel)
500
650
1600
1950
REFLECTION WEITHER NEEDED OR NOT Determines slope
OPENED UP FOR VIEW
ANGLE is FACING VIEW
TOP VIEW
FRONT VIEW
VIEW
500
325 1600 325
325
1950
325
OPENS UP TO VIEW
650 1600
650
REFLECTION
ANGLE FACING VIEW
OPTIONAL

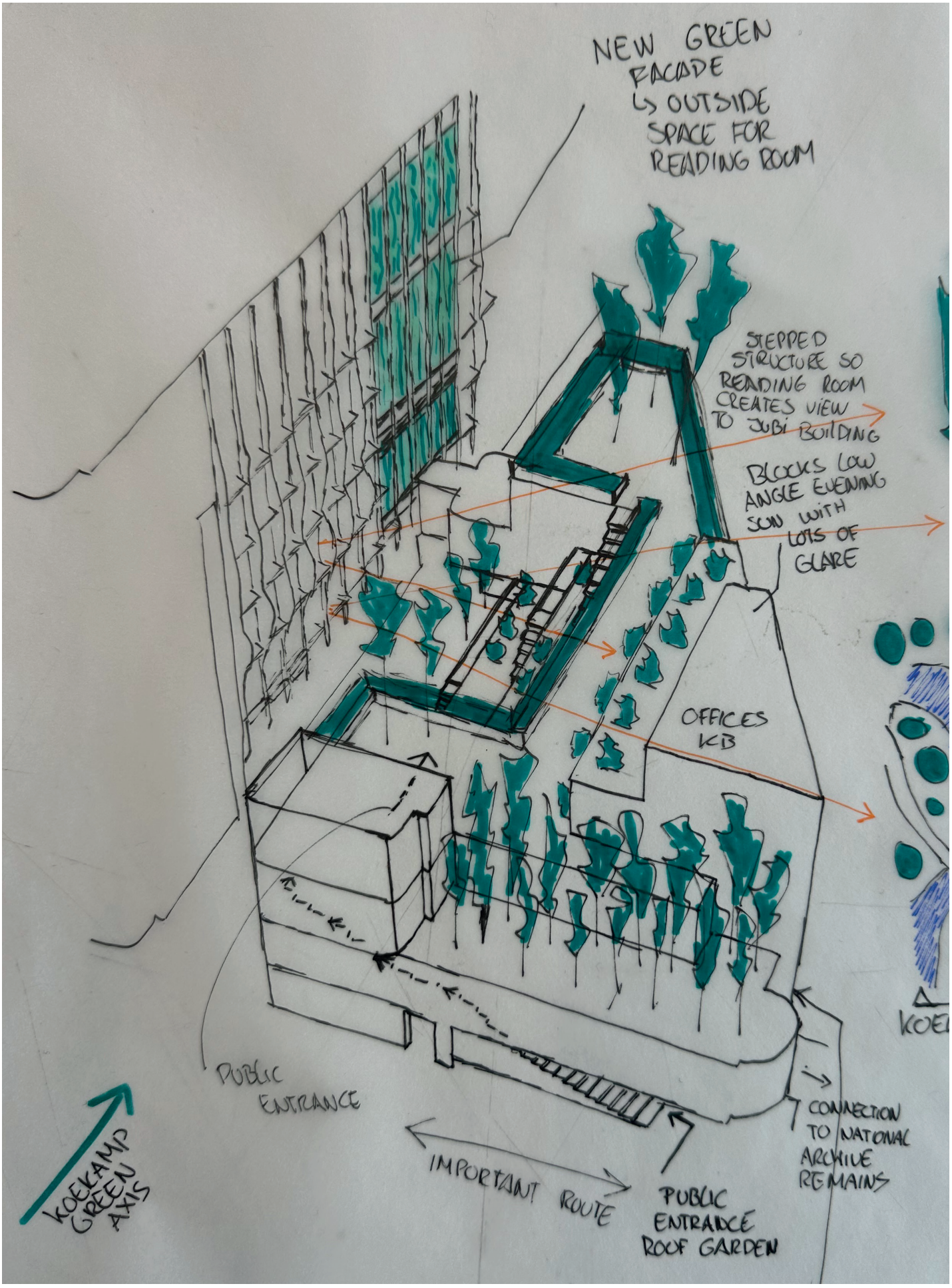

NEW (x2 ON LOWEST PART OF ROOF)
CURRENT (x4)
NO VIEW SO REUSE OF OPAQUE PANELS
EXTRA OPENINGS ON THE SIDES (FACING NORTH)
1950
5850
EXTRA OPENINGS ON THE SIDES (DIRECT SUNLIGHT) is BLOCKED BY CURREN STRUCTURE
CURTAINS POSITIONED IN SUCH WAY THAT THEY CORRESPOND WITH INTERIOR IN TERMS OF HEIGHT
↳ BENEFITS VIEW
NORTH
PASSIVE VENTILATION IN BETWEEN THE SAW-TOOTHS
1950
5850
OBSTRUCTED VIEW
NORTH
SAME PRINCIPLES USED FOR THE STRUCTURE
A LOT OF PANELS CAN BE REUSED

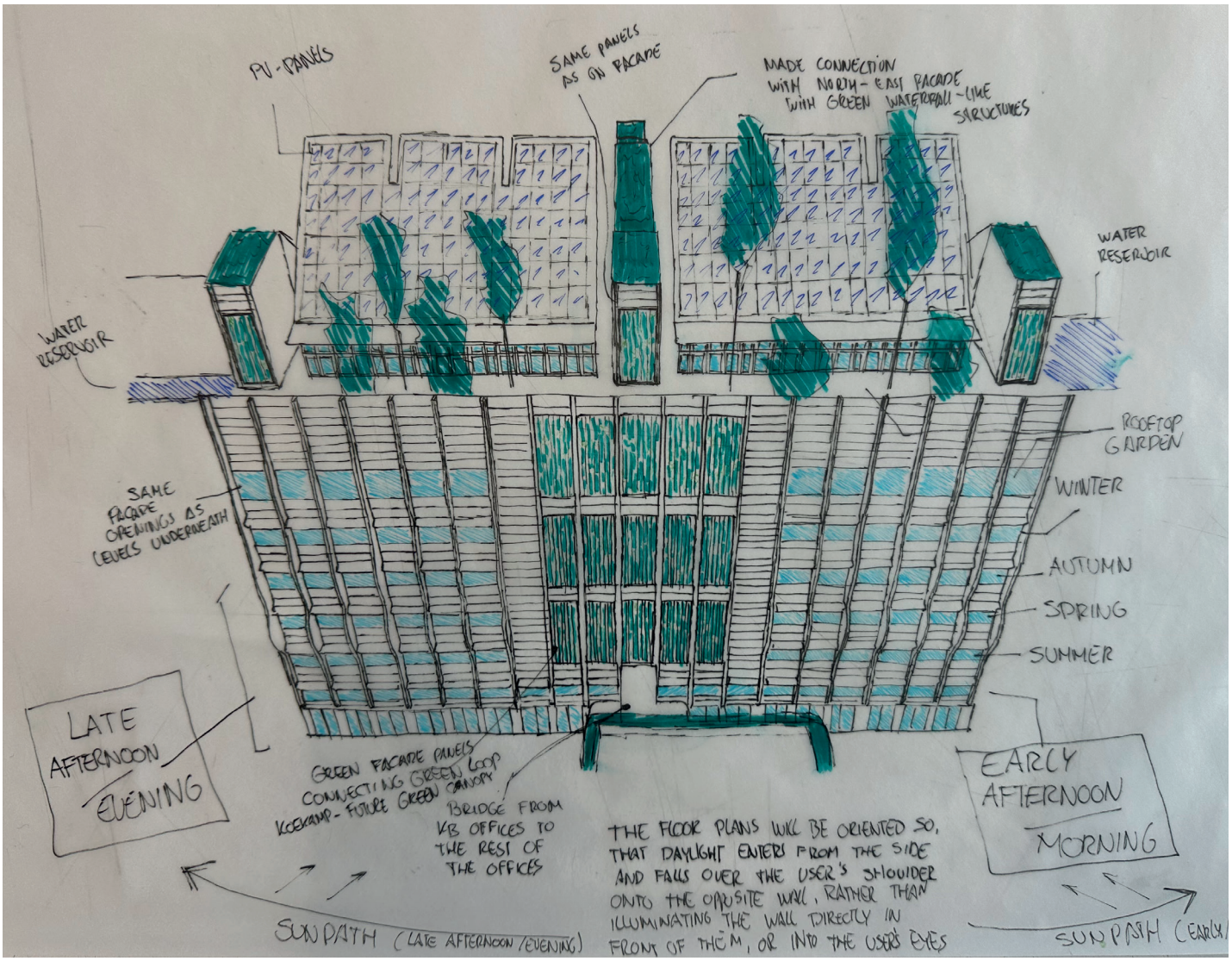

NEW SAW-TOOTH ROOF
2X LOWEST PART OF ROOF/BUILDING
REUSE OF THE OPAQUE PANELS, WHERE BEHIND THE STRUCTURE IS POSITIONED
NEW ROOF
NEW CURTAIN WALL IN SAME STYLE
6TH FLOOR
EXISTING ROOF CURTAIN BUILDING
1950
5TH FLOOR
4TH FLOOR
3RD FLOOR
2ND FLOOR
TRUSS ROOF STRUCTURE
NORTH-EAST
NEW CURTAIN WALL IN SAME STYLE
EXISTING CURTAIN WALLS ON THE EXACT SAME LOCATION
NEW (X2 ON HIGHEST PART OF ROOF)
OPENED UP THE VIEW FOR 6TH FLOOR
HORIZONTAL OVERHANG
WINDOWS FACING SW
PV PANELS
1950
NORTH

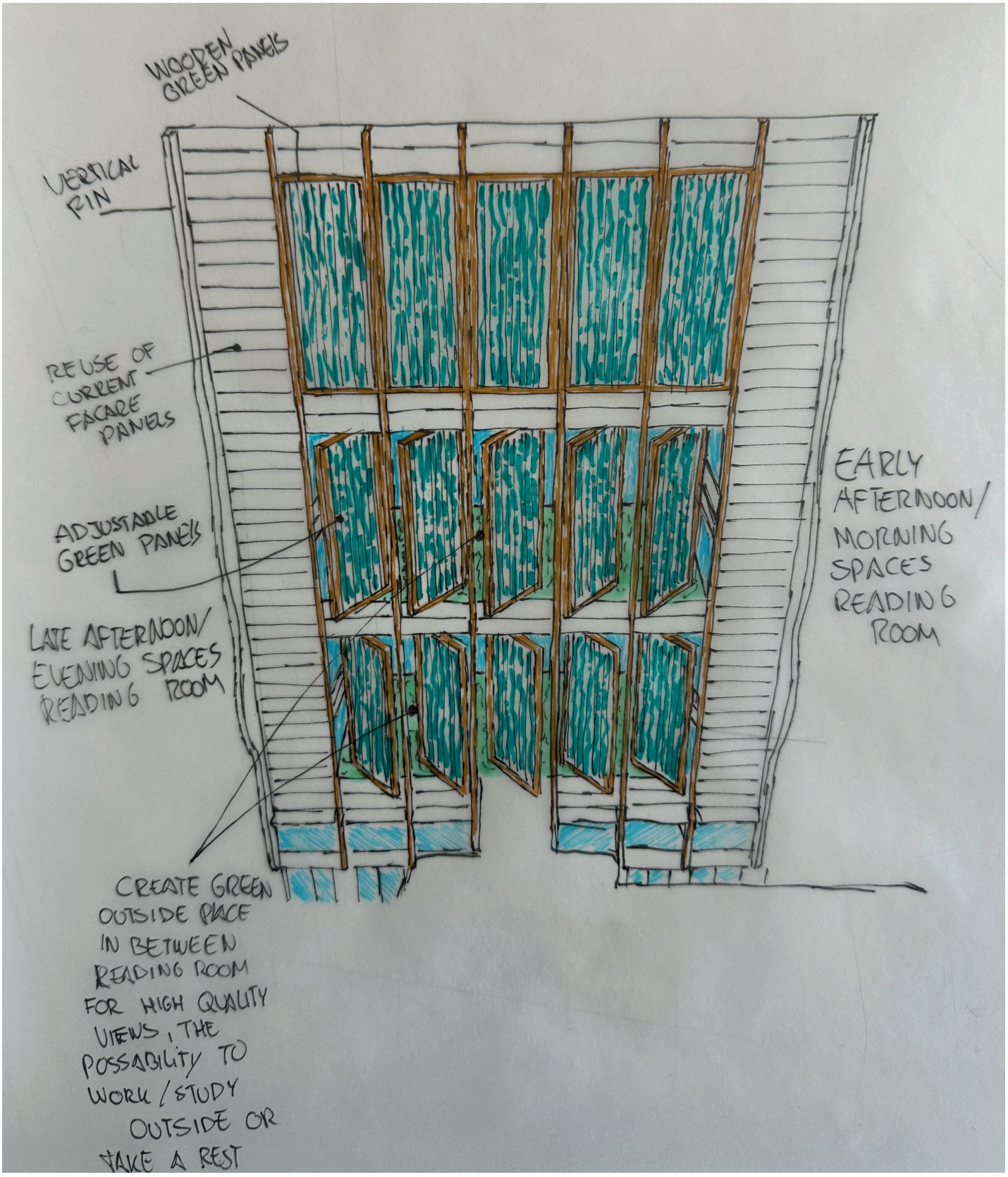

PRESERVE SAME ROOF STRUCTURE
'WATERFALL LIKE' IDEA AS CURRENT
BUILDING (HERITAGE VALUE)
NEW SAW-TOOTH ROOF
2X HIGHEST PART
OF ROOF/BUILDING
SOUTH-WEST
PRESERVE CURRENT FACADE PARTIALLY TO BLOCK VIEW OF PV-PANELS & PRESERVE HERITAGE VALUES
PV PANELS CAN GENERATE LOTS OF ENERGY
STRUCTURE OF VERTICAL FINS
HORIZONTAL OVERHANG
3900
VIEW TO SOUTH-WEST OF THE-HAGUE FROM 6TH FLOOR
5TH FLOOR
6TH FLOOR
5TH FLOOR
CREATES A VIEW FROM 6TH FLOOR TO S-W OF THE HAGUE
WHILE BLOCKING & PREVENTING HEAT STRESS,
PRESERVES HERITAGE & CREATES A ENORMOUS
AMOUNT OF DIFFUSE NORTH-EAST DAYLIGHT
WHICH IS VERY BENEFICIAL FOR READING ROOM

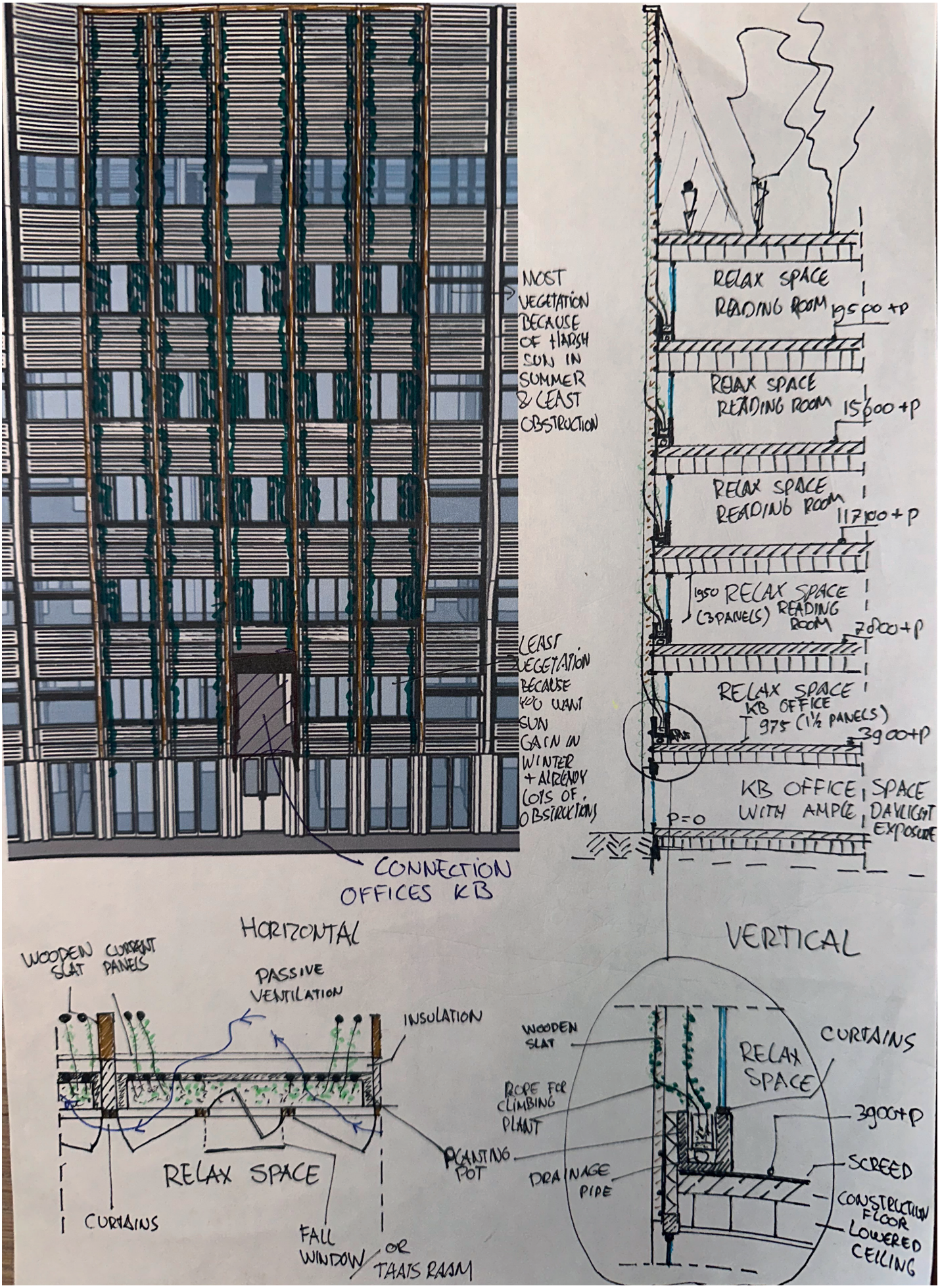

TYPICAL VIEW OF THE HAGUE SKYLINE
'KILLER VIEW'
JUBI
BUILDING
STEPPED STRUCTURE FOR VIEW
ROOF GARDEN
ATRIA'S
CORE
CS
GREEN CONNECTORS CLOSING OFF AXIS LOOP
ROOF GARDEN
WATER STORAGE ABOVE WET ROOM COMPARTMENTS
CONNECTION WITH GREEN AXIS
FUTURE GREEN CANOPY AXIS
IMPORTANT ROUTE
SECTION
IMPORTANT ROUTE
COMING OUT OF CS, HAVE A LOOK AT
CS
ICEKAMP GREEN AXIS

