GRÖN

VISITOR CENTRE FOR RENEWABLE ENERGY

ARCHITECTURE & DESIGN
MASTER THESIS
MSc04-ARK9, MAY 2021

CAMILLA CHRISTINA EDEN, CAROLINE TORDRUP ELKJÆR, CHRISTIAN IRMING FRIIS BUHL

0.0 TITLE PAGE

INSTITUTION	AALBORG UNIVERSITY FACULTY OF IT AND DESIGN DEPARTMENT OF ARCHITECTURE, DESIGN AND MEDIA TECHNOLOGY
PROGRAMME	ARCHITECTURAL DESIGN 2021
TITLE	VISITOR CENTRE FOR RENEWABLE ENERGY
THEME	SUSTAINABLE TECTONICS
PROJECT	MASTER THESIS 2021
GROUP	MA4-ARK9
SUPERVISOR	ZAKARIA DJEBBARA POSTDOC, PHD, CAND.POLYT.ARCH
THESIS PERIOD	02.02.2021 - 27.05.2021
NO. OF PAGES	151
AUTHORS	CAMILLA CHRISTINA EDEN CAROLINE TORDRUP ELKJÆR CHRISTIAN IRMING FRIIS BUHL

AALBORG UNIVERSITY

0.1 ABSTRACT

This thesis details the process of developing a proposal for a Visitor Centre for Renewable Energy to be located at harbour promenade at Kanalbyen in Fredericia in southern Denmark. A theoretical and methodological approach is introduced in the first part of the thesis, based on tectonic, phenomenological and sustainable theory about affecting user behavior. These theories are expanded upon and contextualised through a series of case studies into three focus areas: responsibility. mediation and awareness, which become the basic drivers in the design of the centre. The analysis puts an emphasis on the need for gesturing the user through affordances, which are integrated into the structural system using wood as a sustainable construction material. In the final design these affordances are realised as curvilinear geometries, drawing upon phenomenological principles to create engaging kinaesthetic experiences on the exterior and interior of the building. The result is a curved roof shape that meets the ground to the north and south, inviting visitors as well as passers-by to take a stroll and enjoy a breathtaking view of Lillebælt and experience the building's solar panels at close hand. The exhibition thus transcends the limits of the building volume and expands into the urban space seeking to invoke a greater sense of environmental awareness.

0.2
PREFACE

This thesis is our final project as part of our education at Aalborg University as civil engineers in architecture and design. As we live in a world, which is increasingly threatened by climate change, we want to be part of the solution and dedicate our thesis to a project with the theme of sustainable development. With our specialisation in tectonic design and personal interest in how architecture can be used to shape and influence human behaviour, this thesis describes our initial analyses, our process and finally a resulting architectural design as our attempt at combining those three fields into a cohesive whole. This thesis is our contribution to the ongoing challenge of climate change and we hope that our process, reflections and findings can inspire and inform solutions for mediating sustainable development and technologies within the field of architecture.

Camilla Christina Eden, Caroline Tordrup Elkjær & Christian Irming Friis Buhl
May, 2021

ACKNOWLEDGEMENTS

We would like to acknowledge **Zakaria Djebbara**, our supervisor at Aalborg University during the project period. He has with his competencies within the field of Architecture and Design, and vast knowledge of topics related to and including phenomenology, been a great source of inspiration, as well as critique, guidance and feedback.

A SPECIAL THANKS TO

Christina Aabo, Head of Research and Development at Ørsted, for a great interview early in the design process and for helping us define our problem space and our priorities in this thesis.

Ellen Marie Fonvig, development consultant at 'Det Grønne Rum', for responding so quickly and enthusiastically to our initial inquiry and for helping us get in contact with Fredericia Municipality.

Tommy Lykke Pedersen, senior SCADA PM at Ørsted A/S, for an insightful, and very needed, insight into the world of energy production distribution as well as for putting us in contact with Christina Aabo

Gitte Lyager Ryan, environmental consultant and project leader at Fredericia Municipality for an interesting interview and discussion, with great insight into the current sustainable strategies and development plans of the municipality, as well as providing research and development material for further defining and developing our master thesis.

0 . 3

CONTENTS

MASTER THESIS

1.0
PROLOGUE

1 . 1

MOTIVATION

THE CLIMATE IS CHANGING - WHAT NOW?

Climate change is one of the most relevant, crucial and extensive challenges we face in the modern world today. As of recent, and, finally, this has also become increasingly apparent on a political level. In accordance with the United Nations 2015 Paris Agreement, Denmark has declared a goal to be independent of fossil fuels by 2050[1], yet immediate action is required to achieve this objective. From 1990 to 2017, Denmark's energy consumption from renewable sources has increased from 7,1 % to 34,2 %[2]. However, our total energy consumption has simultaneously increased, thus it is apparent that more effort is necessary[3].

It is a recognised fact that Denmark pioneers within renewable energy technologies, being the originator of globally recognised corporations such as Ørsted A/S, Vestas Wind Systems A/S and Siemens Gamesa Renewable Energy A/S, all of which are concerned with the development of various forms of renewable energies. In order for renewable energy to become the standard way of producing energy, both in terms of domestic and industrial purposes, we as a society need to support the development of new technologies within this field through educational programmes, political initiatives and investments, and education of the general public.