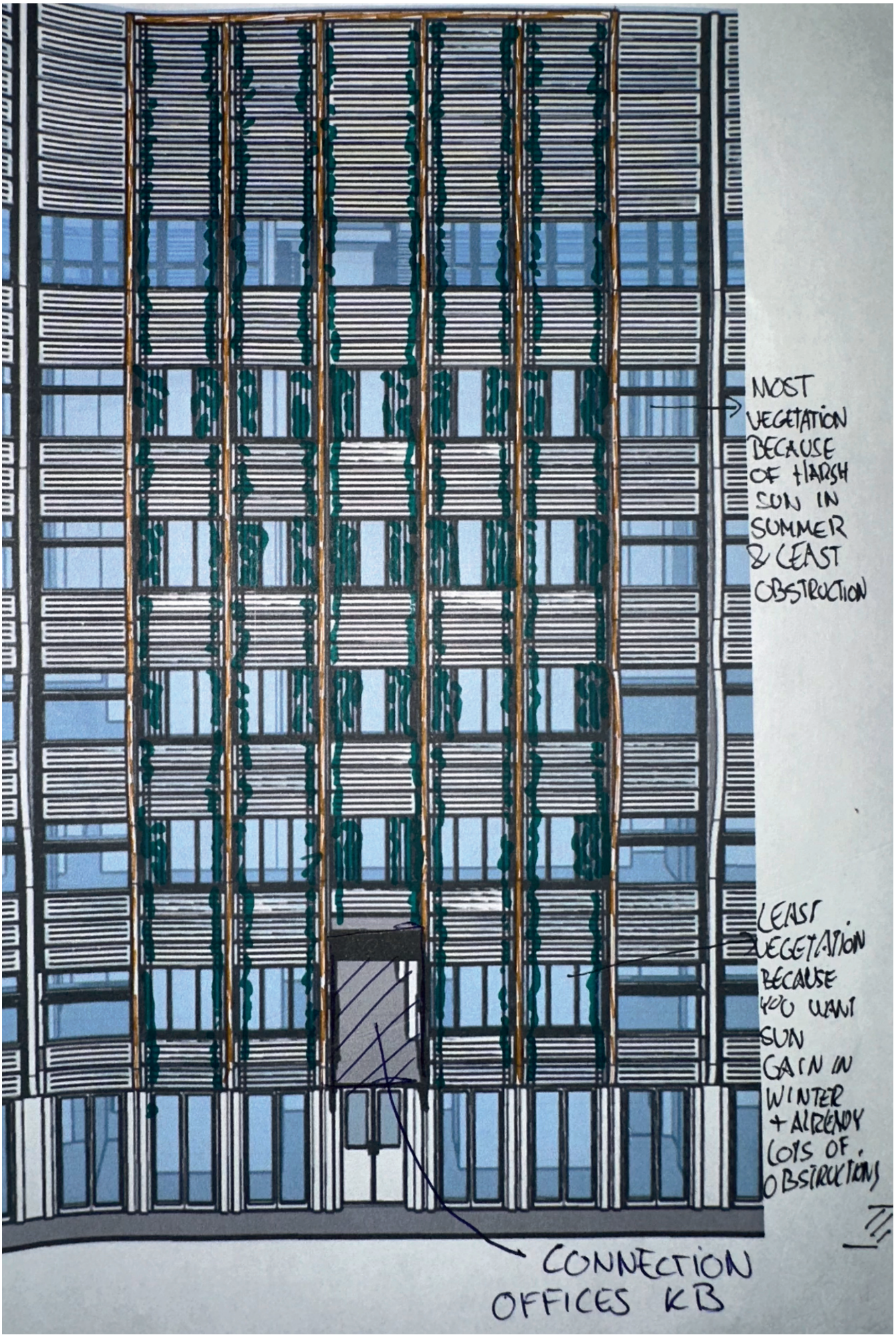

INITIAL IDEA ARIE HAGOORT WAS TO INCLUDE THE KOEKAMP
-> WHY NOT DO IT NOW AND MAKE AN AXIS TO IT?
CURRENT WATERFALL ROOF STRUCTURE -> GREEN AXIS
ATRIA'S
IMPORTANT ROUTE
GROUND FLOOR
FUTURE GREEN CANOPY AXIS
ENTRANCE HOUSING
IMPORTANT ROUTE
IMPORTANT ROUTE
ATRIUM
HOUSING
KOEKAMP
KOEKAMP GREEN AXIS
FUTURE GREEN CANOPY AXIS
CS

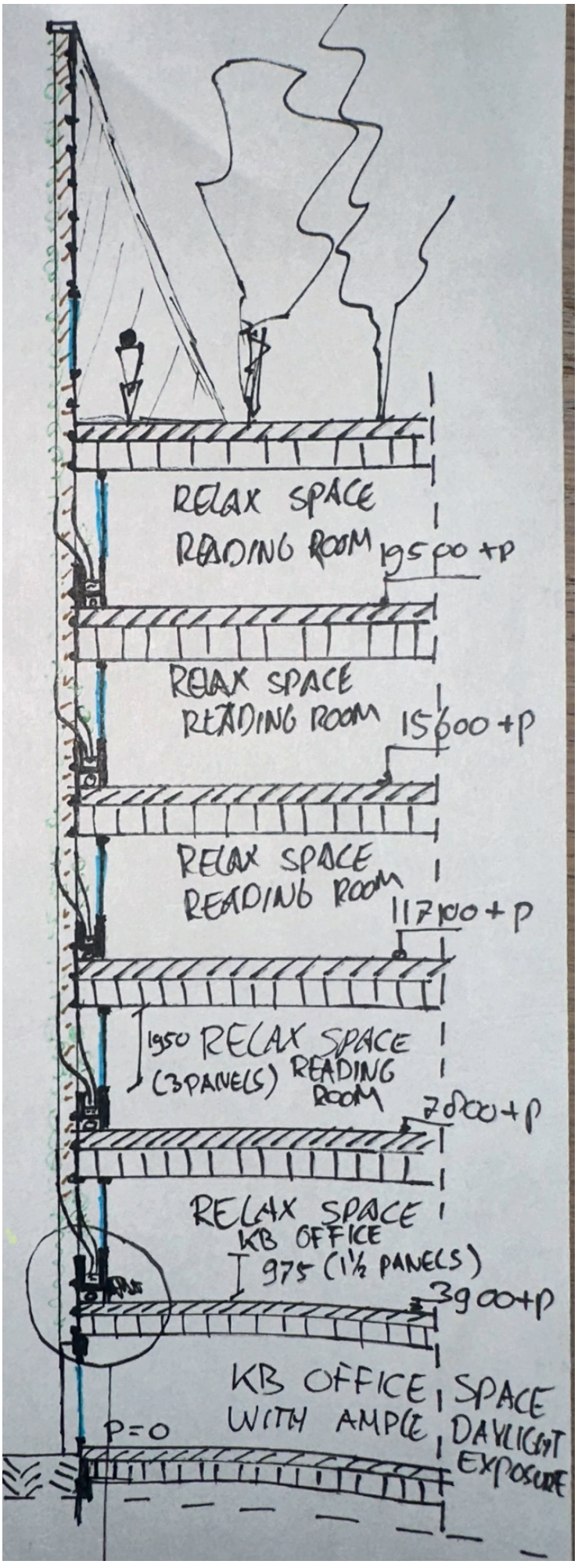

NEW GREEN FACADE
↳ OUTSIDE SPACE FOR READING ROOM
STEPPED STRUCTURE SO READING ROOM CREATES VIEW TO JUBI BUILDING
BLOCKS LOW ANGLE EVENING SUN WITH LOTS OF GLARE
OFFICES KB
PUBLIC ENTRANCE
KOEKAMP GREEN AXIS
IMPORTANT ROUTE
PUBLIC ENTRAIDCE ROOF GARDEN
CONNECTION TO NATIONAL ARCHIVE REMAINS

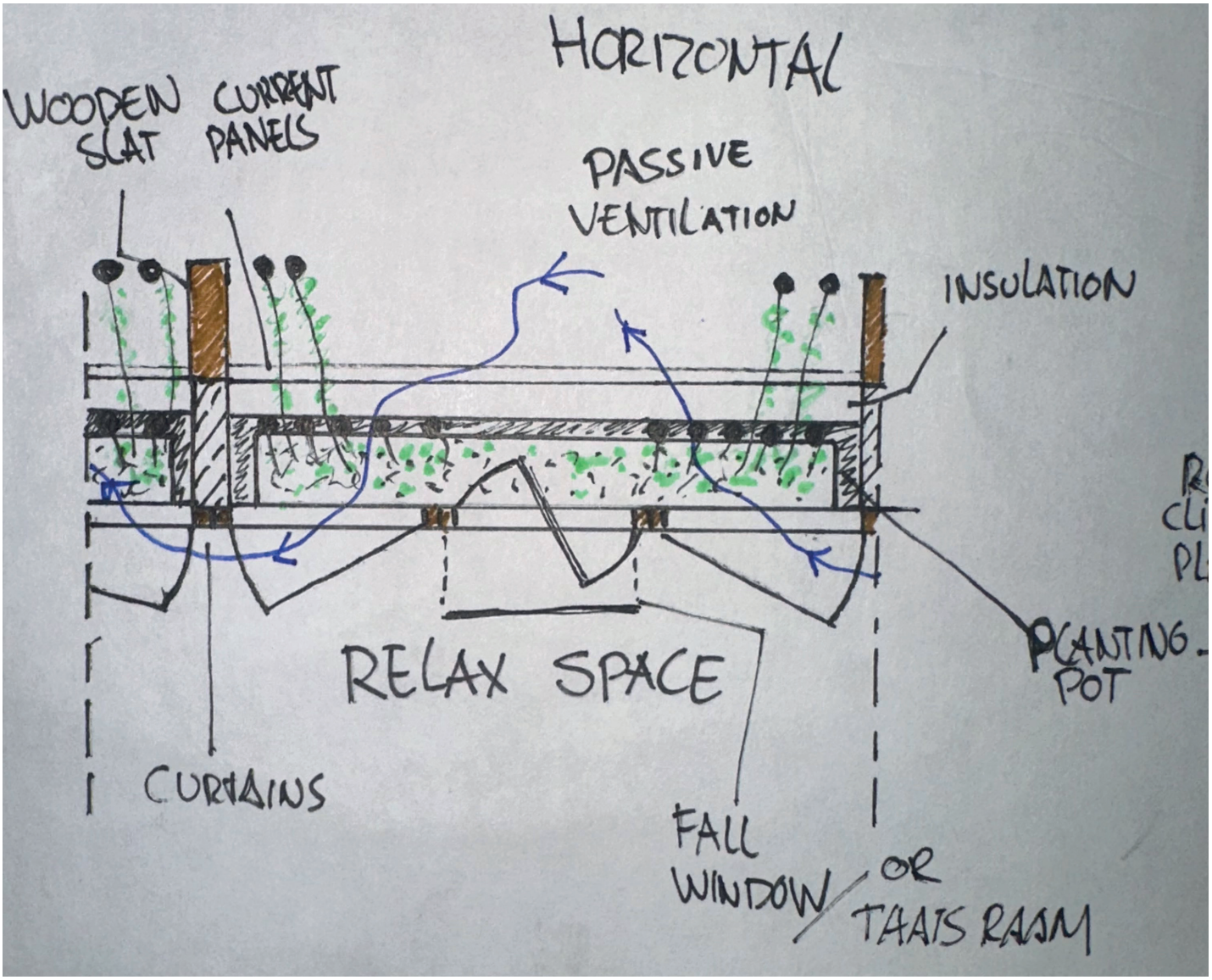

PV-PANELS
SAME PANELS AS ON FACADE
MADE CONNECTION WITH NORTH-EAST FACADE WITH GREEN WATERFALL-LIKE STRUCTURES
WATER RESERVOIR
WATER RESERVOIR
ROOFTOP GARDEN
WINTER
AUTUMN
SPRING
SUMMER
SAME FACADE OPENINGS AS LEVELS UNDERNEATH
LATE AFTERNOON EVENING
GREEN FACADE PANELS CONNECTING GREEN LOOP
BRIDGE FROM KB OFFICES TO THE REST OF THE OFFICES
THE FLOOR PLANS WILL BE ORIENTED SO, THAT DAYLIGHT ENTERS FROM THE SIDE AND FALLS OVER THE USER'S SHOULDER ONTO THE OPPOSITE WALL, RATHER THAN ILLUMINATING THE WALL DIRECTLY IN FRONT OF THEM, OR INTO THE USERS EYES
EARLY AFTERNOON MORNING
SUN PATH (LATE AFTERNOON/EVENING)
SUN PATH (EARLY

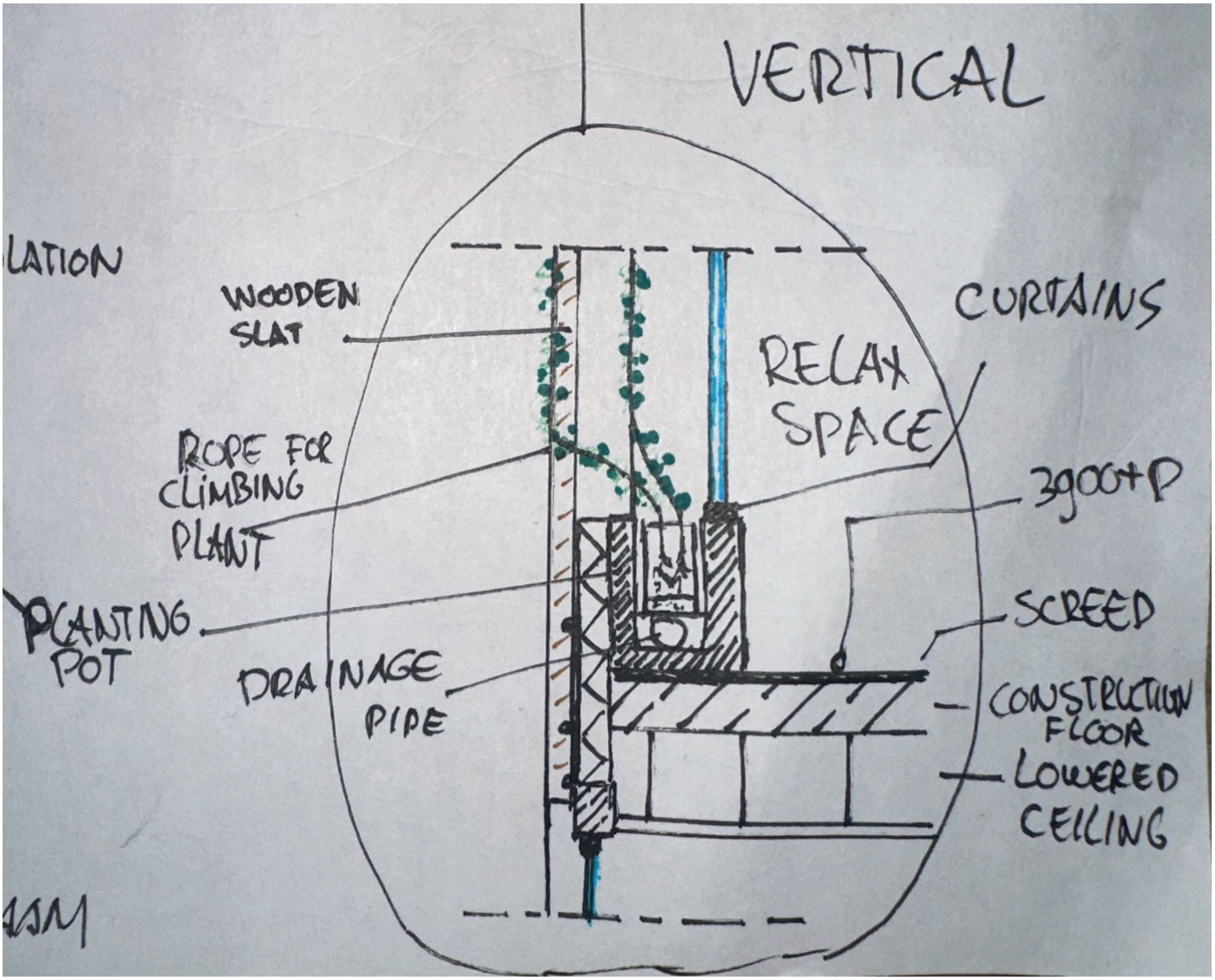

WOODEN GREEN PANELS
VERTICAL FIN
REUSE OF CURRENT FACADE PANELS
ADJUSTABLE GREEN PANELS
LATE AFTERNOON/ EVENING SPACES READING ROOM
EARLY AFTERNOON/ MORNING SPACES READING ROOM
CREATE GREEN OUTSIDE PLACE IN BETWEEN READING ROOM FOR HIGH QUALITY VIEWS, THE POSSABILITY TO WORK/STUDY OUTSIDE OR TAKE A REST


MOST VEGETATION BECAUSE OF HARSH SUN IN SUMMER & LEAST OBSTRUCTION
LEAST VEGETATION BECAUSE WANT SUN GAIN IN WINTER + ALREADY LOTS OF OBSTRUCTIONS
CONNECTION OFFICES KB
RELAX SPACE READING ROOM
RELAX SPACE READING ROOM
RELAX SPACE READING ROOM
1950 RELAX SPACE (3PANELS) READING ROOM
RELAX SPACE KB OFFICE 975 (1½ PANELS)
KB OFFICE WITH AMPLE DAYLIGHT EXPOSURE
P=0
HORIZONTAL
VERTICAL
WOODEN SLAT CURRENT PANELS
PASSIVE VENTILATION
INSULATION
RELAX SPACE
CURTAINS
FALL WINDOW OR TAATS RAAM
WOODEN SLAT
ROPE FOR CLIMBING PLANT
PLANTING POT
DRAINAGE PIPE
CURTAINS
RELAX SPACE
SCREED
CONSTRUCTION FLOOR
LOWERED CEILING


MOST VEGETATION BECAUSE OF HARSH SUN IN SUMMER & LEAST OBSTRUCTION
LEAST VEGETATION BECAUSE YOU WANT SUN GAIN IN WINTER + ALREADY LOTS OF OBSTRUCTIONS
CONNECTION OFFICES KB


RELAX SPACE
READING ROOM
19500 +P
RELAX SPACE
READING ROOM
15600 +P
RELAX SPACE
READING ROOM
11700 +P
1950 RELAX SPACE
(3PANELS) READING
ROOM
7800+P
RELAX SPACE
KB OFFICE
975 (1½ PANELS)
3900+P
KB OFFICE WITH AMPLE SPACE DAYLIGHT EXPOSURE
P=0


HORIZONTAL
WOODEN SLAT
CURRENT PANELS
PASSIVE VENTILATION
INSULATION
RELAX SPACE
PLANTING POT
CURTAINS
FALL WINDOW
OR
TAAIS RAAM

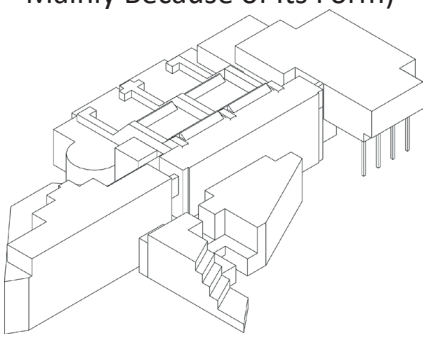

VERTICAL
LATION
WOODEN SLAT
CURTAINS
RELAX SPACE
ROPE FOR CLIMBING PLANT
SCREED
PLANTING POT
DRAINAGE PIPE
CONSTRUCTION FLOOR
LOWERED CEILING

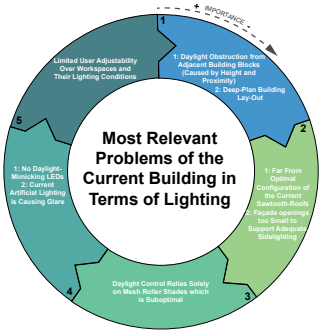




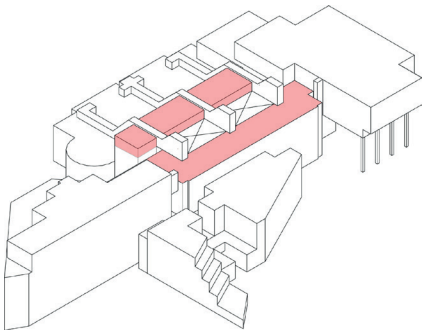
Design Concept

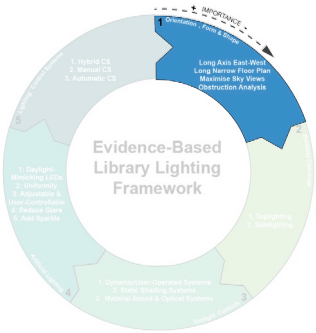
Current Building (Problematic Lighting Mainly Because of Its Form)



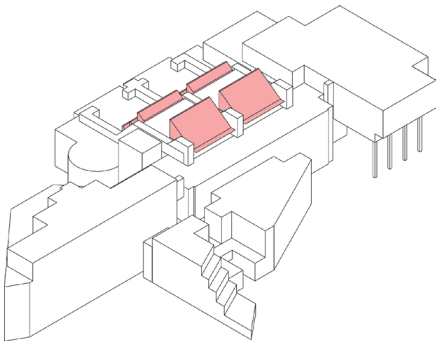


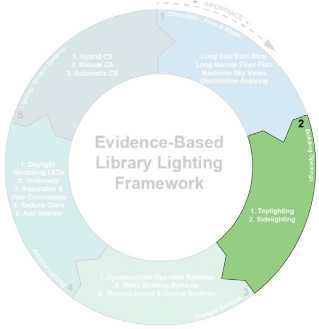
Create Long Narrow Floor Plans With a Higher Volume in the Middle Acting As a Reflective Core



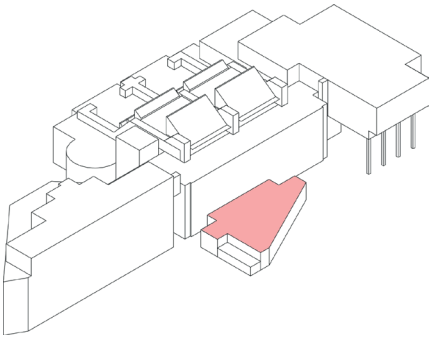


Improving Existing Sawtooth-Roofs Structures



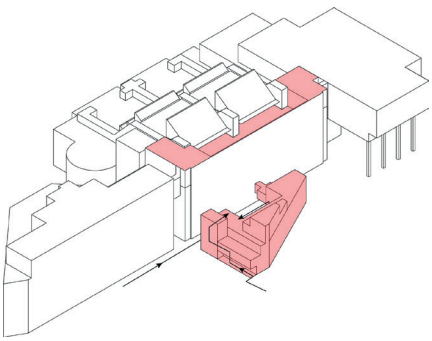


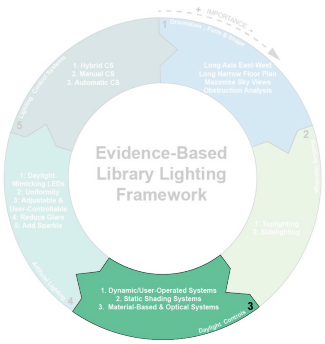
Maximize Sky Views & Remove Obstructions