As architects and engineers, the way we express ourselves and put our ideas into the world, is through the built environment and its effect on the users and the context surrounding it. We are aware that the environmental impact of a single building is very limited compared to the scale of climate change, no matter its level of sustainability. Our motivation and approach in this project is instead focused on users of the building, seeking to explore how to best inform and engage these to help combat climate change. Through a conjunctural approach to design, we want to explore how architecture can both affect the users' experience and awareness spatially, sensorially and narratively through an application of tectonic and phenomenological theory combined with sustainable principles.

1 Klima- Energi- og Forsyningsministeriet (n.d.) *Vedvarende energi*

2 Ibid.

3 Wanscher, H. M. (2020) *Fakta om Danmarks udledning af drivhusgasser samt energiforbrug.* Danmarks statistik

1 . 2

VISION

THE EXTENT OF OUR PROJECT

The vision for this master thesis is a Visitor Centre for Renewable Energy that facilitates communication of renewable technologies, along with their impact and development. Larger corporations with an interest in green energy should be able to purchase a share of the centre and utilise its facilities to promote their work to investors. The building should include spaces for exhibition and experimentation for visitors across a wide span of age and educational level. The exhibition should mediate a macro-narrative concerning energy systems and subsequently focus on strengthening the interests of STEM-subjects (Science, Technology, Engineering and Mathematics) in children and young people.

Situated in the new urban development Kanalbyen in Fredericia, our aspiration is for the centre to become an integral part of the coming local community, working in cooperation with the many companies in and around the Triangle Region concerned with green fuels, ultimately aiming to raise awareness on the theme of sustainability and the ever-growing need for a greener future. More specifically, the ambition is, through interaction and engagement, to secure future workforce, commence behavioural changes and become a beacon for the ongoing development of renewable energy nationally and internationally.

MEDIATION // A playful approach to architecture and learning

AWARENESS // An engaging and welcoming architecture both in exterior and interior

RESPONSIBILITY // A tectonic and sustainable approach to structure and materials

1.3

SETTING

DEVELOPMENT OF A FUTURE-PROOF CITY

This text presents an outline of the history of Fredericia, aiming to provide a contextual understanding of the site, as well as how it has been and will be developed in the future.

The historic city of Fredericia in the Southern part of Jutland can be dated back to the midst of the 17th century when it was first established in 1648 by the Danish King Frederick III. Due to its position and the large amount of coastline, the city was built as a fortress to support the defense of Jutland in response to a number of raging wars in the first half of the century. The unification of city and fortress is apparent in the unique urban grid-structure which, together with the rampart, has since become characteristic for Fredericia[1]. In the early 19th century a dock was provided, which allowed for the arrival of larger merchant ships, and later the dock was expanded with a boat harbour and shipyard. The great depth of the harbour meant that it was possible to attract even bigger merchant ships which led to a tremendous expansion. Later, larger companies such as the chemical factory Kemira A/S and the oil and gas company Shell, started to build factories and plants at the harbour. Nationally, Fredericia became the primary traffical centre of the rail network and in general, as arrival and selling of goods was possible by both train and sea[2].

Today, Fredericia still remains an important traffical nerve, especially as part of the so-called Triangle Region from where there is high mobility and access to every part of the country, as well as internationally via Billund Airport. The region is in rapid growth and has attracted several large companies within the energy industry. As of February 2021, some of these companies have made an agreement to transform the Triangle Region into a beacon for the production of green fuels, or Power-to-X, in Northern Europe within the next five years[3]. Furthermore, the municipality of Fredericia is currently working on transforming the city into a catalyst for the development of the Triangle Region. This desire has manifested itself in their new urban development project, Kanalbyen, where remnants of the historic fortress city interplays with a sustainable city development bordering Lillebælt. Here, the overall intention is to generate awareness and educate on a sustainable way of life amongst inhabitants, and to focus on energy, supply and use of renewable sources[4]. A number of companies concerned with the production and development of renewable energies are placed in the vicinity of Fredericia, including Ørsted A/S in Skærbæk, Siemens Gamesa Renewable Energy A/S in Vejle, and Swedish Vattenfall in Kolding. With the overall strategy for the area in and around Fredericia, we believe it makes for a suitable location for our project.

1 Fredericia Historie, (n.d.) *Fredericias Historie*

2 Fredericia Historie, (n.d.) *Industrialisering og transport*

3 Sørensen, B. J. (2021) *Unikt samarbejde: Trekantområdet som internationalt produktionscentrum for grønne brændstoffer*

4 Koch, C. (n.d.) *Kanalbyen i Fredericia: Udviklingsplan*

FIG. 1: MAP

1 . 4

LOCATION

A HISTORICAL PERSPECTIVE

Our site for this thesis is located as part of Kanalbyen, the latter of which covers a total area of around 20 hectares that will be in development during the coming 20-25 years. Upon completion, the area will accommodate approximately 1,200 homes and around 2,800 workplaces, along with cultural institutions, shops, cafées, restaurants, etc. The municipality aims to transform Fredericia into a new attractive location within the Triangle Region, addressing both future residents as well as companies and investors[1].