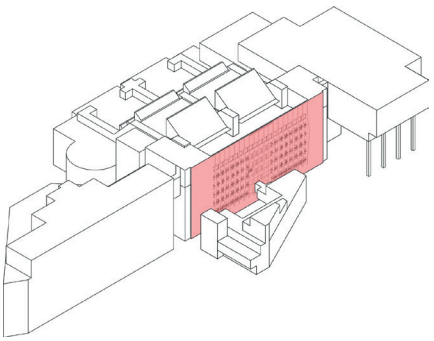


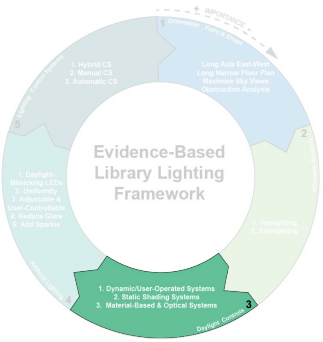
Connect Within Urban Scale and Combine With (Natural) Daylight Controls



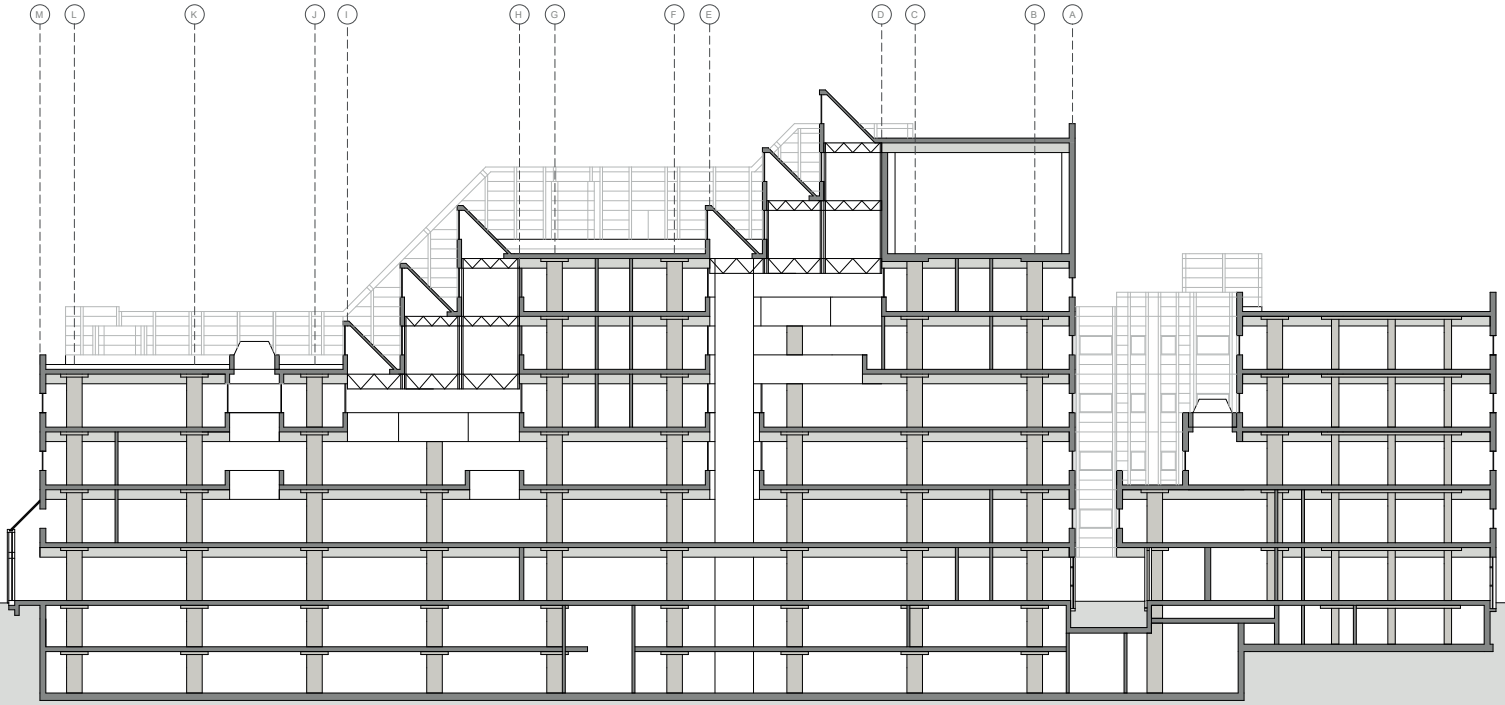


Improve Most Important Facades for Better Lighting and Less Glare Issues





STEP 1


M
L
K
J
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G
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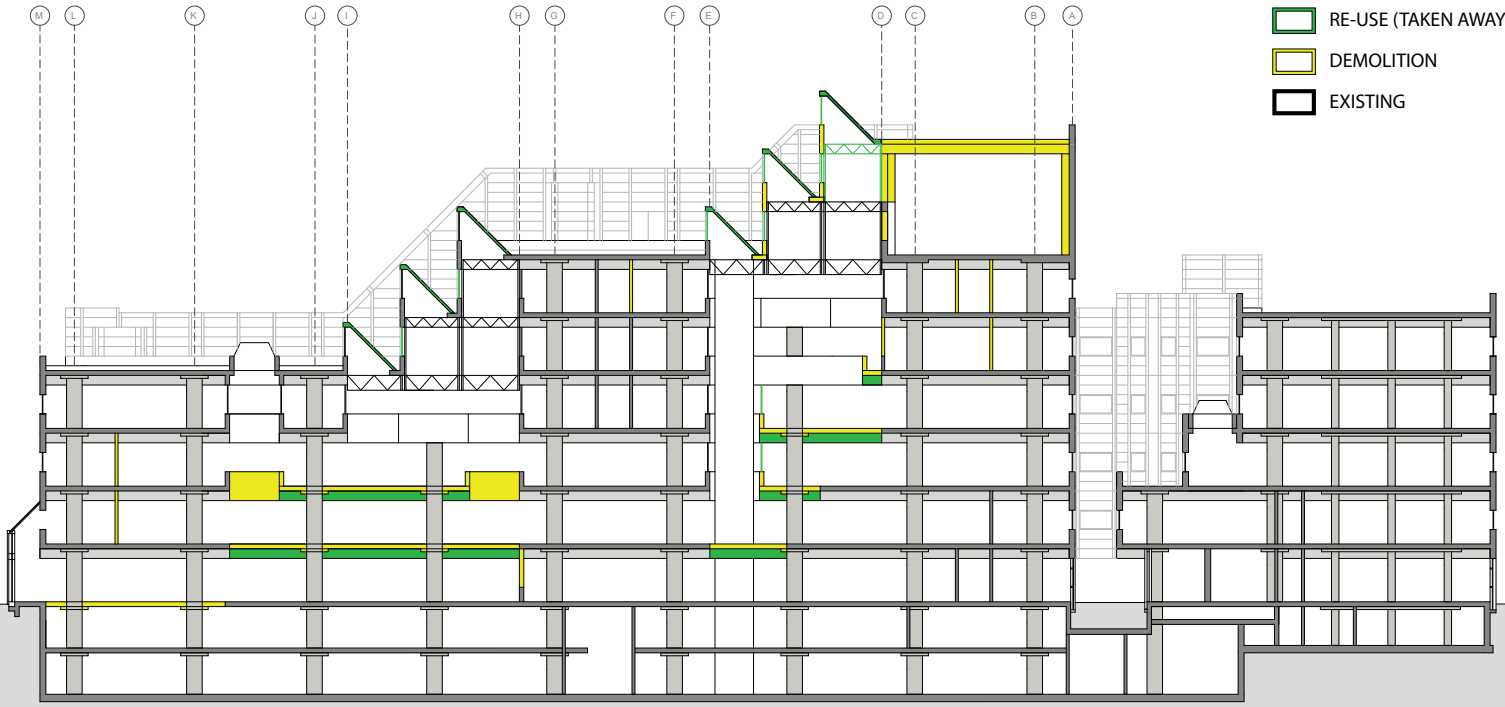
E
D
C
B
A

STEP 2


M
L
K
J
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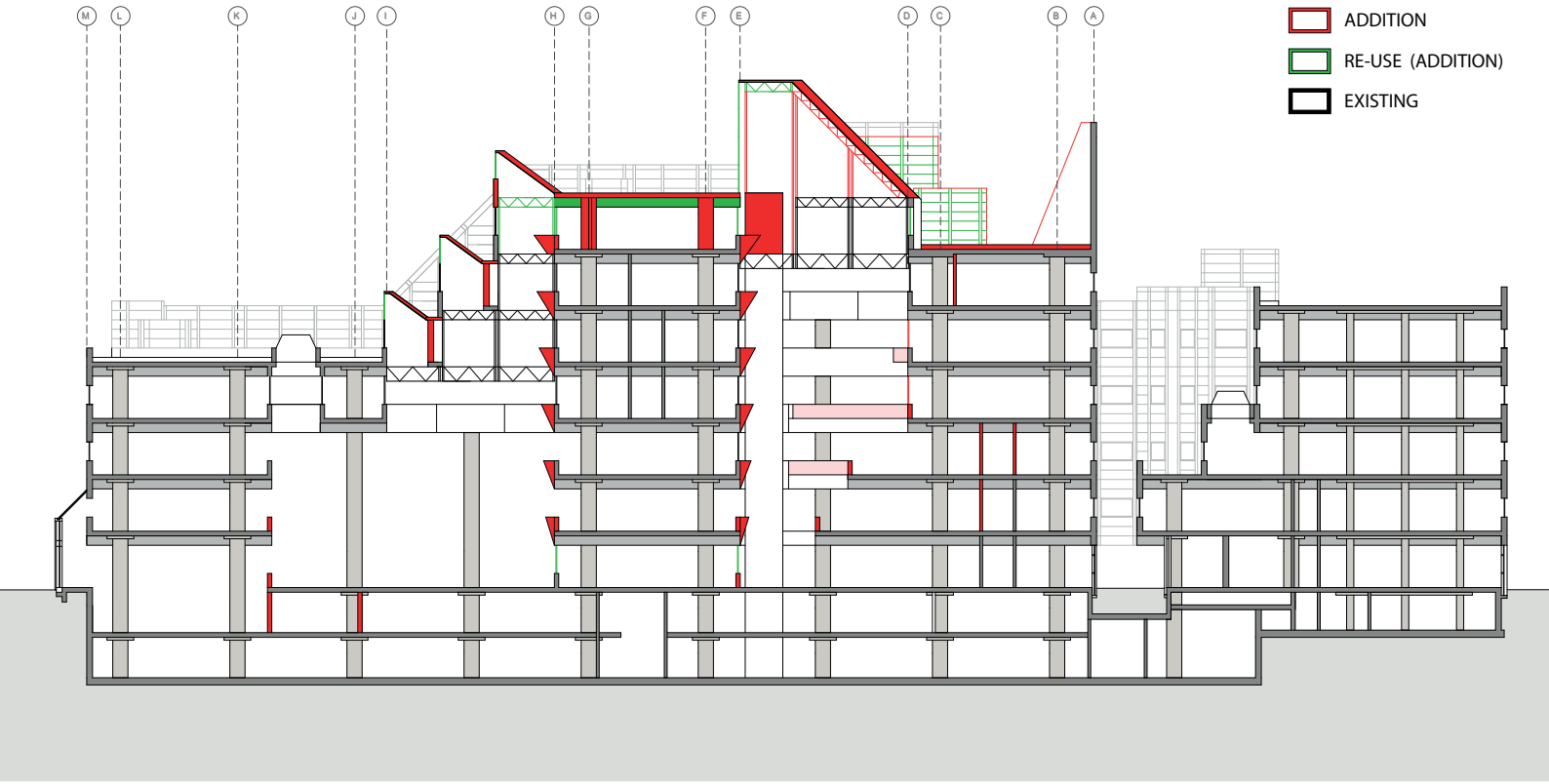
H
G
F
E
D
C
B
A
RE-USE (TAKEN AWAY)
DEMOLITION
EXISTING

STEP 3


M
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G
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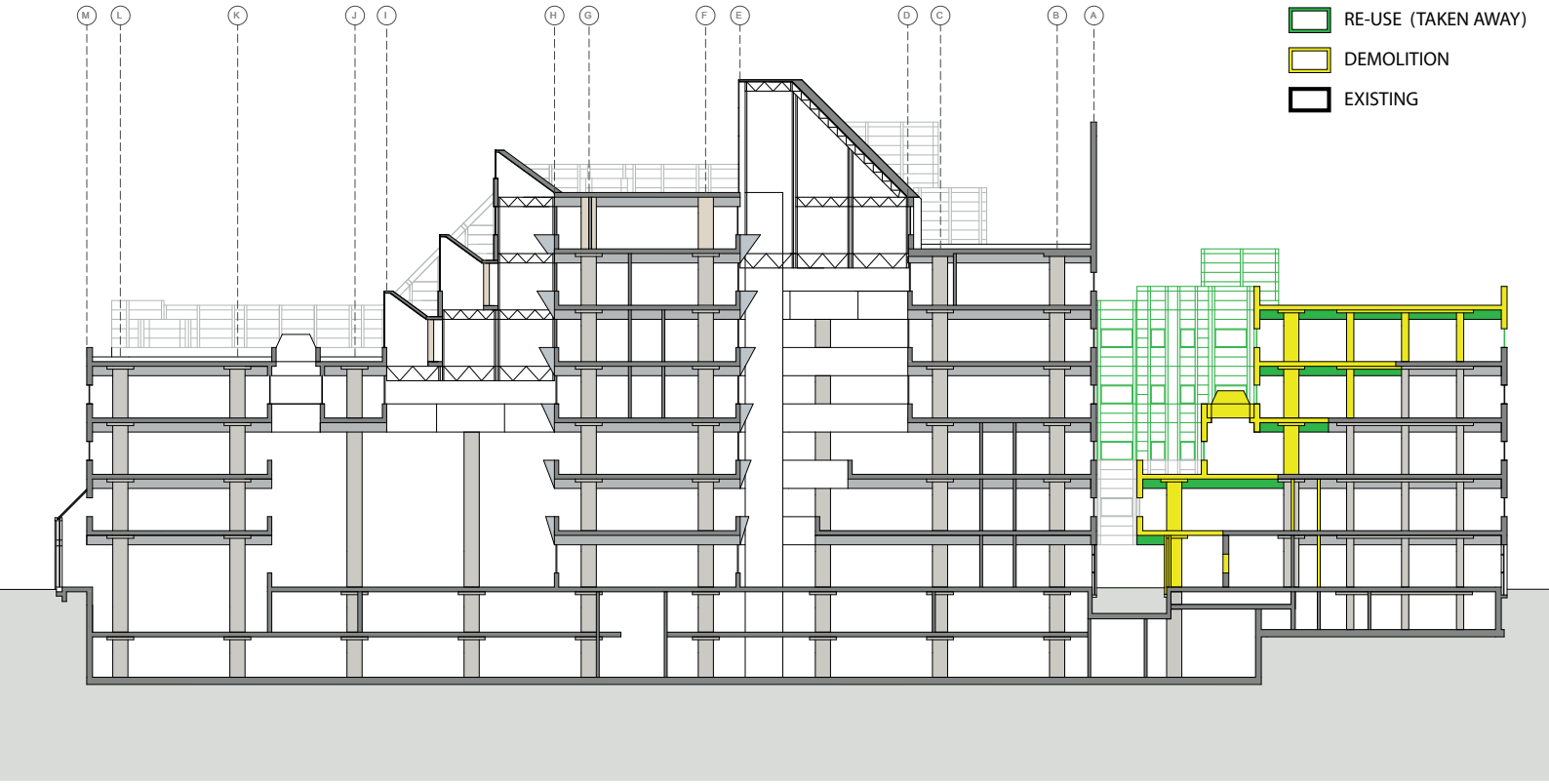
D
C
B
A
ADDITION
RE-USE (ADDITION)
EXISTING

STEP 4


M
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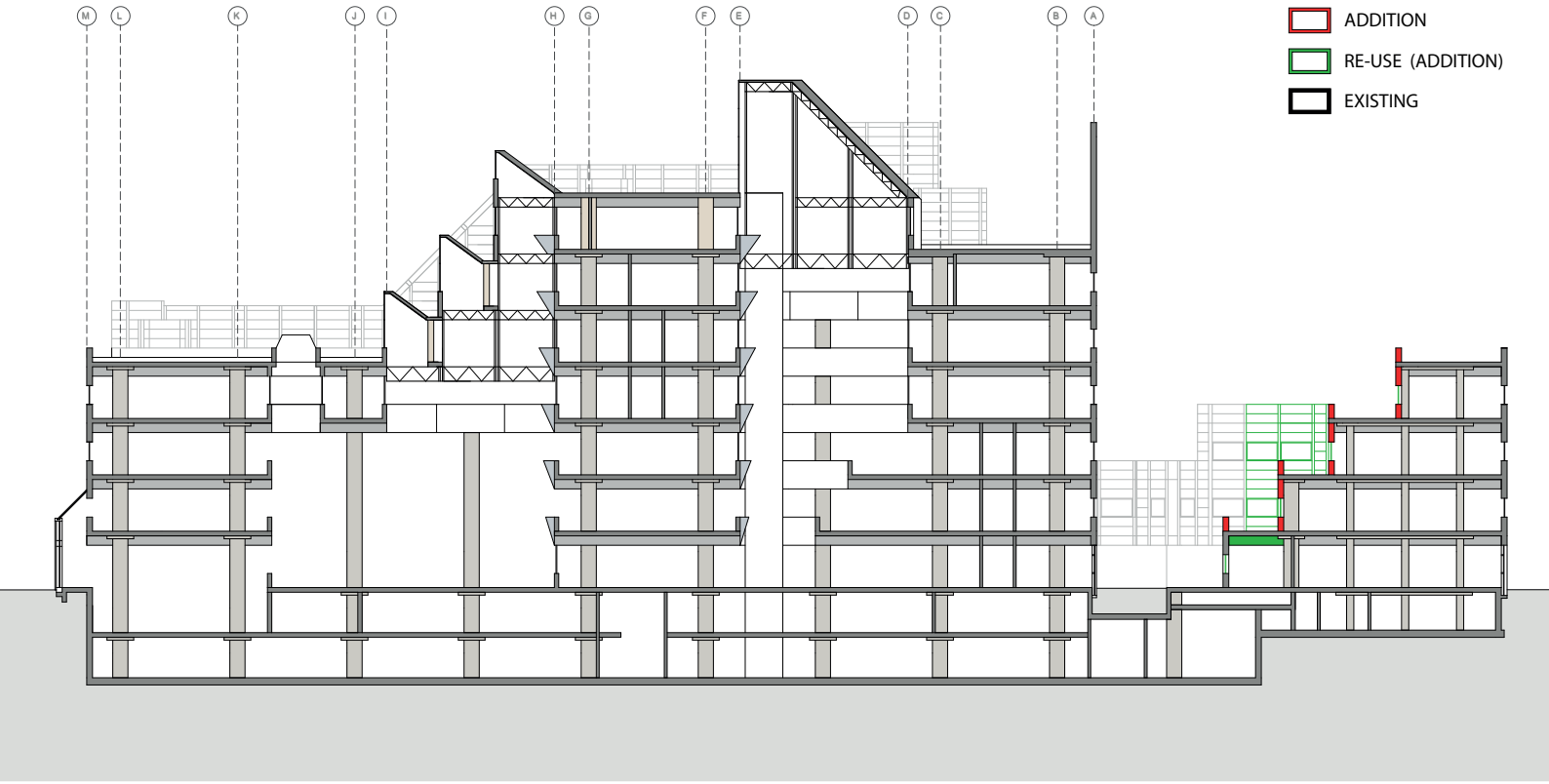
E
D
C
B
A
RE-USE (TAKEN AWAY)
DEMOLITION
EXISTING