Kanalbyen is positioned in-between the historic part of Fredericia towards the North and Lillebælt towards the South. This area has previously hosted the aforementioned chemical factory Kemira A/S, which was closed down in 2004, providing room for a development of the city. Since then, a temporary environment has been established with areas for activities such as fishing, sports, retail and urban gardening, as a way of testing what could potentially be implemented permanently in Kanalbyen [2]. During the development process, user involvement and dialogue has been highly prioritised, both in terms of temporal and permanent circumstances. Using this strategy means that future residents and entrants become familiar with the area before it is even built, and that the municipality knows what activities are seemingly successful. Working with a sustainable strategy has been pivotal, and thus sustainability in its three forms - social, environmental and economic - are all included in the project of Kanalbyen. Socially, this includes a multifarious composition of residents, housings, workplaces and cultural activities. Furthermore, educating and creating awareness of a sustainable way of life amongst residents and additional users as well as focus on supply and use of renewable energy sources are other aims within this new urban development[3]. Currently, only a small part of the development has been constructed, however additional functions have already been planned and laid out. The specific site for this thesis is positioned on a plot intended for both cultural and café or restaurant purposes, which would be in line with the intent of our thesis project. The plot is around 3000 m^2 and is located on the outermost part of the harbour, and next to the canal leading through the rest of Kanalbyen.

1 Koch, C. (2018) *Kanalbyen i Fredericia: Udviklingsplan.*

2 Ibid.

3 Ibid.

FIG. 2: SITE

2.0
METHODOLOGY

2.1

APPROACH

OUR WAY OF THINKING DESIGN

As architects and engineers, we work on interacting complex problems and solutions in an interdisciplinary field, with an end goal of a holistic work that meets both the requirements of the site, user, client and our own subjective vision as designers. For such an endeavour, it is our opinion one needs to approach methodology and the design process with a curiosity and consciousness of how we best work and think creatively, while continuously working on developing and understanding our own methods as designers and shaping these to fit the unique project. This text outlines our understanding of the Integrated Design Process (IDP) and discusses how different methods for designing can be applied, while complementing and informing each other.

Throughout our education at Aalborg University, an embedded foundation for working on projects has been through the use of the IDP, as formulated by Mary-Ann Knudstrup[1]. The theory aims to structualise the design process through five phases: framing of the problem/idea; analysis and gathering of empirical data; sketching of possible solutions; synthesis of solutions to a holistic product; and presentation of the project, as well as receiving feedback from supervisors, clients, peers, etc. The IDP displays an informative map of how elements of the design process are interconnected and structured, however it cannot be characterised as an actual method for designing. In lieu, IDP can be viewed as a way of maneuvering between a "problem-space" (relating to problem and analysis-phases of IDP) and a "solution-space" (relating to sketching and synthesis-phases of IDP). These spaces, as introduced by Bryan Lawson[2], describe two different approaches to problem solving, which can also be referred to as "co-evolution". According to Lawson, the problem-space is the phase in which data is collected and analysed, for instance through research, case studies and testing. As aspects of the problem are being understood, the design enters the solution-space of sketching or modelling based on these findings, which can then be further tested and iterated upon. The whole process is rather cyclic as the design becomes increasingly informed, fits the requirements better, and different aspects get more integrated into the final design.

While the concept of co-evolution is useful for illustrating the iterative process, it does not provide any insight into how to actually go about being creative and design. For this, Lawson introduces the concept of primary generators. Generators are based on and inspired by what is broadly defined as requirements or objectives imposed on the project by either the designer, the client, the user, or legislators, and can either be implicit to the built environment or explicit, due to outside factors[3].

1 Knudstrup, M.-A. (2004). *Integrated Design Process in Problem-Based Learning in The Aalborg PBL Model: Progress, Diversity and Challenges.*

2 Lawson, B. (2005) *How designers think: the design process demystified.*

3 Ibid.

Each of these requirements can act as generators, as ideas for solutions are formulated, through an increasing understanding of these, which can be combined through synthesis to a cohesive design solution. A combination of a group of generators is usually how a design gets its identity or concept. Jane Drake, a researcher who has often collaborated with Lawson, uses the term conjecture to describe this initial concept and proposes a map and method of designing using these three aspects: generators-conjecture-synthesis[4]. She presents this as an overall solution-oriented approach, informed by research of how designers actually design. The conjecture here provides the link between the generators and the solution, formulated by synthesis. Drake's method proposes that the conjecture, once being formulated, needs to be continuously tested against different constraints and objectives, which will alter the proposed solution - a process similar to the one formerly described. The difference is that instead of purely analysing the problem and constraints on their own merits, these are understood through the application and testing of the solution, which itself is iterated and changed, as new information and ideas are introduced.

Gaining inspiration, generating ideas and thinking creatively are delicate subjects to approach and difficult to put into formula. In this context, Lawson introduces the concept of "parallel thinking"[5], which suggests that a certain "incubation" period is often needed for inspiration to strike. As a project is a finite process with a deadline, these periods are often a luxury few designers can afford to waste on being idle. Furthermore, inspiration is often helped by reaching a better understanding of the problem(s), helped by parallel thinking through continuous work on other parts of the project. Instead of working on only one solution and approach, the designer can work on several aspects of the design simultaneously and independently, shifting their attention as inspiration and insight on one aspect is exhausted. This way of working is also very fitting to the solution-oriented approach, although great care needs to be taken as to not let the project spiral out of control in an ever increasing scope, as well as to work towards the different solutions becoming more integrated to ensure a holistic whole. For this, the conjecture could be a tool to provide a general path through the initial concept, as well as for our theoretical positions and themes.
In informing the method of conjecture-synthesis and to better assess the proposed solutions in the interdisciplinary field, a following part of the thesis will outline three theoretical positions regarding sustainability, tectonics, and phenomenology respectively, as each of these will work in conjecture in the different aspects of the design. These will further provide a perspective useful for framing the requirements and how to approach these in coherence with the overall vision of the project.

4 Drake, J. (1979) *"The primary generator and the design process"* in *Design Studies*, vol. 1, no. 1.

5 Lawson, B. (2005) *How designers think: the design process demystified.*

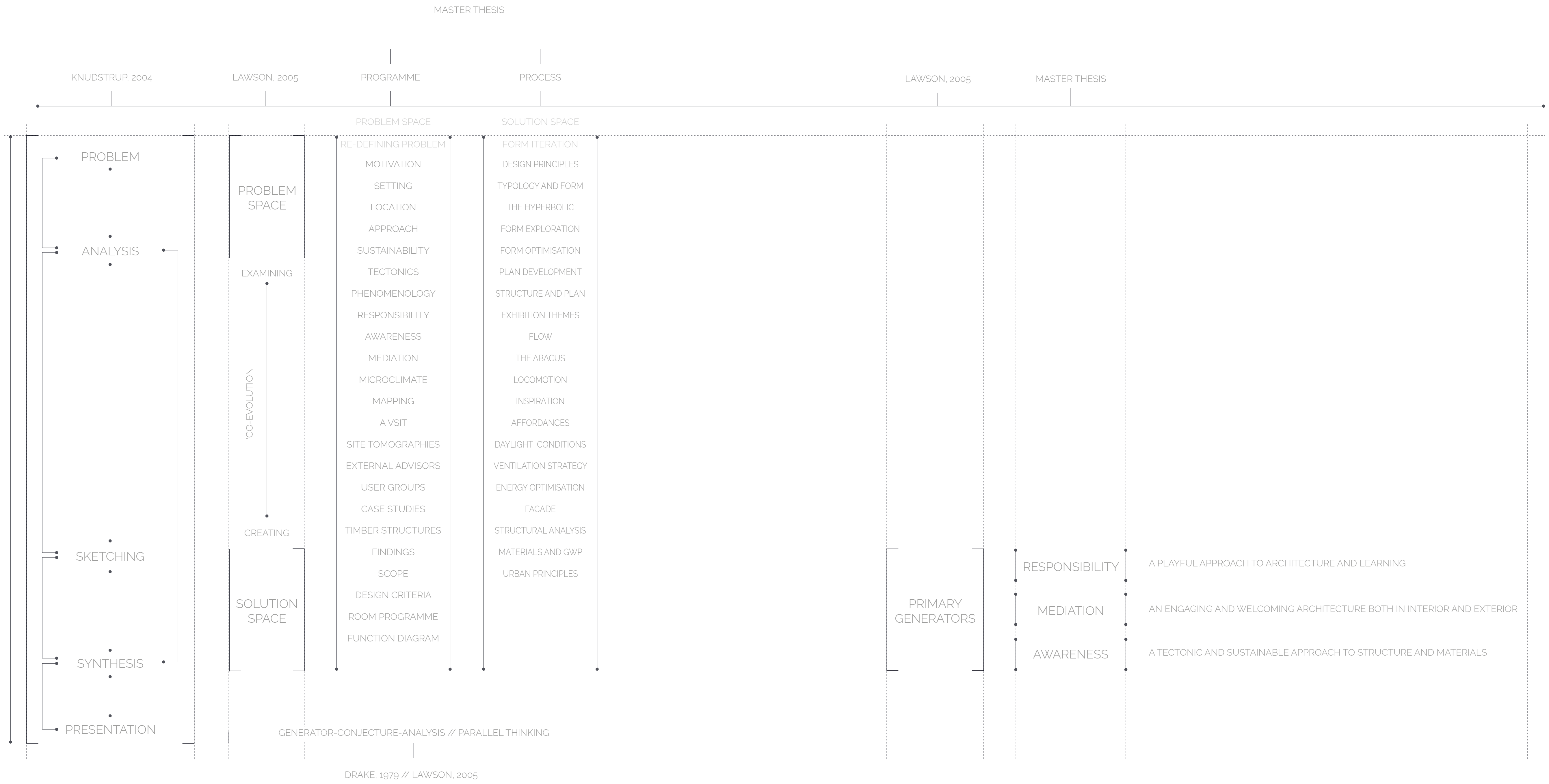


FIG. 3: METHODOLOGICAL OVERVIEW

3.0
THEORY

3.1

POSITIONING

OUR WAY OF PERCEIVING ARCHITECTURE

As already outlined, the task and aim of this project has multiple facets, of which different theoretical approaches and frameworks are needed to work together to reach a cohesive and holistic work of architecture. Three of such frameworks have been chosen for exploration and application in the project: a position regarding Sustainability, the concept of Phenomenology and the poiseis of Tectonics. All of these frameworks or fields have different foci and theories attracted to them, which the following three parts will explore. Later in the thesis, the fields are used and examined further in practice as they relate to actual projects, in the form of design cases, each relating to three positions relevant to the goal of the project.