STEP 5


M
L
K
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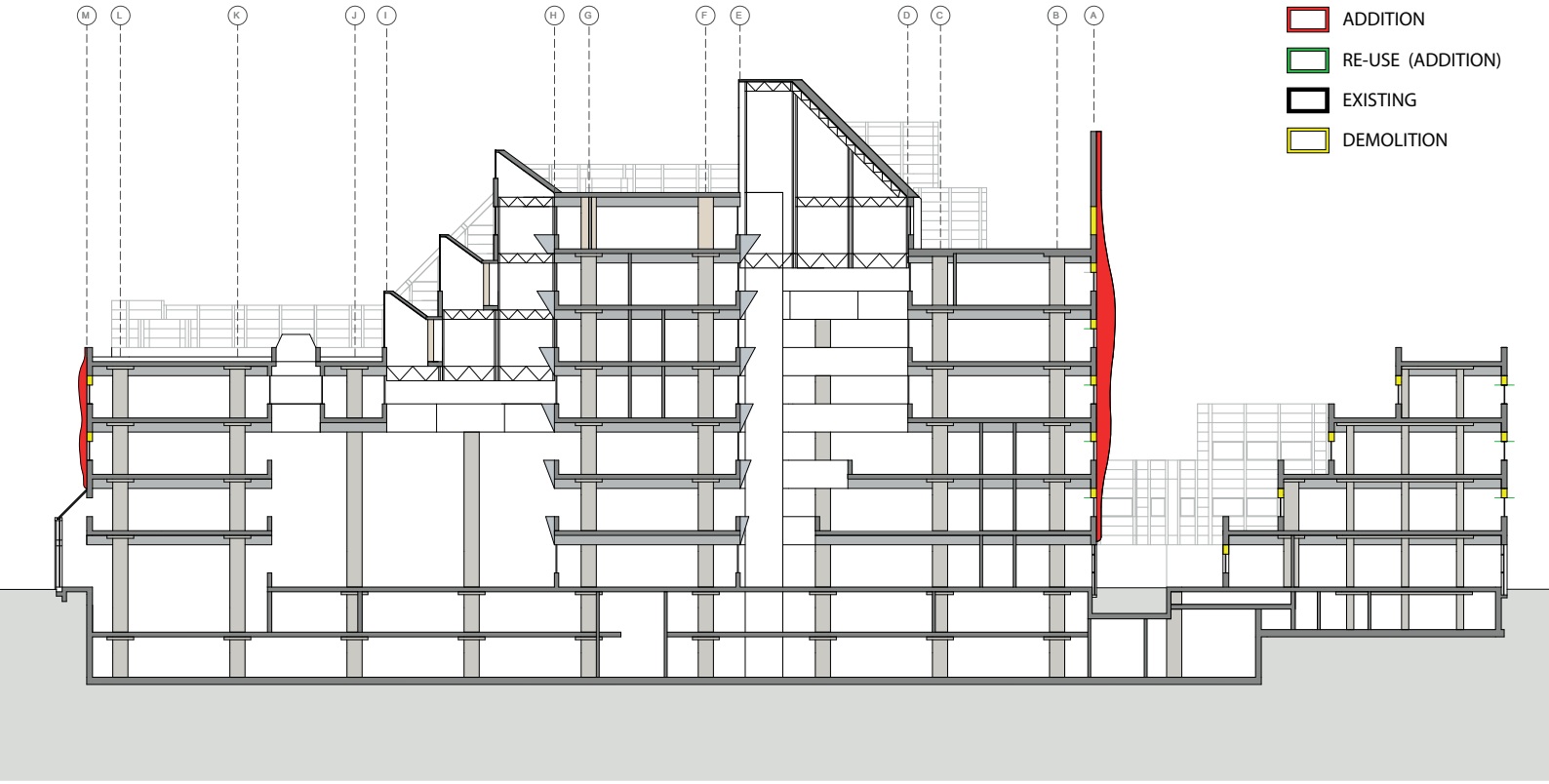
I
H
G
F
E
D
C
B
A
ADDITION
RE-USE (ADDITION)
EXISTING

STEP 6


M
L
K
J
I
H
G
F
E
D
C
B
A
ADDITION
RE-USE (ADDITION)
EXISTING
DEMOLITION

APPENDICES: Appendix N, Set of Drawings P5

STEP 1



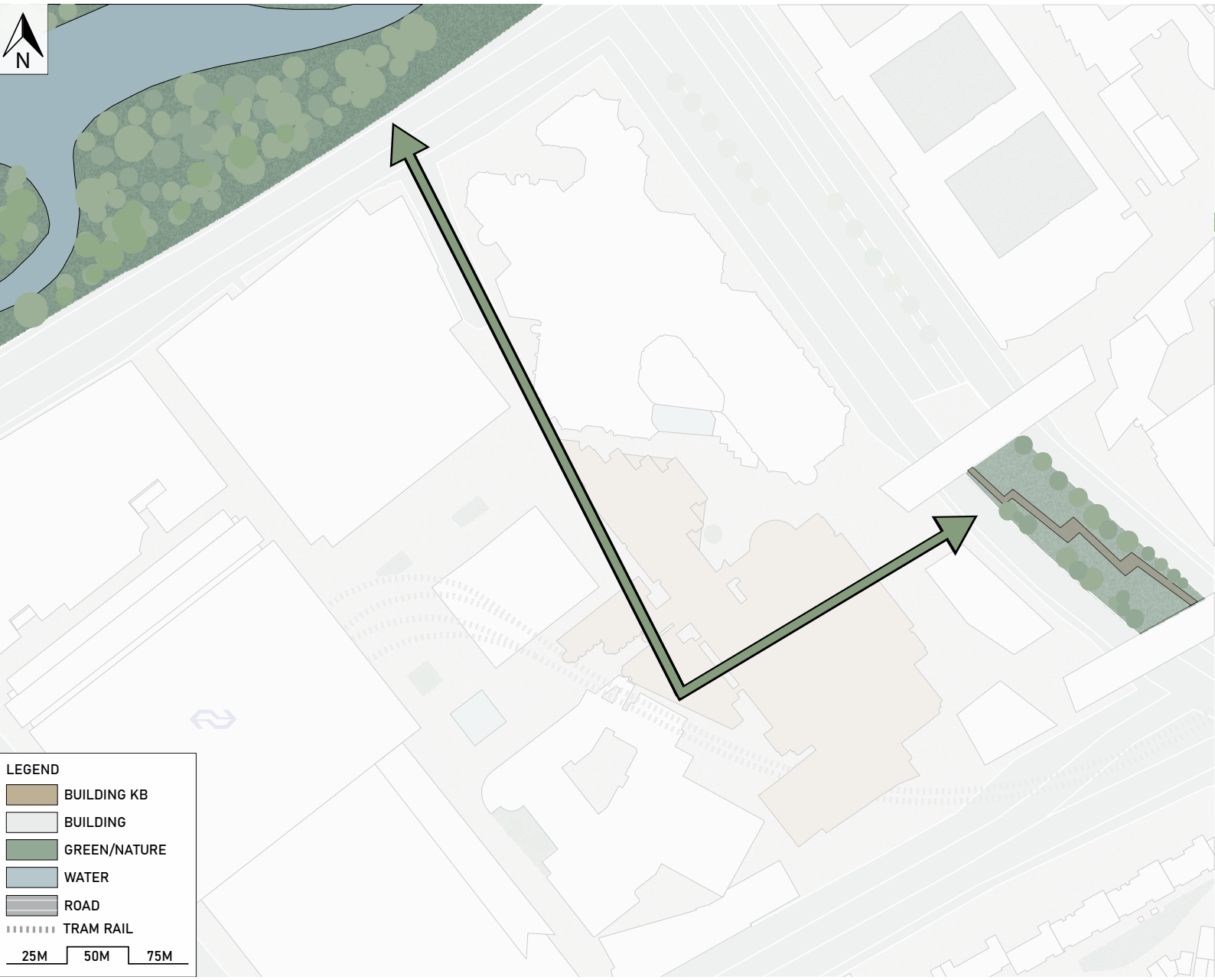
APPENDICES: Appendix N, Set of Drawings P5

STEP 2



APPENDICES: Appendix N, Set of Drawings P5

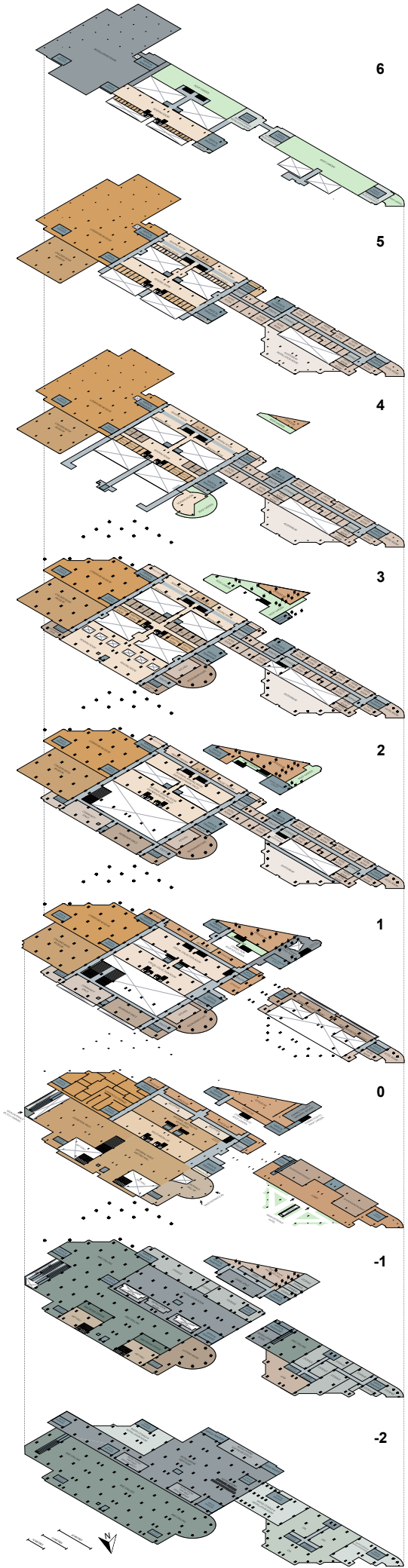
STEP 3



APPENDICES: Appendix N, Set of Drawings P5

STEP 4

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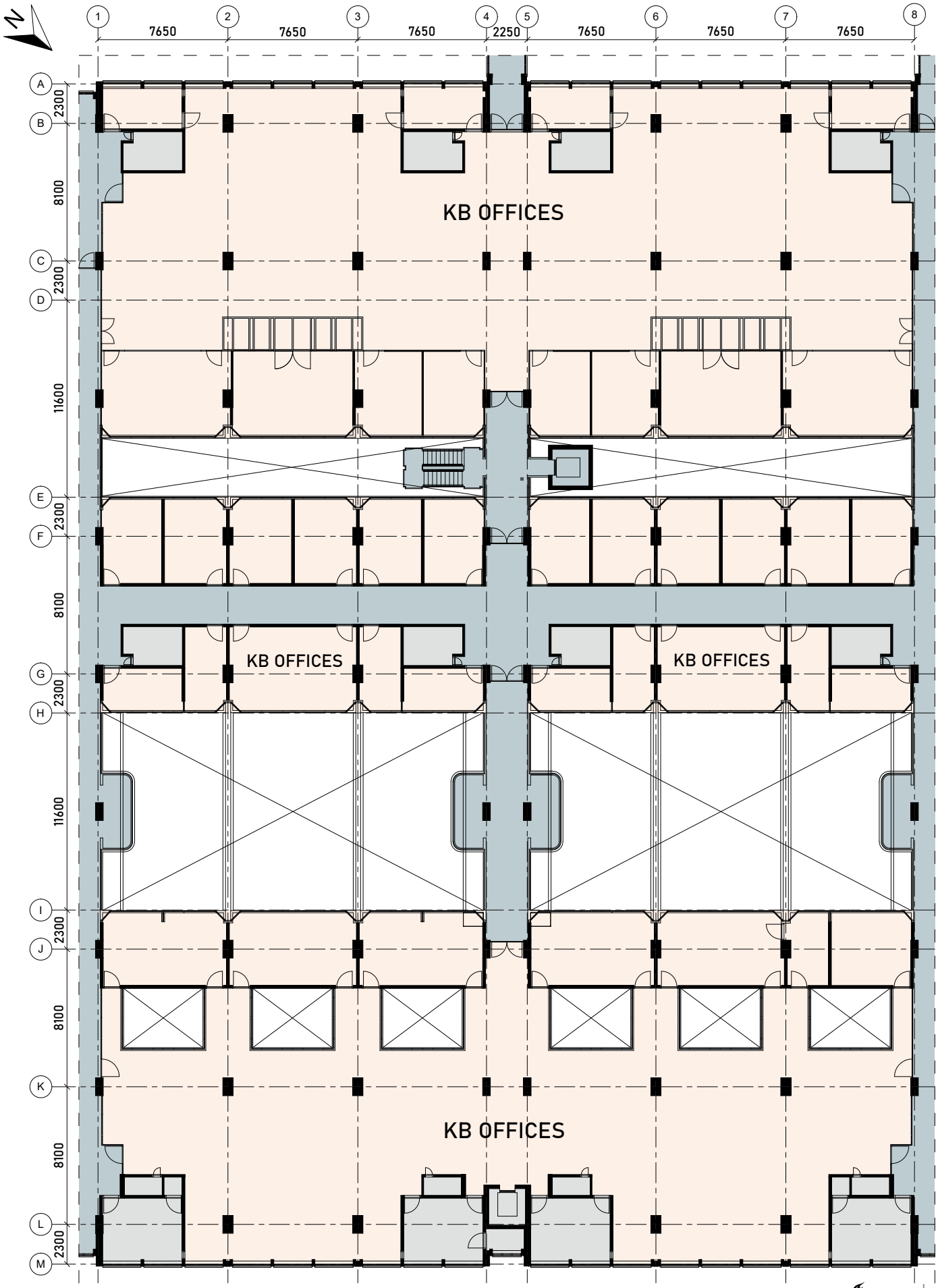
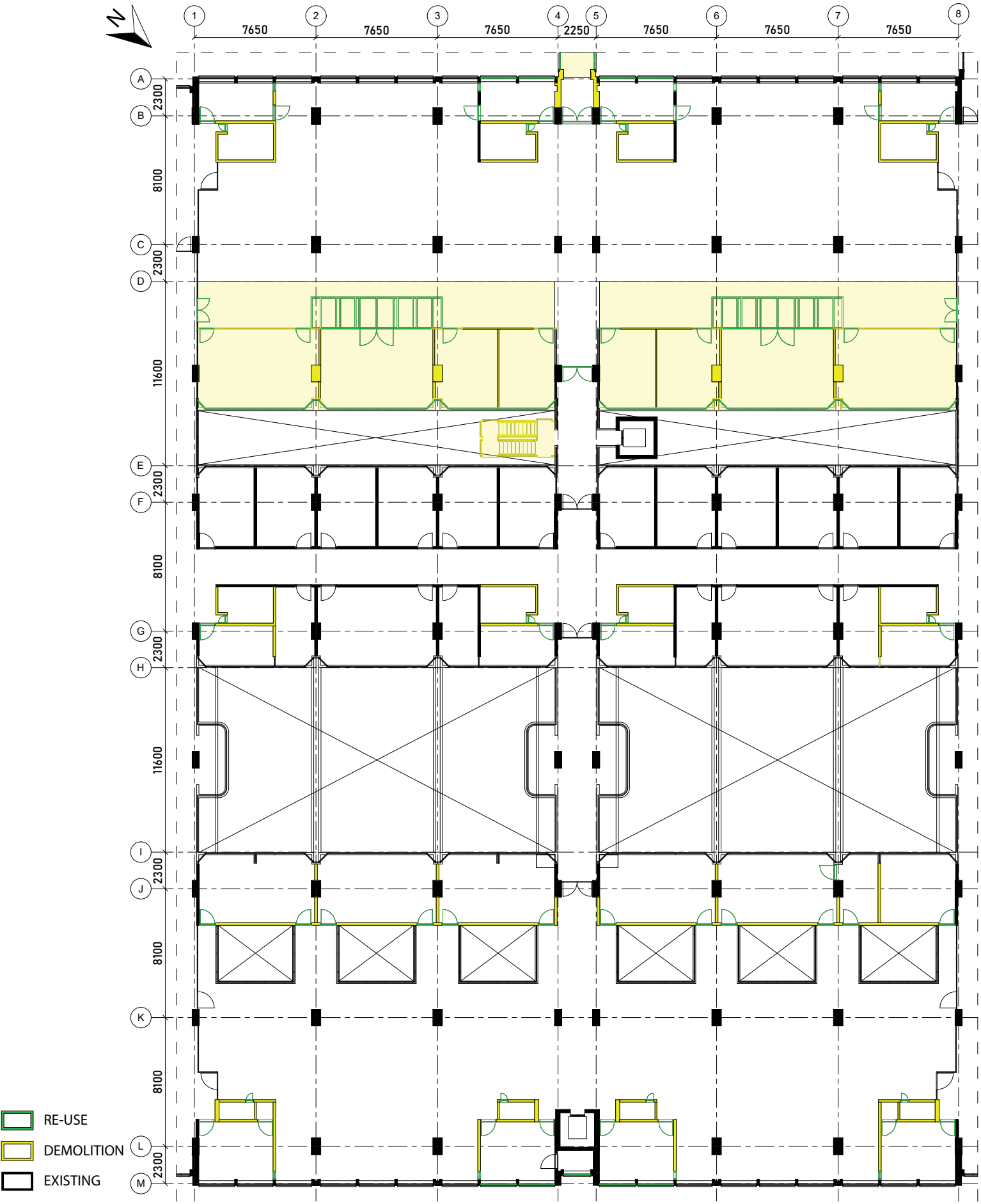
APPENDICES: Appendix N, Set of Drawings P5

STEP 1



STEP 2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C
D
E
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G
H
I
J
K
L
M
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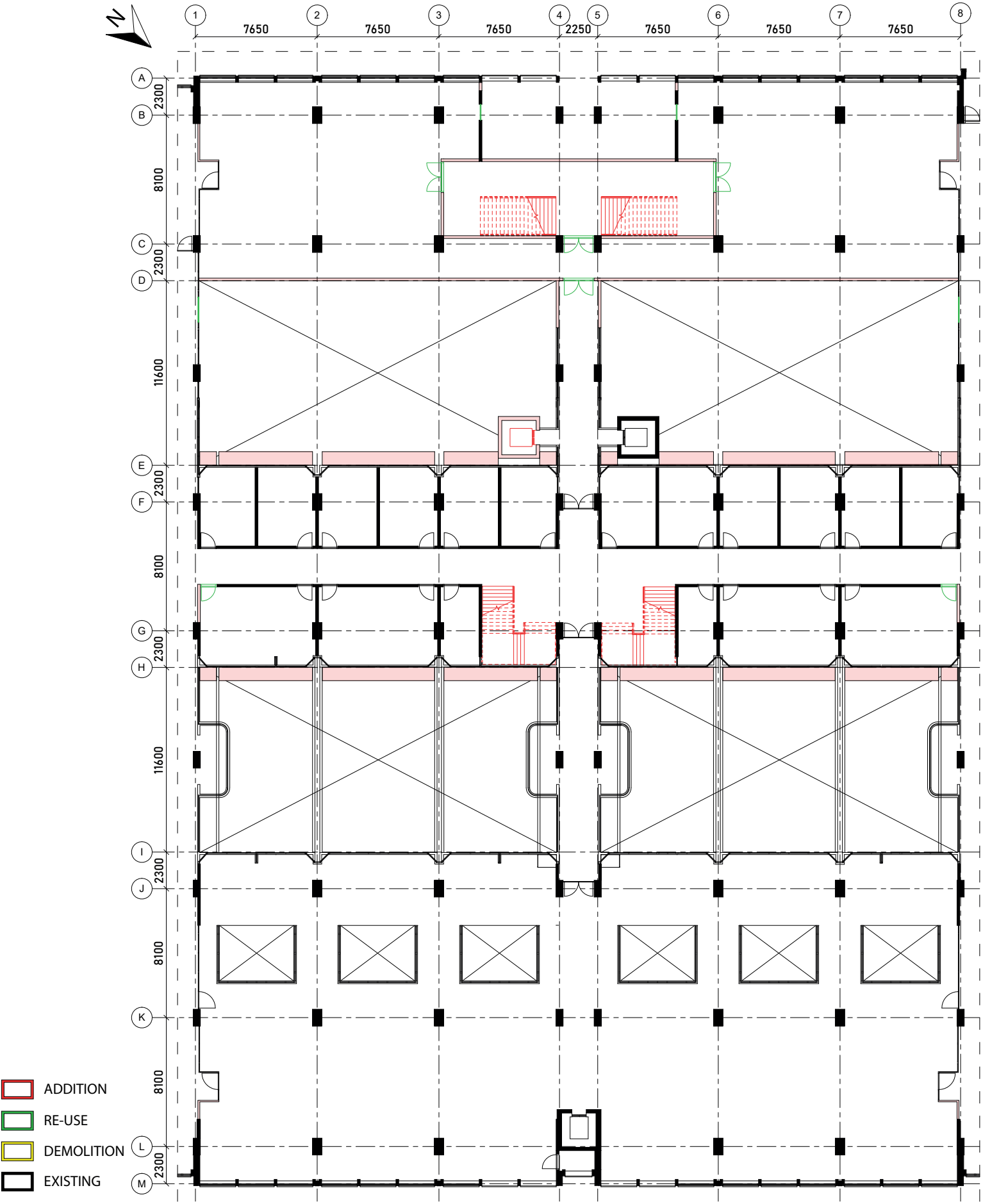
2300
RE-USE
DEMOLITION
EXISTING

STEP 3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J
K
L
M
2300
8100
2300
11600
2300
8100
2300
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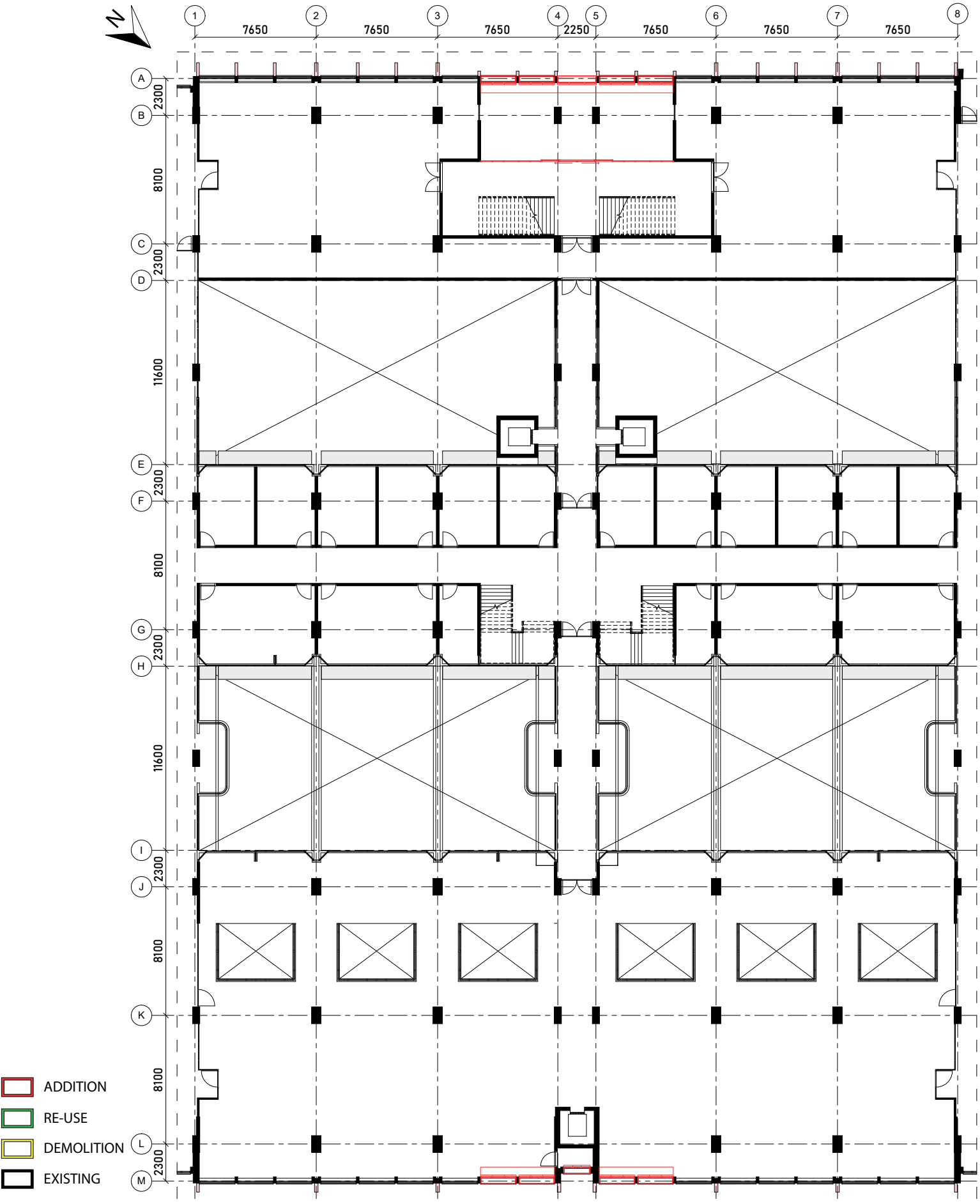
8100
2300
ADDITION
RE-USE
DEMOLITION
EXISTING

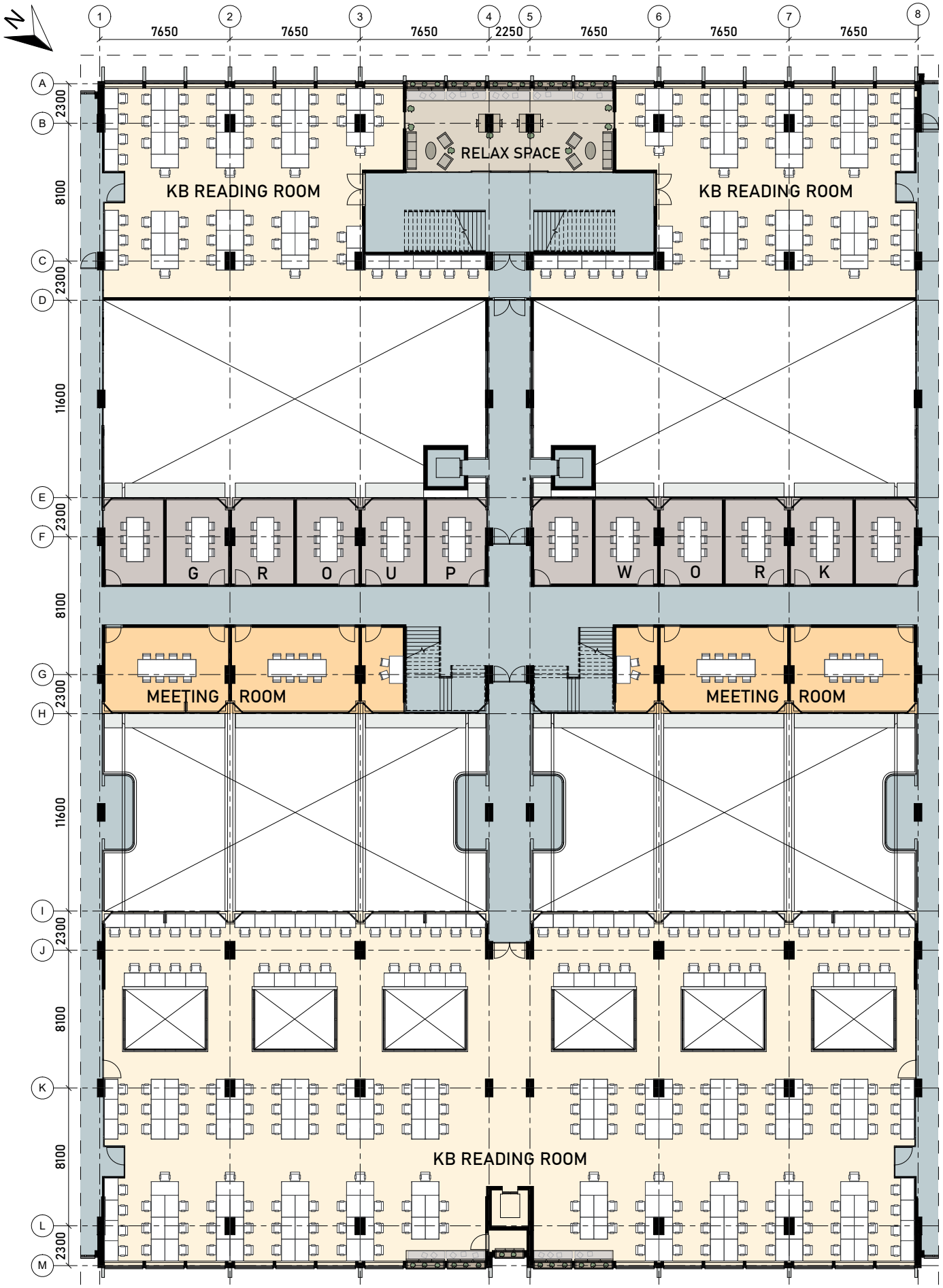
APPENDICES: Appendix N, Set of Drawings P5

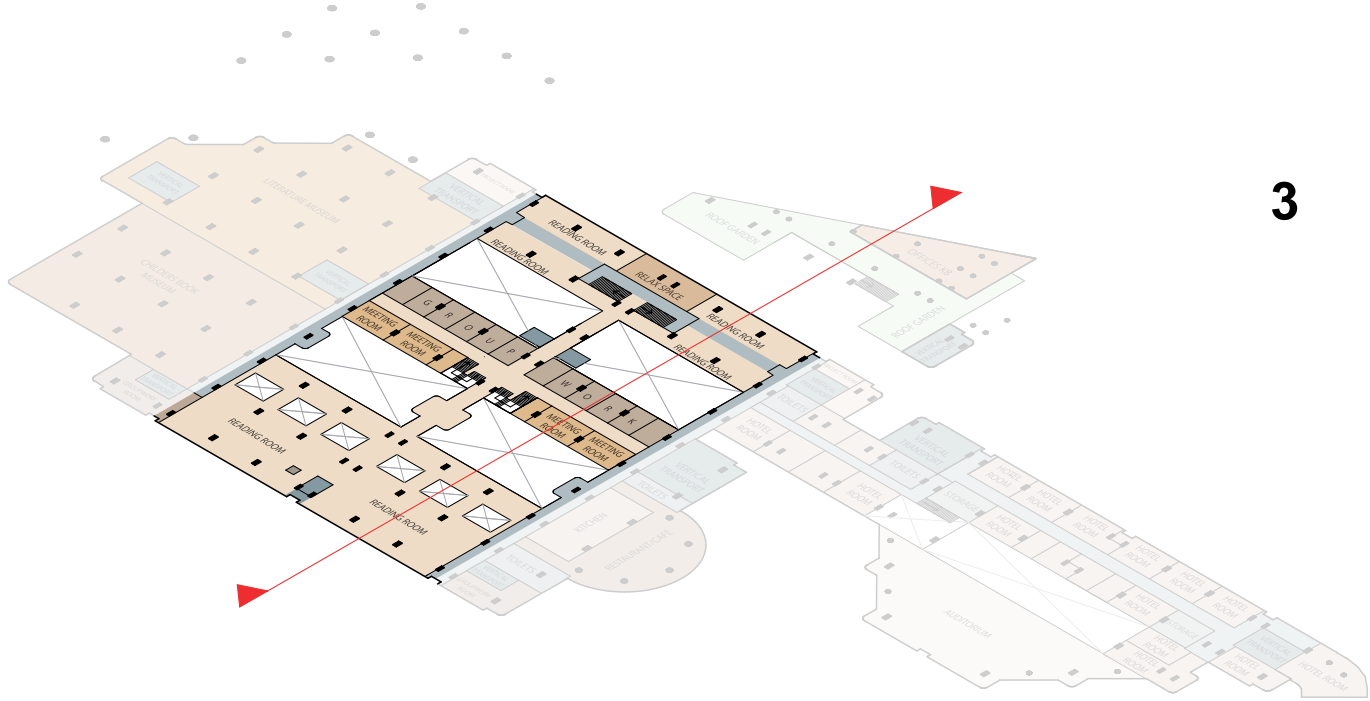
STEP 4



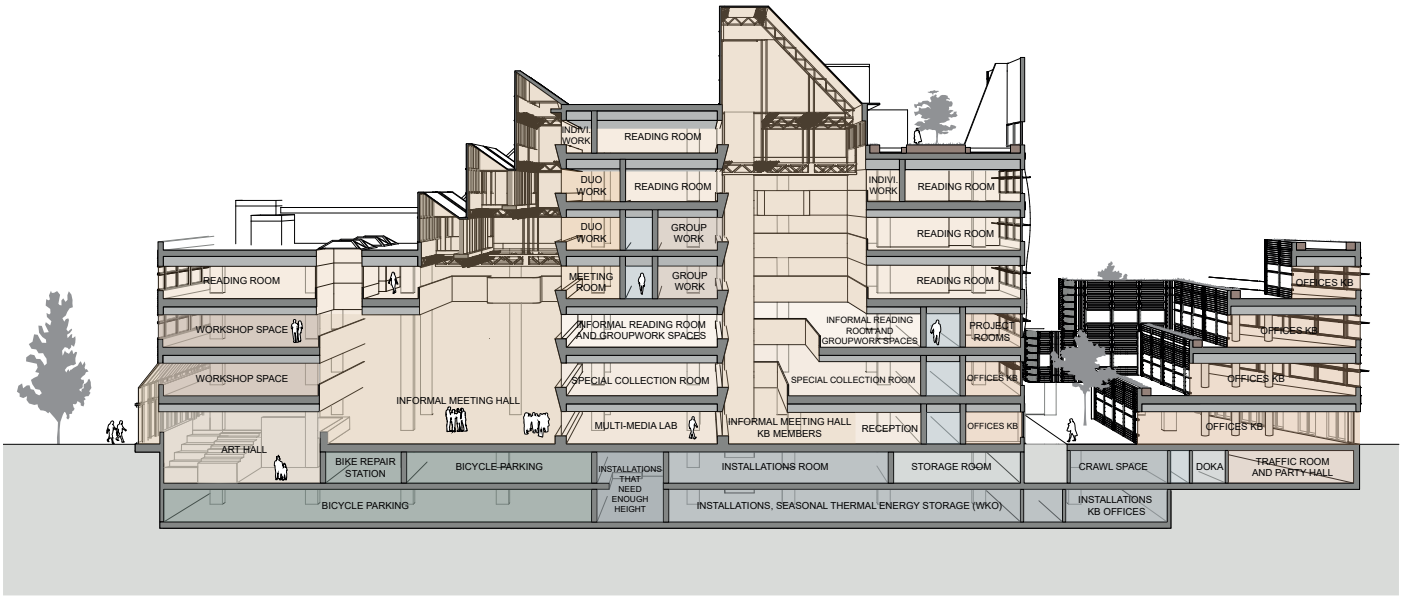
APPENDICES: Appendix N, Set of Drawings P5

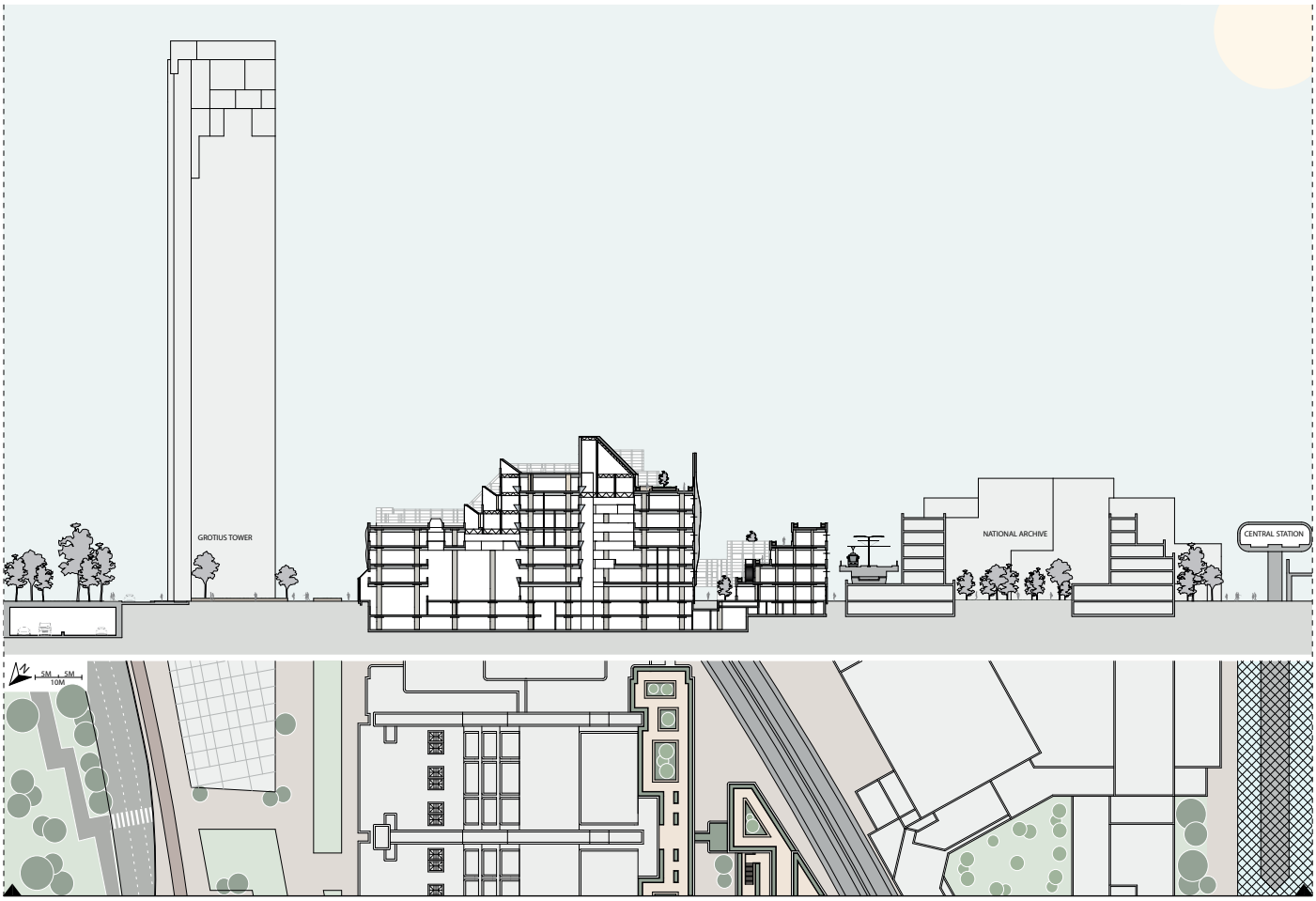
STEP 5



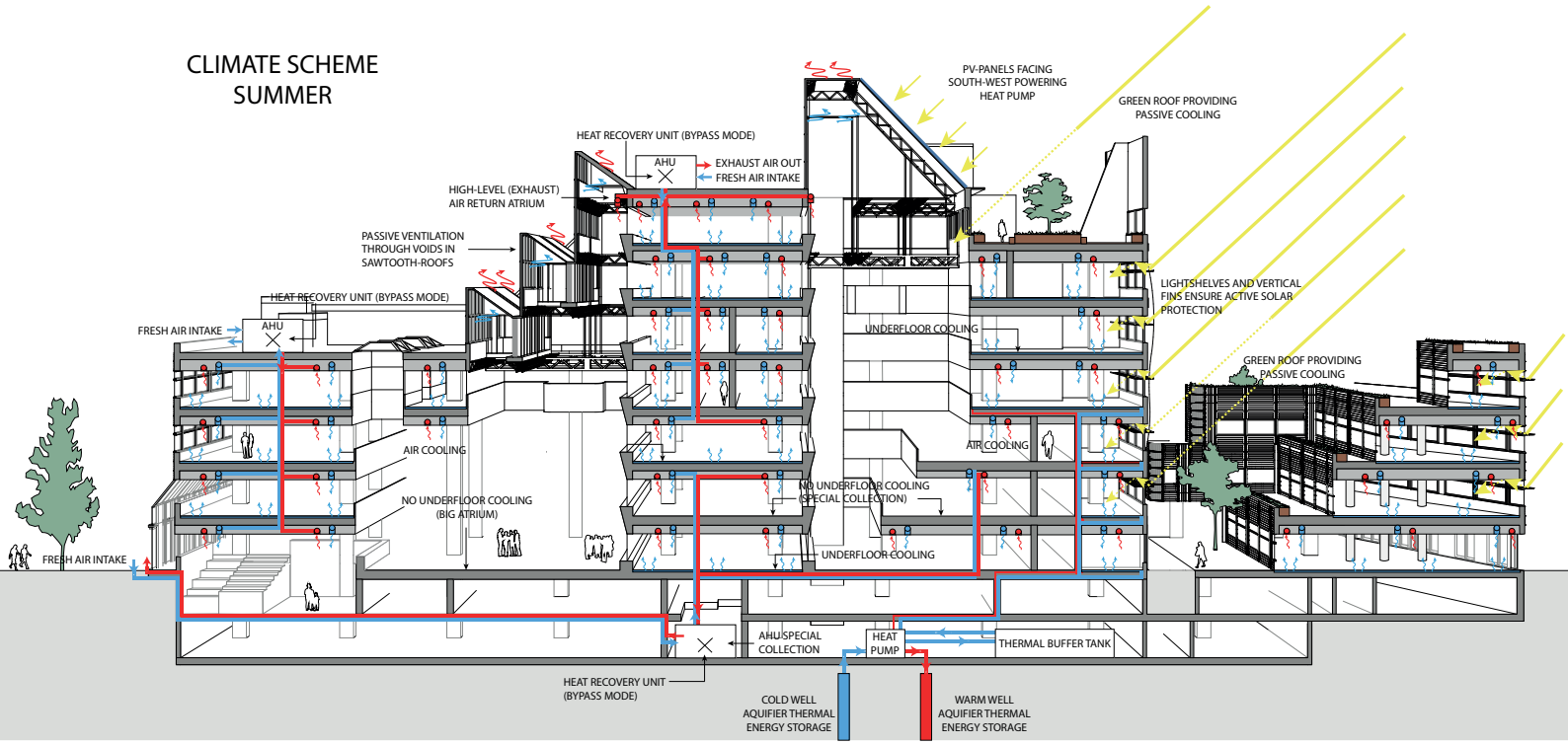

READING ROOM
RELAX SPACE
MEETING ROOM
GROUP WORK
READING ROOM
OFFICES KB
ROOF GARDEN
HOTEL ROOM
AUDITORIUM
KITCHEN
RESTAURANT/CAFE
TOILETS
VERTICAL TRANSPORT
LITERATURE MUSEUM
CHILDERS ROOK MUSEUM