To make sure these theoretical fields are integrated in conjunction and elevates the project holistically, such that each one informs the others and creates value greater than the sum of these elements, careful handling is required in the design process. Sustainability and Phenomenology work very much in conjunction, as the stated goal of the visitor centre is to inform and educate the public as well as gesturing to a change in mindset and behaviour. A phenomenological approach is needed for proper gesturing of the user, introducing tools for affecting the sensory aspects of the project and how the built environment is perceived, while a position in Sustainability is needed to make sure this gesture has depth and impact on the user, relevant to the topic of climate change. To tie these two approaches together, the field of Tectonics has essential visual and material attributes that work well to introduce Sustainability and Phenomenology into the physically built environment. While bridging the fields, Tectonics are used in the way the project positions itself within the vast field of Sustainability, the use of materials and carbon footprint, while the gesturing of Tectonics and the affordances of Phenomenology are arguably inseparable and reveal each other.

THEORY

FIG. 4: THEMATIC INTERCONNECTION

3.2

SUSTAINABILITY

BUILDING RESPONSIBLY

The significance of sustainability in contemporary architecture cannot be argued. All major architectural firms have a sustainability strategy, and it is a central criterion in practically all substantial competitions. However, in his text "An Abstract Culture's Search for Concrete Roots" from 2014, Claus Bech-Danielsen argues that in some way architects have been engaged in sustainability for much longer than one should think. Already in modernism architects sought solutions to several health problems related to our way of living; pollution of the indoor air, lack of daylight in most dwellings etc.[1] They wished to create accessible and healthy homes and cities for both mind and body. Nowadays this is what we would categorize as social sustainability. Since then there has been a shift in the cognisance of our environmental problems. According to Bech-Danielsen the issues we now face can no longer be sensed directly by the individual but more so affects society as a whole. It has become more intangible. More imperceptible. Most of the climate changes can only be detected using sophisticated measuring tools and by comparing data years after years[2] . Therefore we have needed new tools and theories that can be applied already in the design phases in order to ensure sustainable development.

These new tools include the "cradle to cradle" approach that introduces a cyclical perspective on construction and designing with the building's lifetime in mind; from procurement and processing of the materials, to construction, use and lastly it's demolition. Another method available is the life-cycle assessment (LCA) analysis, where the environmental impact of a product is evaluated and mapped taking into account it's whole journey from raw material, manufacturing, transportation, use, recycling and final disposal[3].

1 Bech-Danielsen, C. (2014) *An Abstract Culture's Search for Concrete Roots in Towards an Ecology of Tectonics: the need for rethinking tectonics in architecture.*

2 Ibid.

3 Golsteijn, L. (2018) *LCA Basics: life cycle assessment explained.*

The interesting correlation between these two tools is their cyclical basis. The idea that "you were made from dust, and to dust you will return"[4] is a quite compassionate strategy. It is also a recurring phenomenon in natural processes; biological, chemical etc. Thus it has achieved status as a very sustainable approach to life, both in terms of consumption, economy and now even in design methods. Yet the whole building sector is perpetually in search of more sustainable starting points for architecture. Earth is under extreme pressure and the need for changes in our approach to construction and development of our homes and cities cannot be ignored. For much too long humans have exploited earth to an extent it cannot withstand. Essentially the question at hand now is 'how can nature and humans come to live in harmony?'
Bech-Danielsen proposes that a solution to this may lie in the roots of architecture[5] so let's search for inspiration in the past as humans have done so often before across both architecture, arts and literature. Tectonics as a term is commonly understood as the basic starting point of architectural creation. As the foundation on which both architecture and structural engineering is built. A tectonic approach to architecture demands careful attention towards building units and materials, structure and joints. But it also requires within the design of building materials to seek aesthetic experiences and architectural qualities. It is no strictly visual phenomenon nor solely a feeling or experience but rather a fusion of the two. It is a complex term and its meaning has been studied and interpreted repeatedly since antiquity. But tectonics has always strived to unite design with technology. This duality also exists within sustainable architectural development. So maybe a modern tectonics is able to also unite sustainability with design and technology and thus form a united architectural approach.

"It is in this very attempt to reunite a divided architectural world, where there is distance between design and technology, that we find tectonics. The tectonic perspective strives to re-establish a united architectural approach. It is here we find a parallel between tectonics and sustainable development, which also takes a holistic approach to development [...] and focuses on the interplay between cities and their surroundings. In short, sustainable development strives to link culture and nature." (Bech-Danielsen, 2014, p. 61)

4 *Genesis 3:19, The Holy Bible, New Living* Translation

5 Bech-Danielsen, C. (2014) *An Abstract Culture's Search for Concrete Roots in Towards an Ecology of Tectonics: the need for rethinking tectonics in architecture.*

3.3

TECTONICS

APPLICATION OF TECTONICS IN THE BUILT ENVIRONMENT

Tectonics is a delicate topic in architecture with numerous theories and interpretations thereof in regard to how to apply tectonic theory to the built environment, the use of it and - most crucial perhaps - what it is. This text presents an outline of how tectonics can be understood and used theoretically and will explore the notion of tectonic architecture and how this approach can be a useful tool in integrating sustainability and phenomenology into the built environment. As an introduction, Sekler's definition of structure, construction and tectonics is explained and then expanded upon by applying the notion of revealing and causality as well as gesture and principle by Foged and Hvejsel respectively.

Often we do not differentiate between terms like structure and construction, to which tectonics are definitely tied. In his essay from 1965, Eduard Sekler seeks to precise the language and properly define these terms and their relationship as to be able to better discuss how tectonics plays a part in the delicate concept of architectural quality. Structure is more abstractly defined as the concept of the system or principle of a building, relating to how the building deals with forces, while construction is the realisation of that system: the selection and use of materials, of technique and process. In separating the two concepts, a possibility for individual assessment is made possible, as an elegant structure can still be realised in a poor construction and vice versa, although the two in practise should be inseparable and work together in continuous interaction[1].

The realisation of a structural concept through construction, Sekler argues, results in certain qualities, which are visual and expressive of the relationship between forces and form and cannot solely be attributed to either structure or construction alone. They derive from the visual result of realising a structural concept and are understood as tectonics. Tectonics is thus defined as the relationship between structure and construction, something visual resulting from the system and the means of the built environment. This definition of tectonics as an expression of gravitational forces seems to be the general understanding of the term in the field of architecture.

1 Sekler, E. F. (1965) *Structure, Construction, Tectonics* in Reader: Tectonics in Architecture, Foged, I. W. & Hvejsel, M. F.

Danish architect and theorist Karl Christiansen offers a similar definition, and argues that tectonics only happens when three basic parameters; material, technique and form become equally significant parts of a whole. They should reinforce each other and depend on one another "*in such a way that no one parameter can be replaced without decisive consequence for the remaining two*" (Christiansen, 2016 p. 345)

While these notions about structure and construction are useful for analysis, treating the concept of tectonics as purely a visual expression of forces can prove insufficient. This view can limit the understanding of tectonics and does not provide a method for using its great potential in architecture. In his essay *Environmental Tectonics* exploring Heidegger and causality, Foged introduces the concept of revealing as the primary use of tectonics. The act of revealing, he argues with reference to Heidegger, is the act of bringing something into existence, both, but not limited to, artistically, poetically and as a handcraft. If tectonics were bound to an expression of gravitational forces, it would only be visually perceivable, which is in direct opposition to the concept of revealing as described in the Greek philosophy so often used to define tectonics in architecture[2] . In the process of revealing, Foged argues that limiting tectonics to just a visual representation of forces is too narrow a scope and states *"Thus, when tectonics resides in techné, it cannot be prioritised towards gravity or the visual, but must be open to a larger field of causes and objectives."* (Foged, 2018, p. 381)

The causes mentioned, were formulated by Hedigger and expanded upon in Foged's text: causa materialis (the materiality), causa formalis (how the object physically presents itself), causa finalis (why it was made and for what purpose), causa efficiens (the effect that brings it into being) as well as - added by Foged - causa humanus (how humans can and will perceive it) and causa circumiectum (the effect of the environment)[3]. This viewpoint provides insight into which causes are relevant to consider as tectonics reveals the built environment, but a critical method is still needed in order to intentionally apply tectonic theory in architecture for a purpose.

2 Foged, I. W. (2018) *Environmental Tectonics: Convergences Between Six Causalities* in Reader: Tectonics in Architecture, Foged, I. W & Hvejsel, M. F.

3 Ibid.

Such a method is presented by Hvejsel in the concepts of gesture and principle, and the mutual dependency between them[4]. Gesture denotes the envisioned and experienced quality of architecture: how the built environment relates to the human perception and senses, and spatially gestures the human to use it. Principle in this context is understood as the means of how the gesture is realised. The two establish a constructive junction, much like Sekler's definition of structure and construction. The introduction of 'gesture' is thus crucial to architectural quality and the job of the contemporary architect. Hvejsel adds:

"Without such a 'gesture,' the work [of the architect] reduces to a structural framework. This is evident when [buildings] end up being dominated by technical installations and spatial monotony; they lack the vital ability to 'gesture' their inhabitants beyond mere practicality" (Hvejsel, 2018, p. 396)

The previous section has already outlined how sustainability and tectonics may be linked and how tectonics might play a crucial role in the making of a sustainable building. The choice of materials and their handling, as related to construction, plays a key part in LCA and thus the climate impact a building will have during its lifetime. Likewise, a tectonic approach is both relevant and needed in regards to the system of the construction: the structure as defined by Sekler. Efficient and appropriate handling of how materials join together and can be taken apart, how efficiently structural elements deal with forces compared to the material used, also greatly affect the carbon footprint of a building as it is being built, but also when it is taken apart. Approaching sustainability this way, from a tectonic perspective, influences the building in a visual sense, but also relates the built environment to the other senses through spatial composition and materiality. As tectonics visually and physically reveal the environment, gesturing to its use, the application of tectonics greatly influences how an environment is perceived and understood by its users as well. To be able to perceive, the user must be able to sense the built environment, and this is further explored in the following study of phenomenology.