3

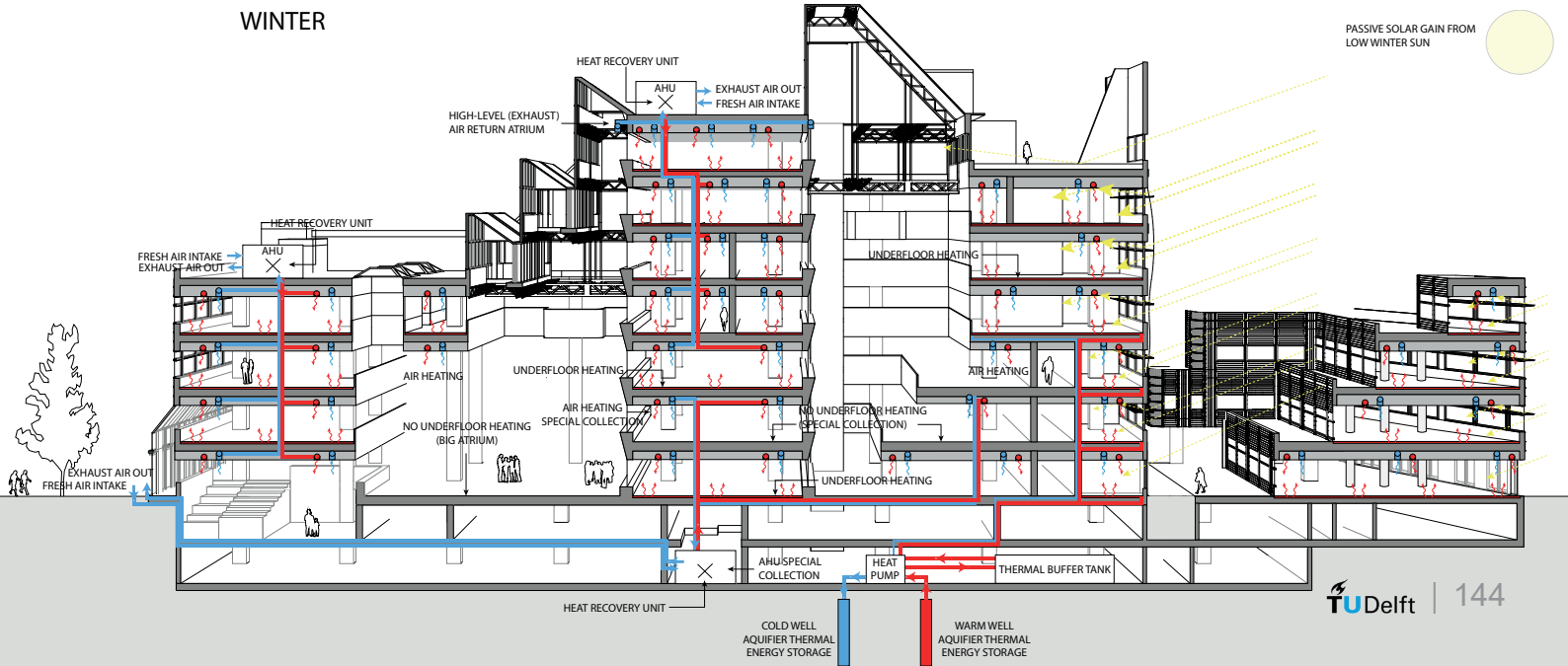

INDIVI. WORK
READING ROOM
DUO WORK
READING ROOM
INDIVI. WORK
READING ROOM
DUO WORK
GROUP WORK
READING ROOM
READING ROOM
MEETING ROOM
GROUP WORK
READING ROOM
OFFICES KB
WORKSHOP SPACE
INFORMAL READING ROOM AND GROUPWORK SPACES
INFORMAL READING ROOM AND GROUPWORK SPACES
PROJECT ROOMS
OFFICES KB
WORKSHOP SPACE
SPECIAL COLLECTION ROOM
SPECIAL COLLECTION ROOM
OFFICES KB
OFFICES KB
INFORMAL MEETING HALL
MULTI-MEDIA LAB
INFORMAL MEETING HALL KB MEMBERS
RECEPTION
OFFICES KB
OFFICES KB
ART HALL
BIKE REPAIR STATION
BICYCLE PARKING
INSTALLATIONS THAT NEED ENOUGH HEIGHT
INSTALLATIONS ROOM
STORAGE ROOM
CRAWL SPACE
DOKA
TRAFFIC ROOM AND PARTY HALL
BICYCLE PARKING
INSTALLATIONS, SEASONAL THERMAL ENERGY STORAGE (WKO)
INSTALLATIONS KB OFFICES

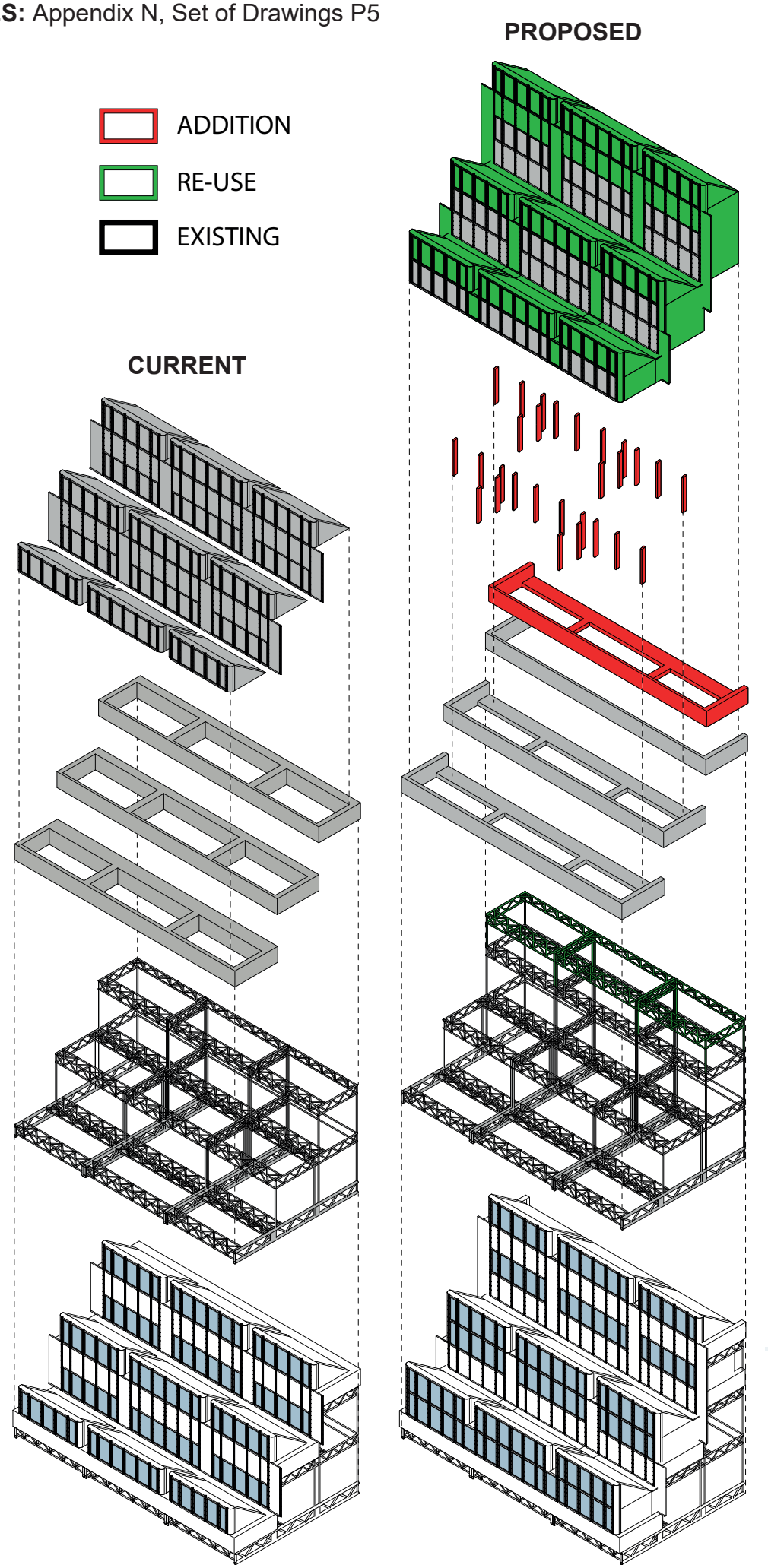

GROTIUS TOWER
NATIONAL ARCHIVE
CENTRAL STATION
5M 5M
10M

CLIMATE SCHEME SUMMER



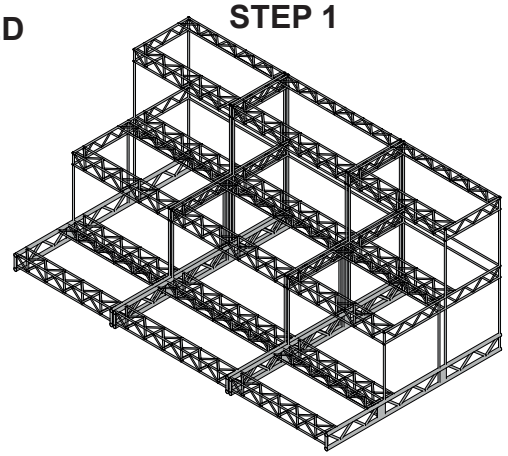
CLIMATE SCHEME WINTER




PROPOSED
ADDITION
RE-USE
EXISTING
CURRENT

PROPOSED

STEP 1



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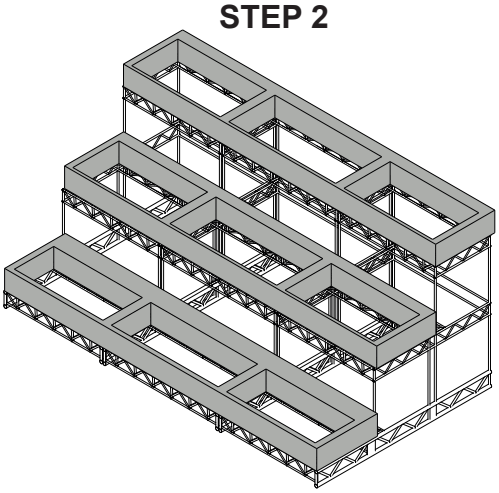
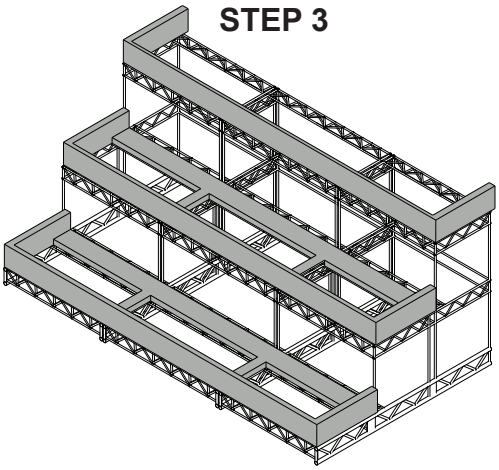
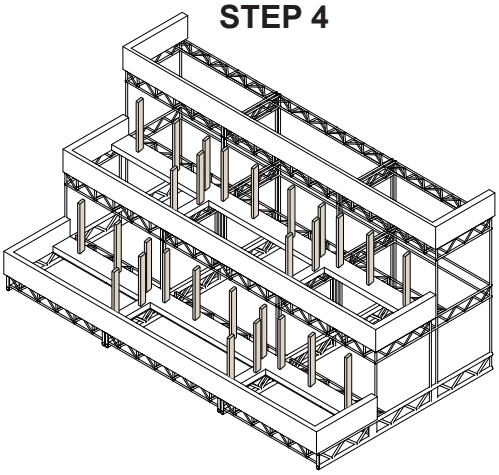


STEP 3



STEP 4



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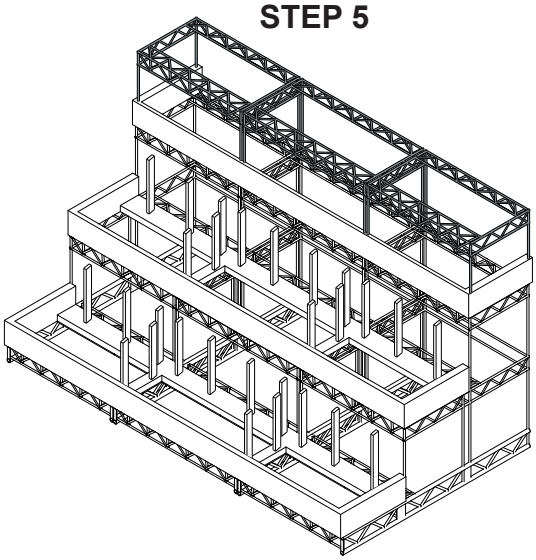

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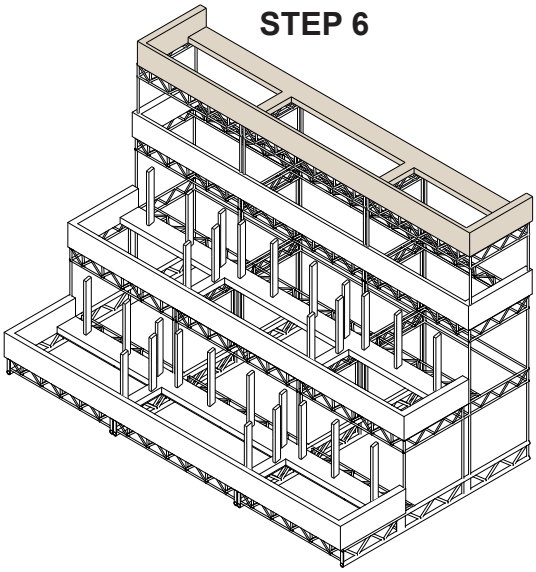

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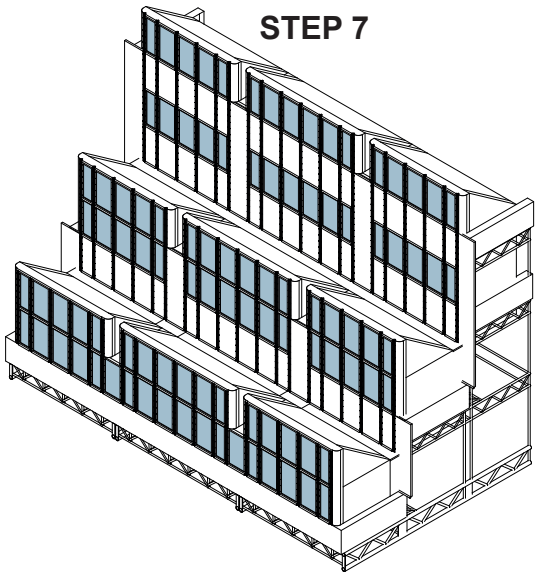
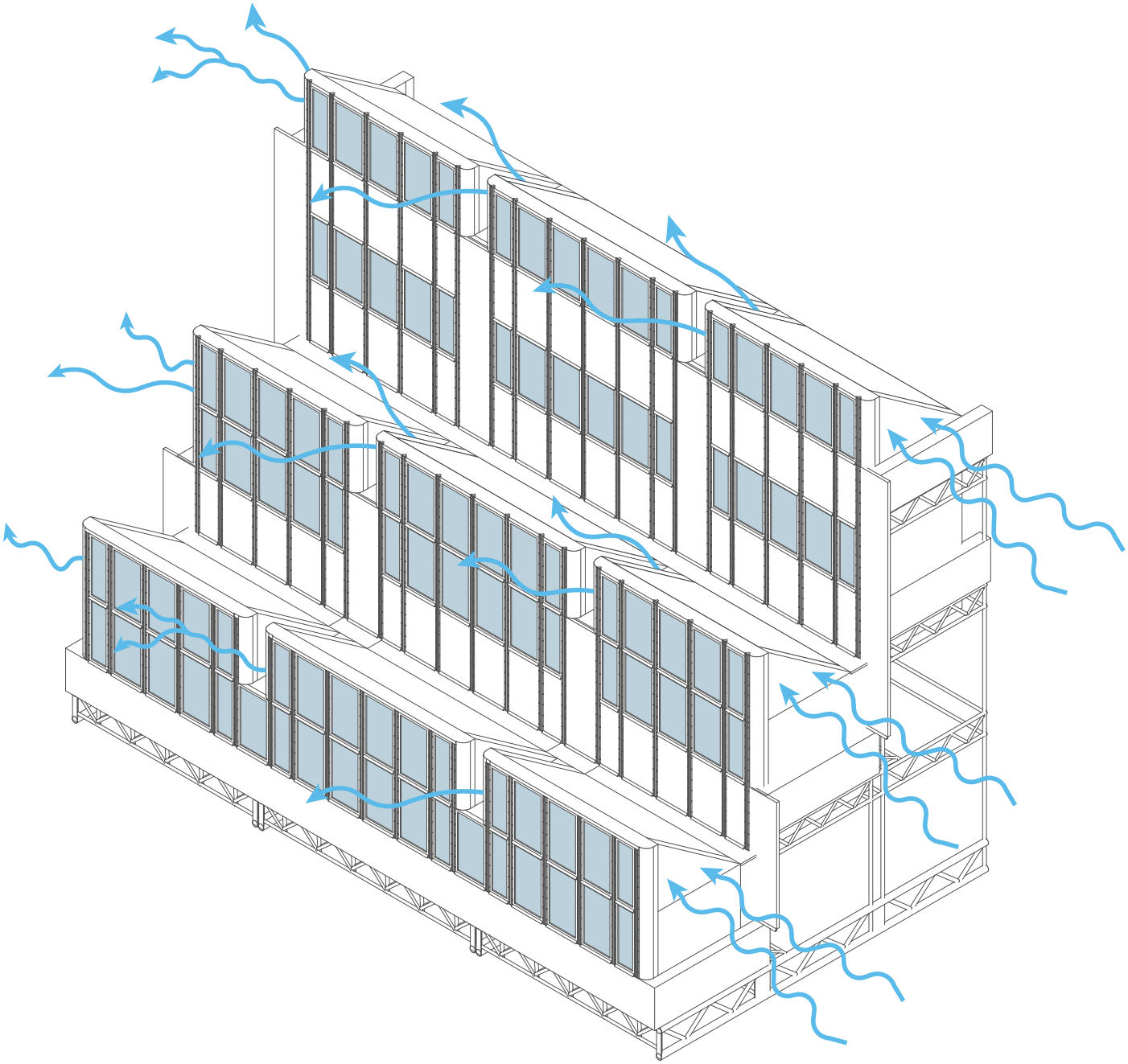
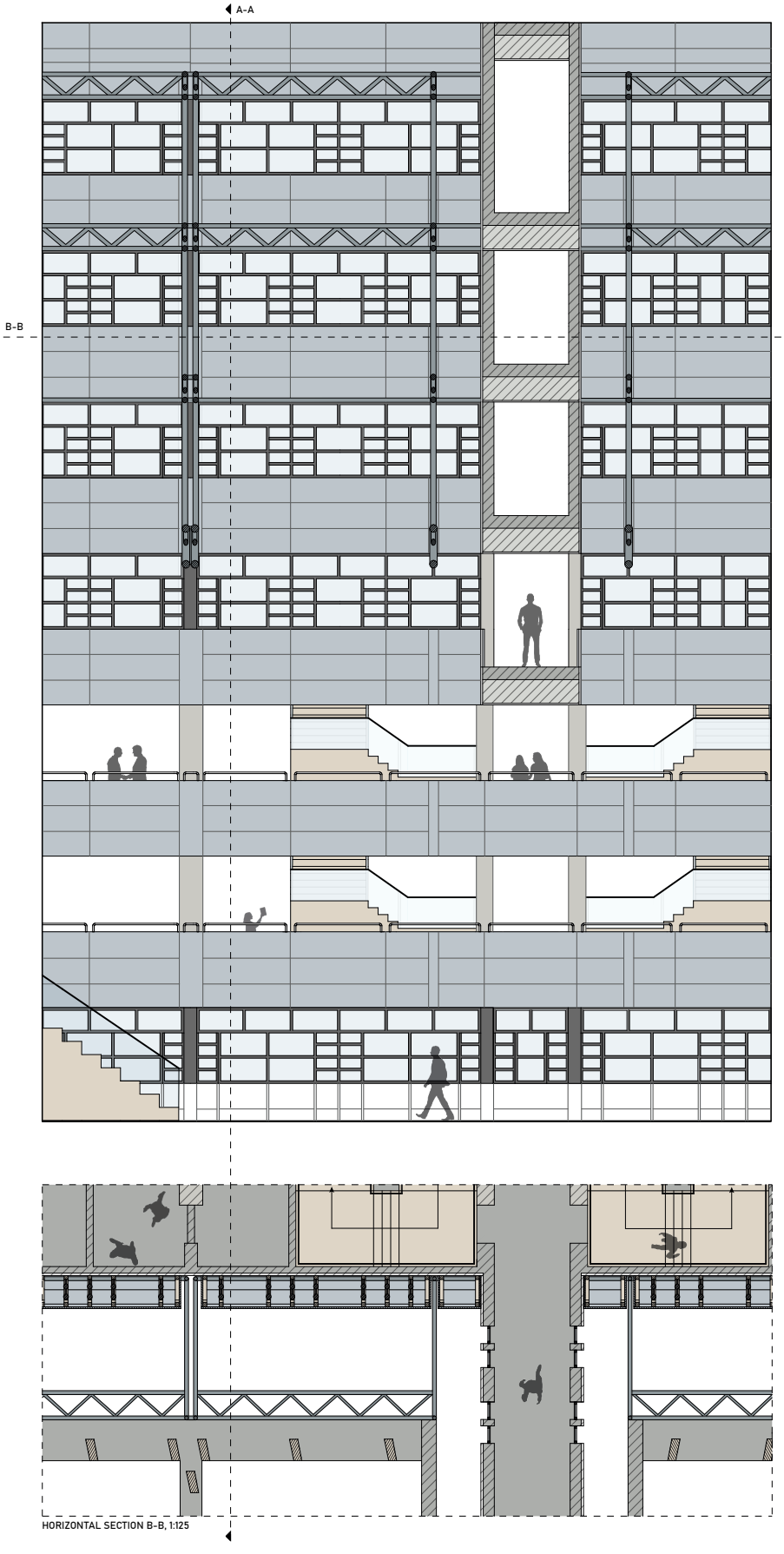
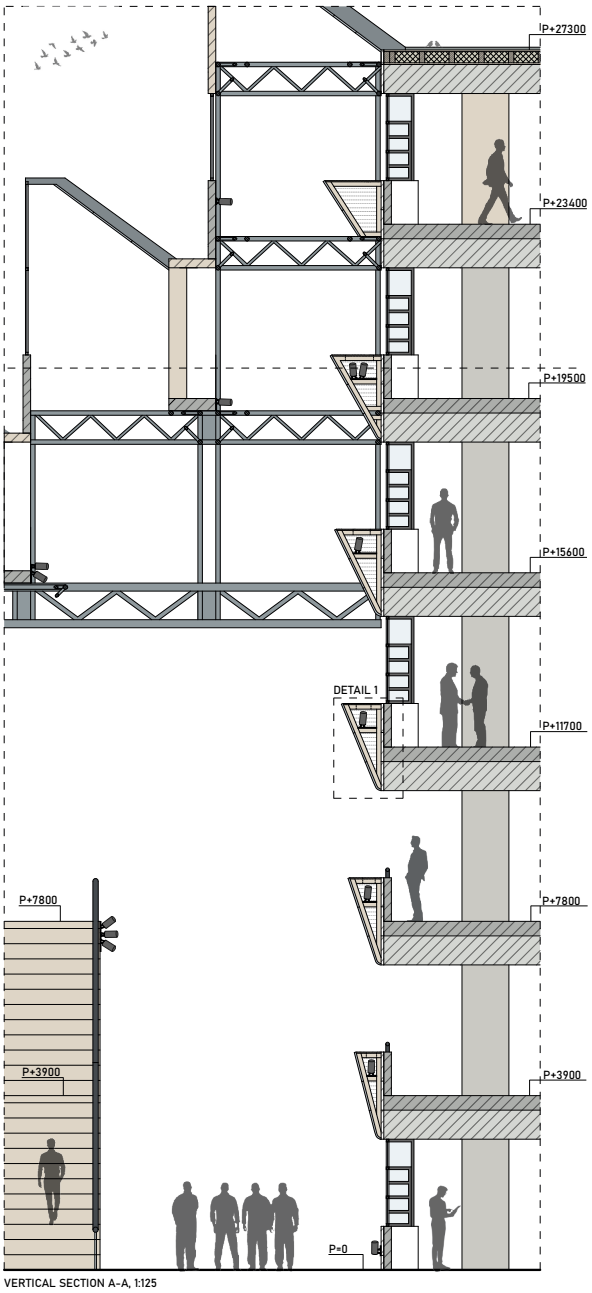