"The way in which any organism can perceive the world is directly connected to the available temporal registrations. Hence, the ability to construct tectonics that is based on appearance, from the originating Greek philosophy via Heidegger, is intimately linked to an individual's sensory apparatus and perceptive capacities" (Foged, 2018, p. 387)

4 Hvejsel, M. F. (2018) *Gesture and Principle: Tectonics as a critical method in architecture* in Reader: Tectonics in Architecture, Foged, I. W & Hvejsel, M. F.

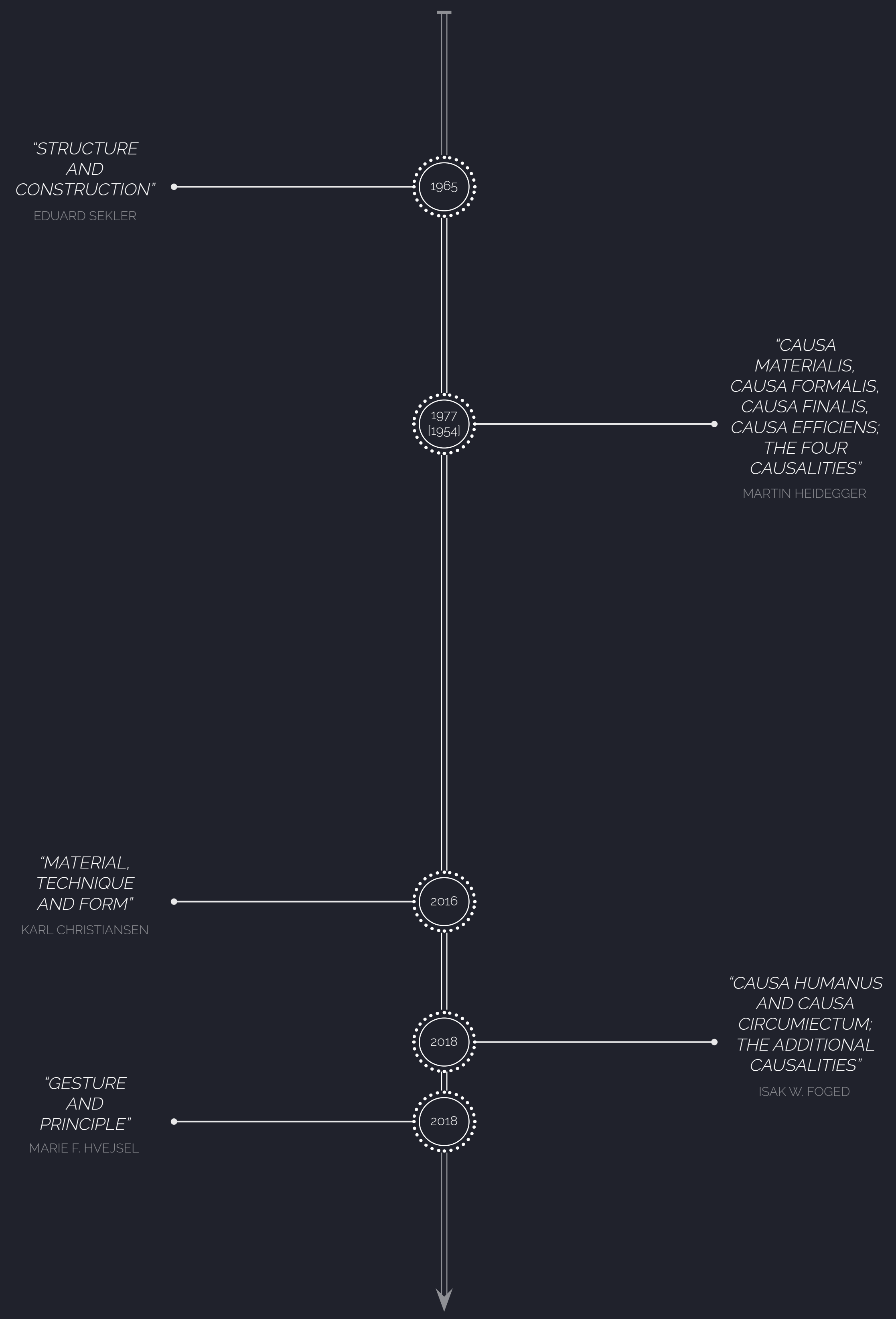


FIG. 5: TECTONIC TIMELINE

3 . 4

PHENOMENOLOGY

A THEORY OF AFFORDANCES

Within the field of architecture, the act of visual perception plays a crucial role in how a building is experienced by the people staying in it. Vision depends on the eyes that see, naturally, but even more so by the physical constraints surrounding the individual or a group of people. The latter is the essence of the term "ecological psychology", introduced by American psychologist James J. Gibson in 1979, as a way of describing how we understand and perceive the environment around us, rejecting the notions of behaviorism and cognitivism, and favoring a more direct approach to perception[1]. Contrary to advocates of a sensation-based indirect realism, where perception is more dependent on the individual, than stimuli in the current environment, Gibson believed that the answers to perception should solely be found in the environment itself. To describe the notion that the environment alone attributes to what we perceive, Gibson invented the term "affordance", which describes the actions that are offered or provided by the environment to the people perceiving it.