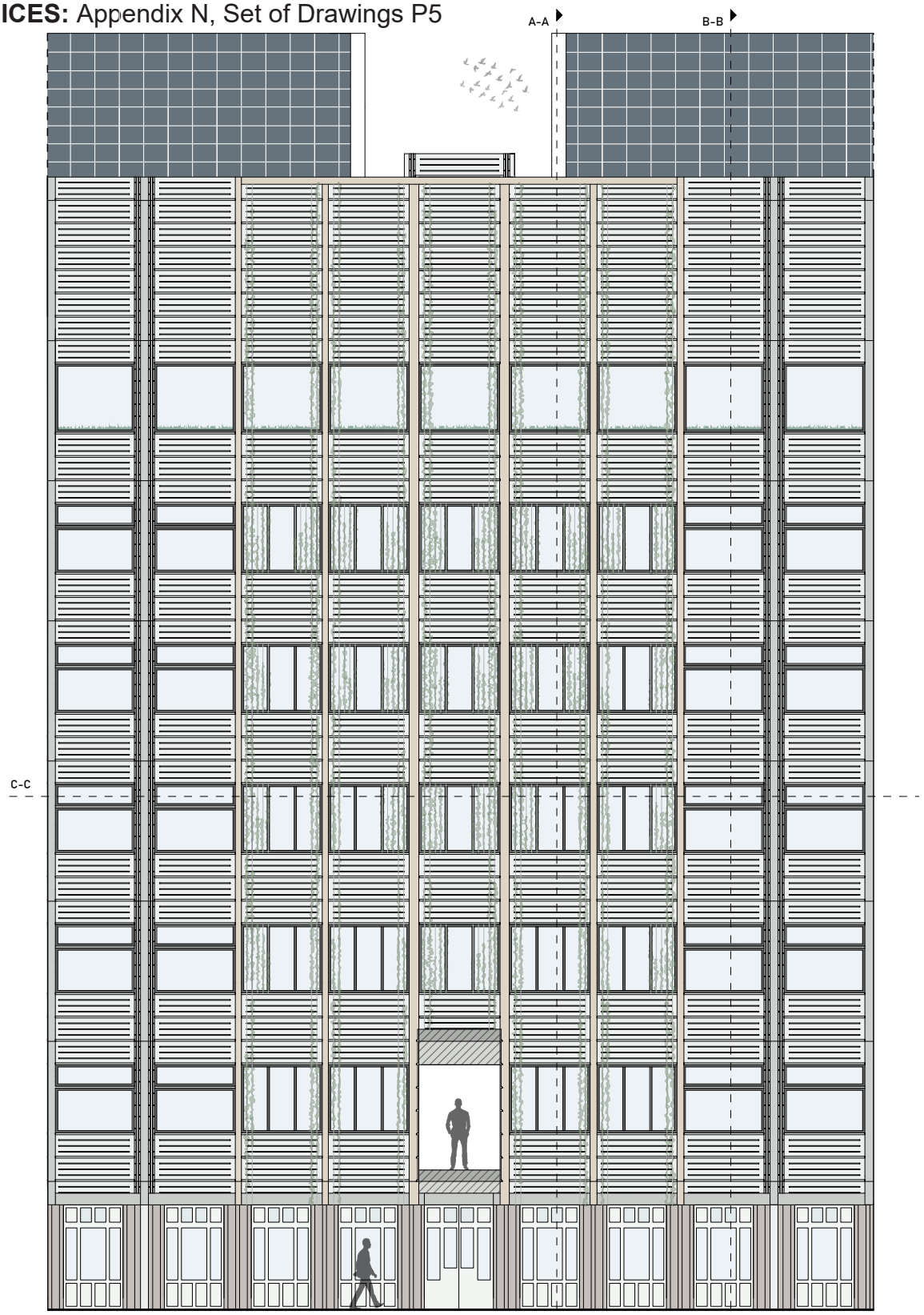


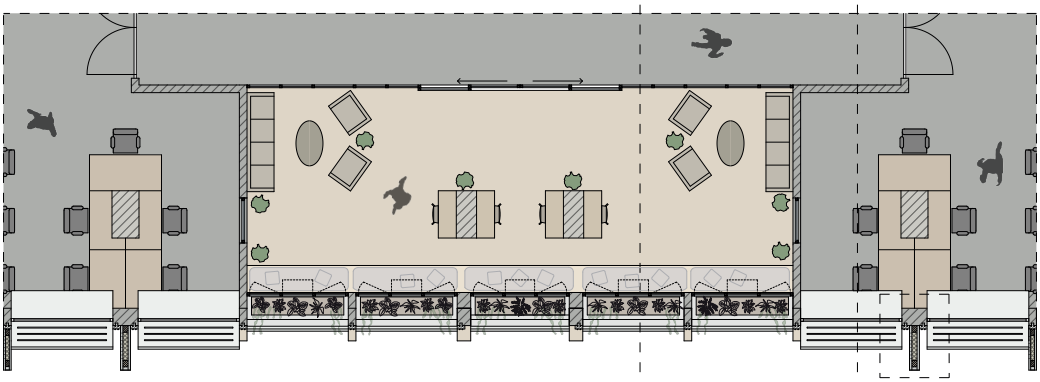


HORIZONTAL SECTION B-B, 1:125

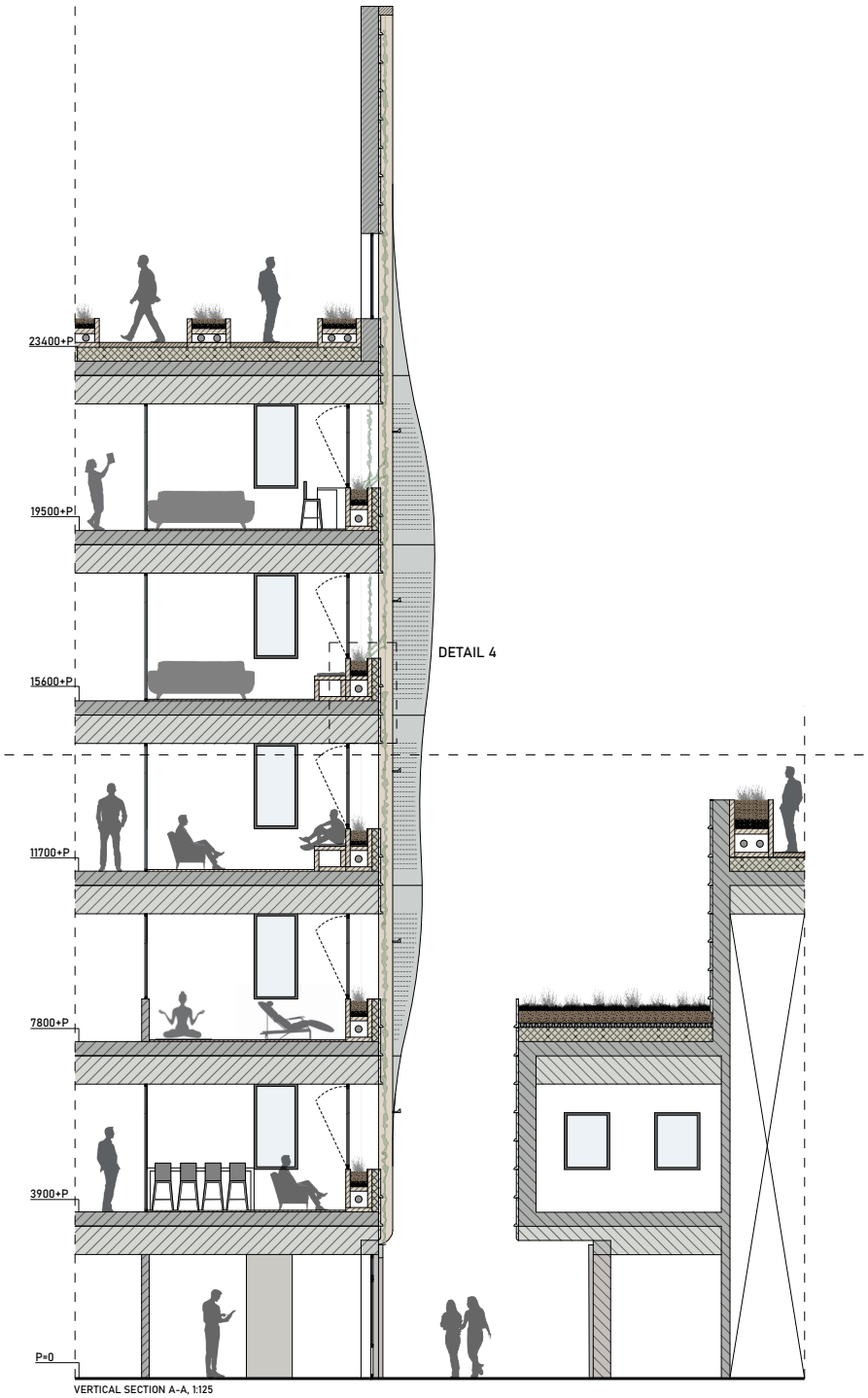


VERTICAL SECTION A-A, 1:125





HORIZONTAL SECTION C-C, 1:125



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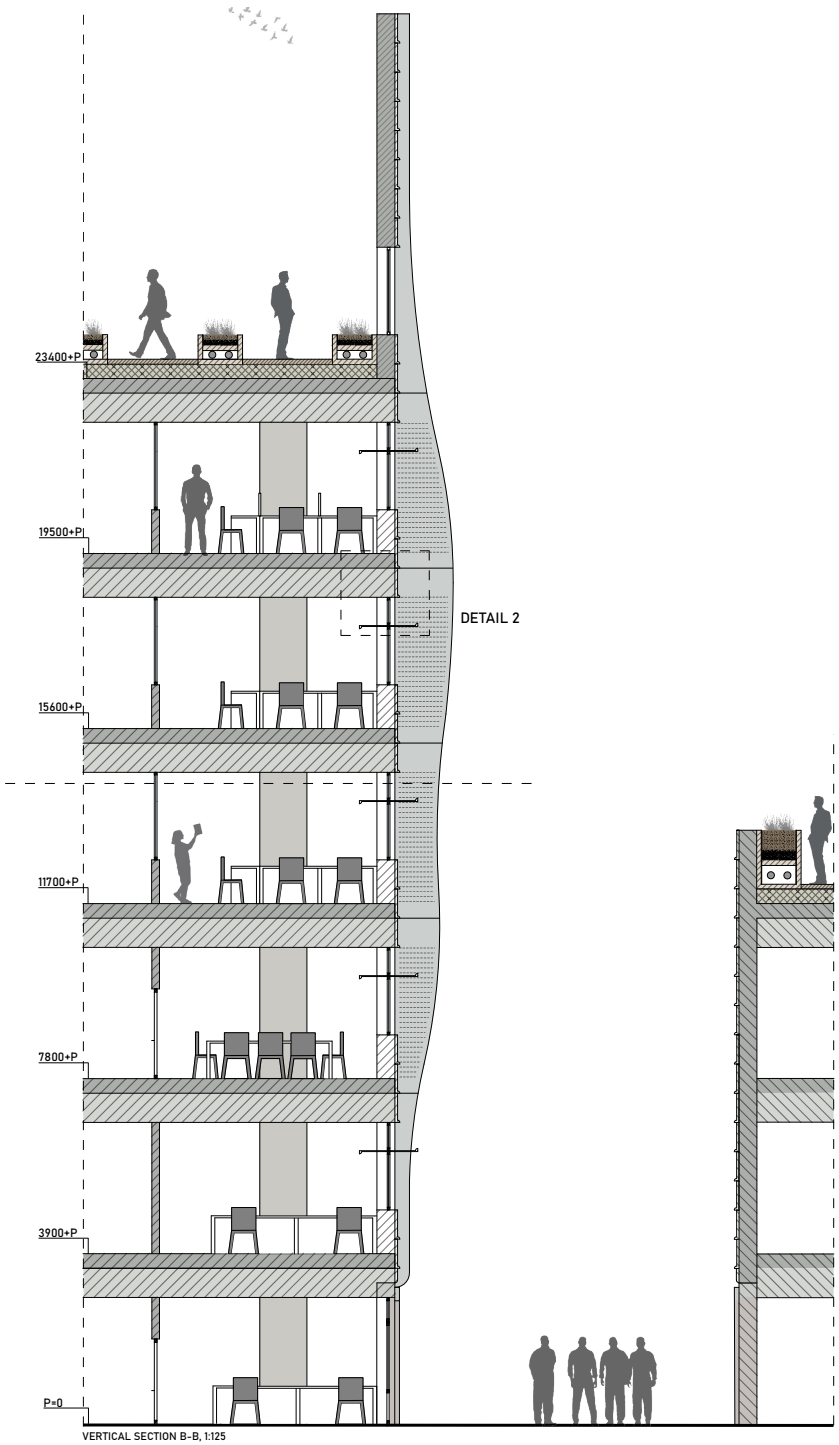
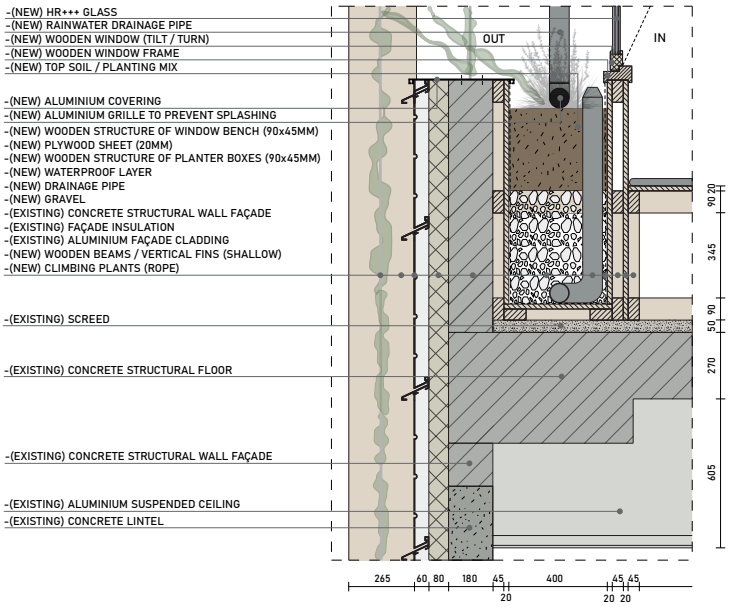
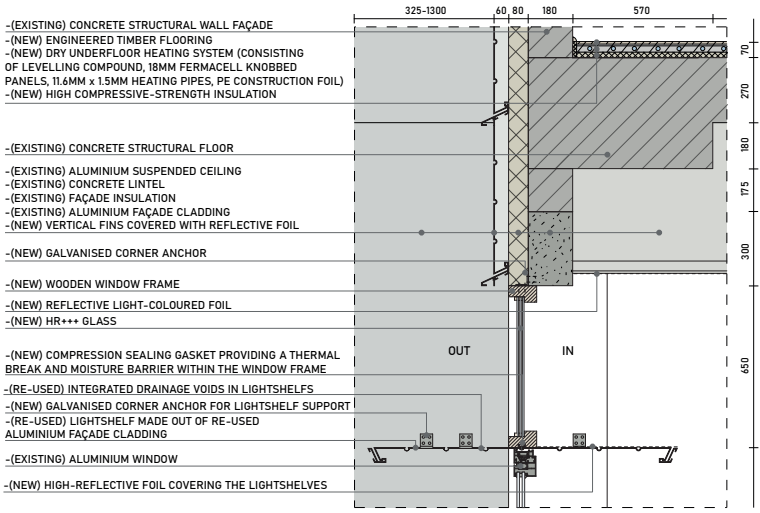


VERTICAL SECTION B-B, 1:125

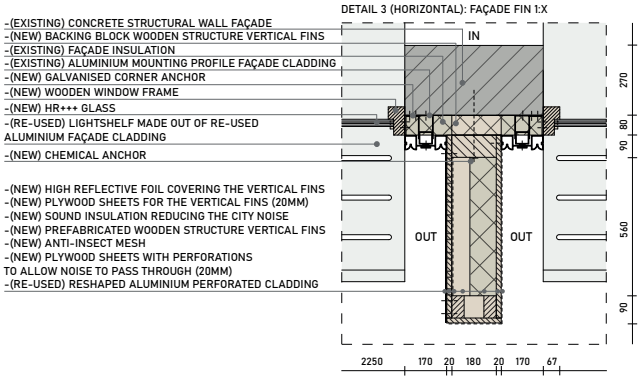
DETAIL 4 (VERTICAL): FAÇADE PLANTER BOX 1:X



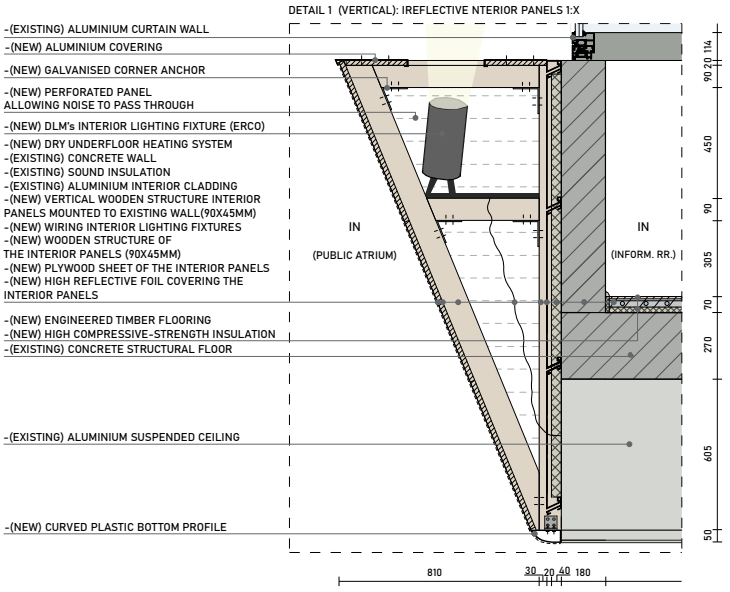
DETAIL 2 (VERTICAL): LIGHT-SHELF FAÇADE 1:X



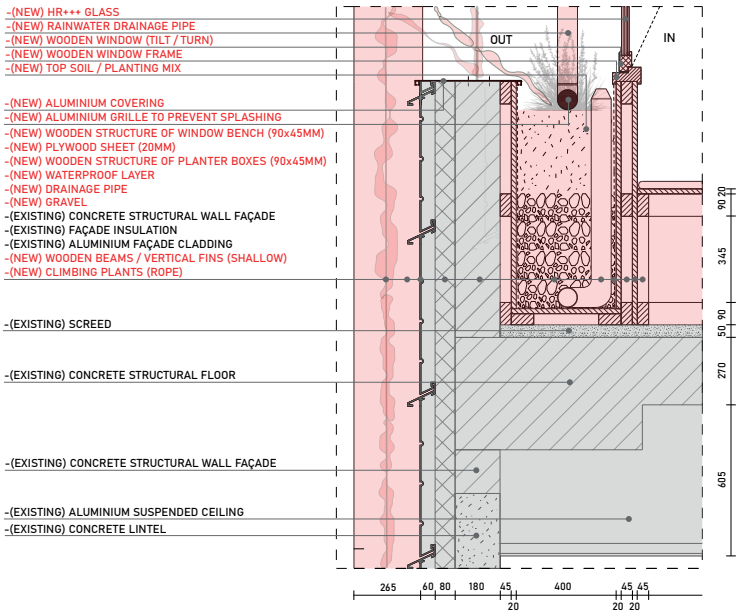
DETAIL 3 (HORIZONTAL): FAÇADE FIN 1:X



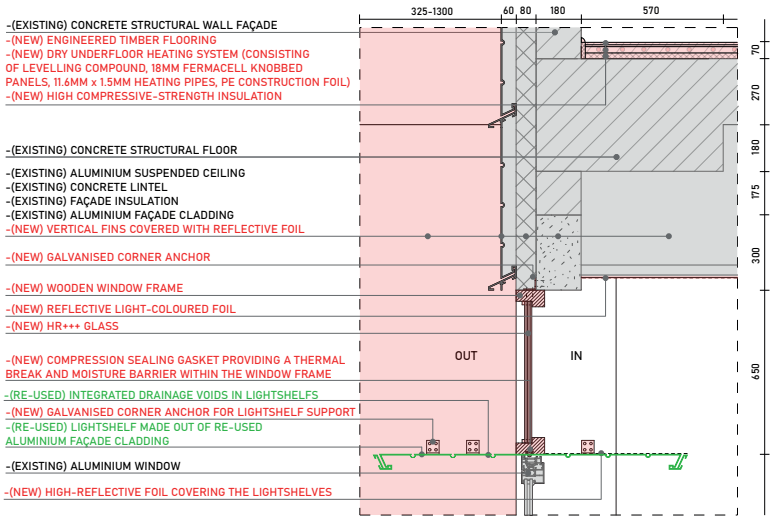
DETAIL 1 (VERTICAL): IREFLECTIVE NTERIOR PANELS 1:X



DETAIL 4 (VERTICAL): FAÇADE PLANTER BOX 1:X



DETAIL 2 (VERTICAL): LIGHT-SHELF FAÇADE 1:X



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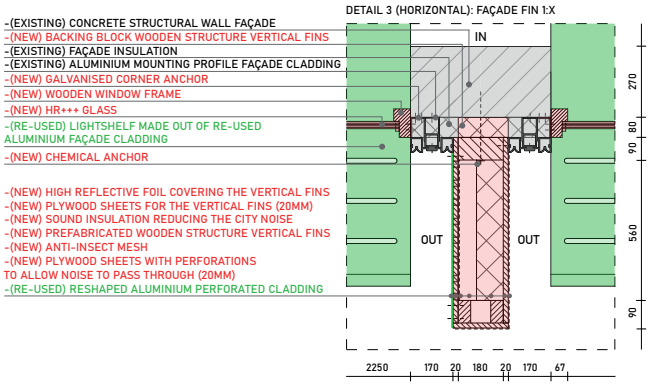
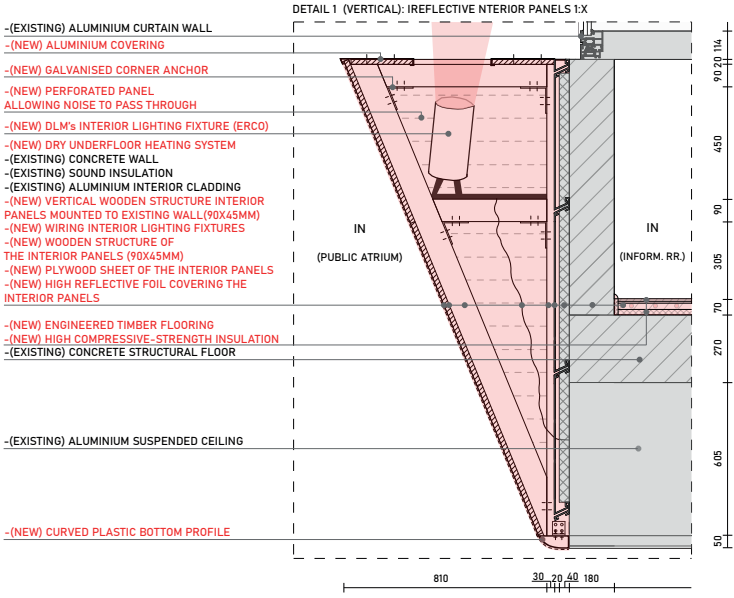


DETAIL 1 (VERTICAL): IREFLECTIVE NTERIOR PANELS 1:X



ADDITION

RE-USE

EXISTING

















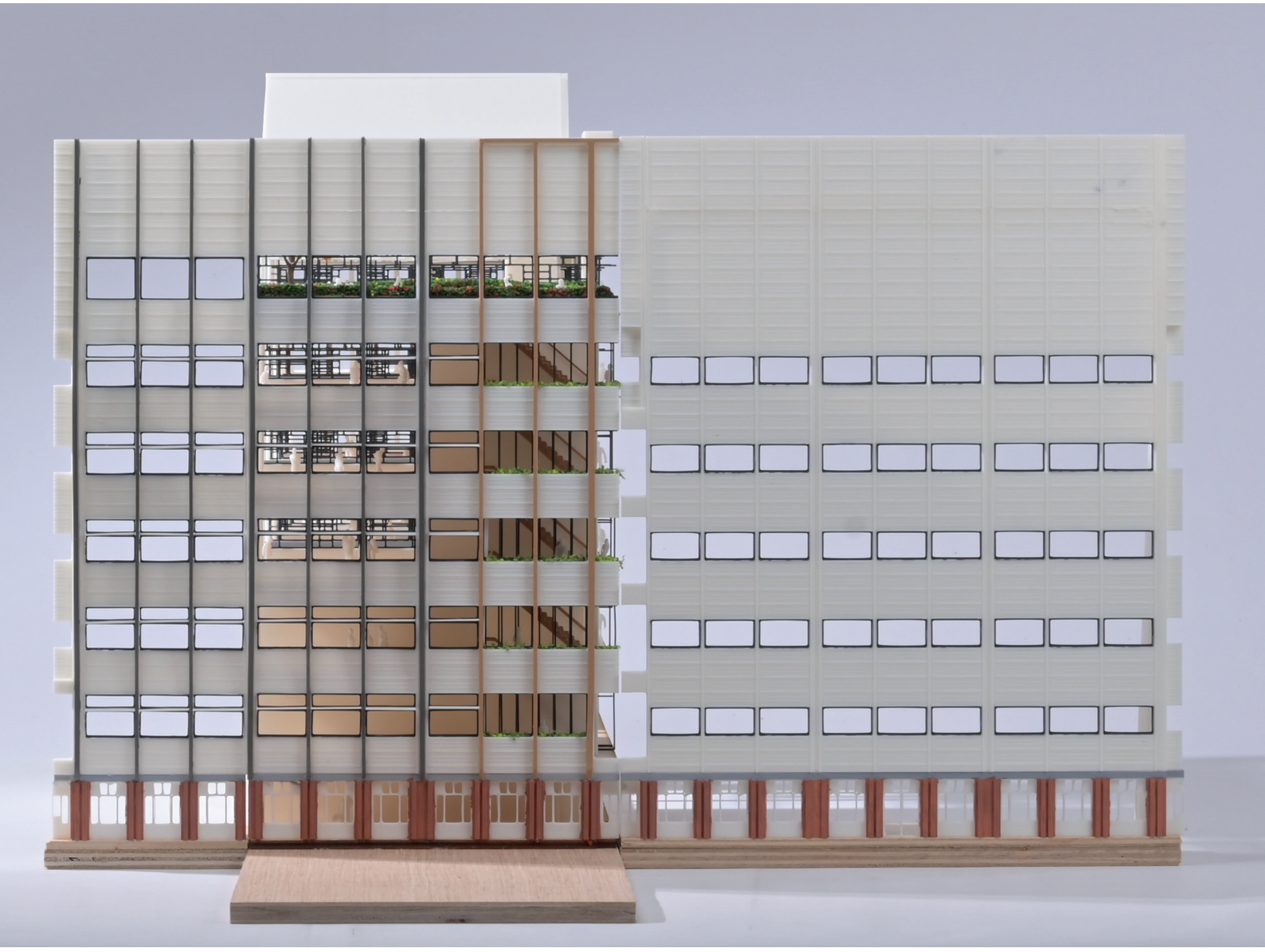




















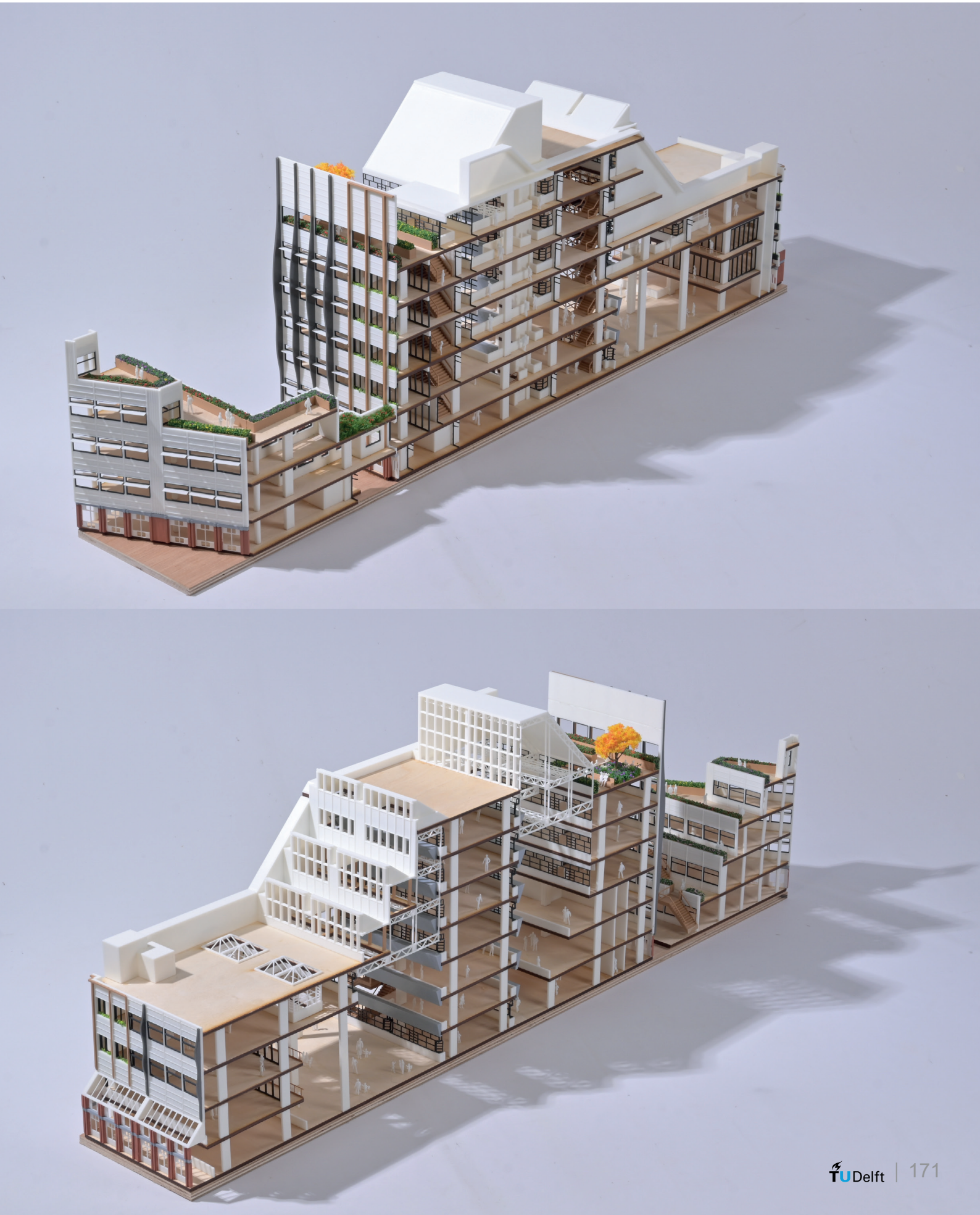



















TUDelft





















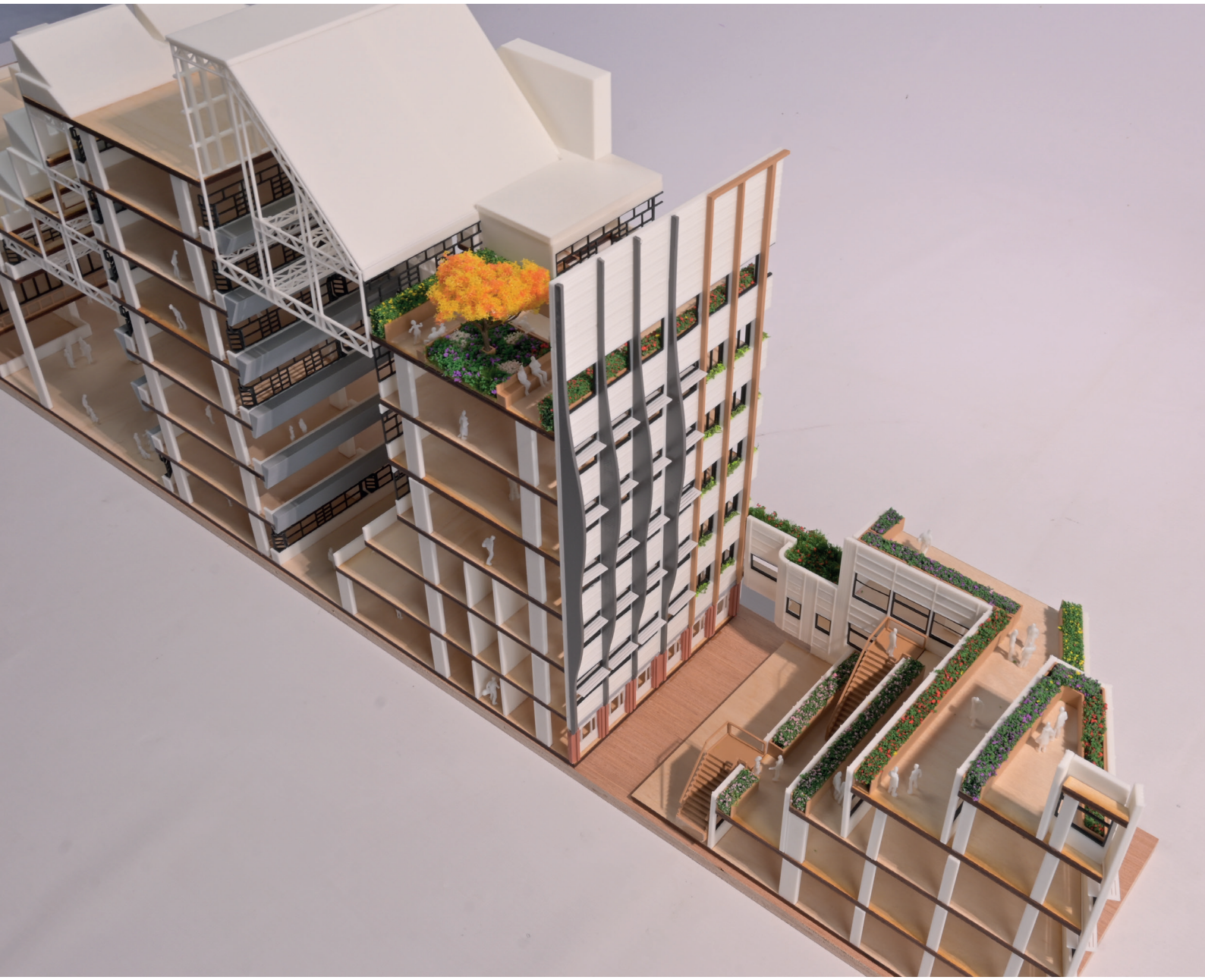


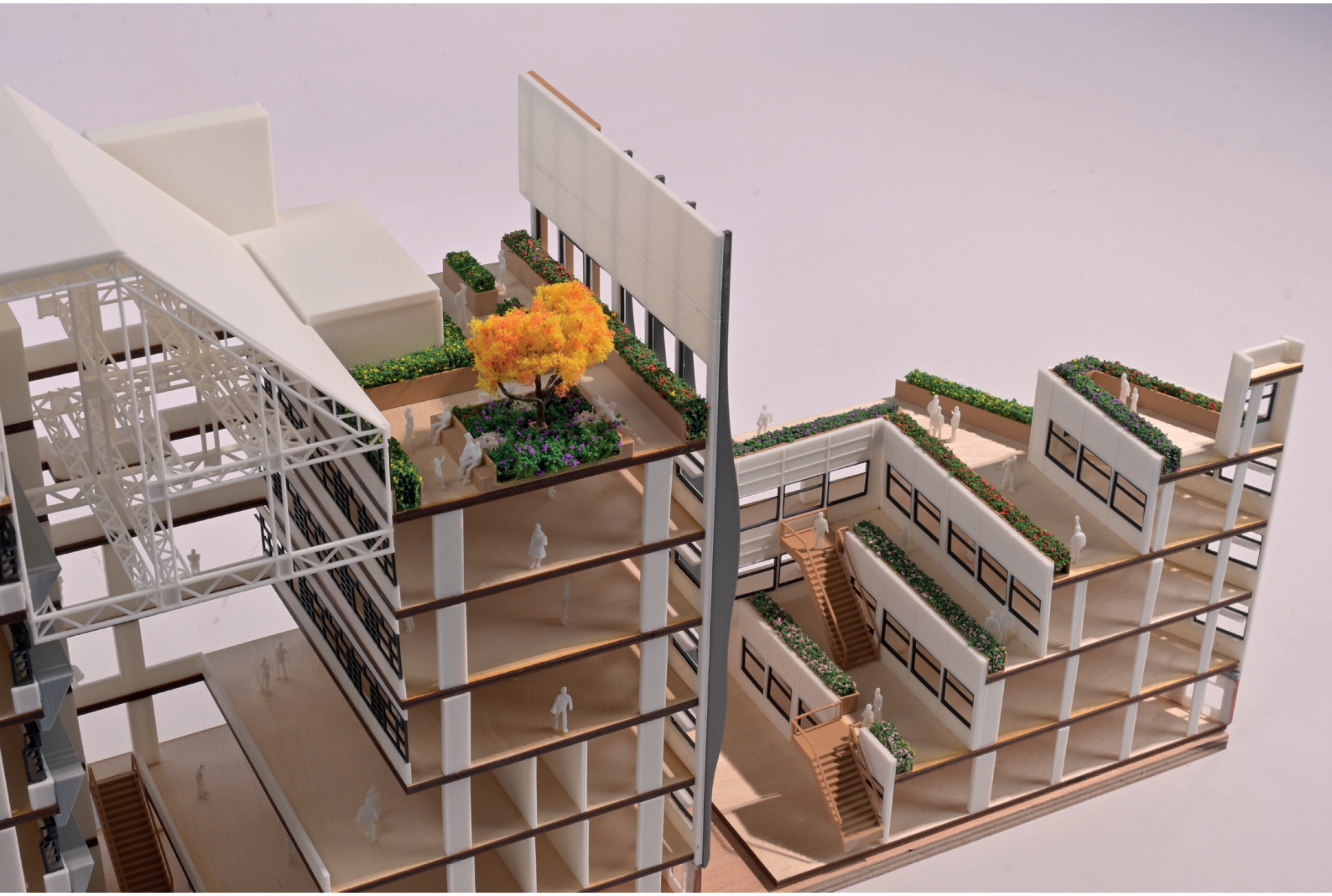













TU Delft





