"The verb 'to afford' is found in the dictionary, but the noun 'affordance' is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment" (Gibson, 2015 [1979], p. 119)

Moreover, Gibson emphasises the fact that an affordance is always relative to the animal, both in terms of posture and behaviour, but also culture and age are important factors in terms of what a certain object affords. If a surface of support in knee-height above the ground is also horizontal, flat, extended, and rigid, we recognise it as a seat, a chair, a bench, and so on, and it affords sitting. However, knee-height for an adult is not equal to knee-height for a child and hence, affordance is always relative to the individual, meaning that different layouts afford different behaviour[2]. In an architectural context, affordances can be used as a tool to influence how a given space is perceived. Here, it is important to note that a space can either be perceived from a stationary point of observation, or with reference to a moving point along a path, due to the act of locomotion - that we as humans move from place to place.

The ground constitutes the basis of human behaviour and perception, while a wall poses a barrier, an obstacle, to locomotion. The question is, how we as architects can work with these elements to create a compelling architectural narrative, that calls for a certain behaviour. If we want to influence and challenge human perception and behaviour, then maybe we need to ask questions that seem simple, for instance "what is human behaviour?" or "what is a wall?" in order to afford new perspective, that is more than solely visual.

So, what *is* a wall? When broken down, the seemingly simple object of a wall has many properties, and can be many different things. A wall can be solid, or it can be porous. It can block vision, or, if constructed cleverly, it can afford seeing without being seen. A wall of glass affords both vision and transmission of light, while a wall of opaque glass affords only illumination. A wall of glass affords seeing through, but not walking through. A curtain affords walking through, but not seeing through. Of course, these are only visual aspects, and the tactile properties of different materials that make up the wall must also be taken into account when talking about spatial and architectural perception as a whole.

Returning to a larger perspective, the theory of affordances can also be used to describe the current crisis of climate change, which can be attributed to human interference. Surfaces and layouts of the Earth itself have been altered by clearing forests, paving roads and paths, and building, leaving only a small portion of natural environment, which has still been reshaped to fit the ever growing needs of human society. Most alarming, however, is the alteration of the air we breathe, which is slowly but steadily worsening and moving towards a state where it cannot be reversed. We as human beings have changed the surfaces and shapes of the environment in order to to change what it affords us[3]. In doing so, we have made more accessible what is beneficial to us and paying less attention to the catastrophic consequences it will have in the coming future.

"There is only one world, however diverse, and all animals live in it, although we human animals have altered it to suit ourselves. We have done so wastefully, thoughtlessly, and, if we do not mend our ways, fatally." (Gibson, 2015 [1979], p. 122)

1 Gibson, J. J. (2015) *The Ecological Approach to Visual Perception*

2 Ibid.

3 Ibid.

3.5
SYNTHESIS
WHAT WE HAVE LEARNED THUS FAR

Concluding on the theoretical positioning, this text will recapitulate the findings of the previous parts and how the terms are expected to converge as they are applied in the design process. Architecture is an interdisciplinary field, in which a critical method is needed to actually use these theoretical positions in the design process as tools to both inform the design and to continuously analyse and make critical judgements on the success of proposed solutions. Sustainability is a major theme, both as the actual built environment, but also as the actual topic being conveyed in the Visitor Centre. The approach tying together Sustainability and Tectonics will be the selection and handling of sustainable materials. This is done by using LCA on a conceptual level and optimising the structure as to not waste material in the construction. The handling of materials also introduces Phenomenology into the design field as a way of handling tactile qualities and sensory, embodied experiences within the building, drawing on the concept of affordances, as introduced in the text. The phenomenological affordances and the concept of gesture and principle introduced in the Tectonics text will work in conjunction, as the tectonics are revealed through the active interaction with and sensing of the environment. The essence of this conjunction is that behavior of the individual is tied directly to how they perceive their environment and that this perception is a collection of all sensory inputs, as the individual exists and moves around in the environment: a lived, embodied experience in the built environment. As a whole, the three fields will together inform the form, volume, and spatial qualities of the built environment. To describe how these will emerge and be revealed, three themes emerge as the foundation of the core concept of the building: Mediation, Awareness, and Responsibility, which will all be explored in the next section through three case studies.

4.0

ANALYSIS

4.1 RESPONSIBILITY

A CALL FOR CHANGE

"We are now in a climate emergency."[1]. These are the alarming words stated by the World Green Building Council (WorldGBC) to initiate their 2019 report "Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon", in which they shed light on the tremendous impact the building industry has on global carbon emissions. The report was made in connection with the 2015 Paris Agreement, in which the 196 member states of the United Nations Framework Convention on Climate Change (UNFCCC) committed to reduce emission of greenhouse gases, aiming to keep the increase in the global average temperature well below 2 °C, preferably limiting the increase to 1.5 °C[2].

As of now, the building sector is responsible for 39 % of global carbon emissions [3] – a fact that calls for a decarbonization across the entire industry. Carbon is not only emitted during operation and usage of the buildings, but also during phases of manufacturing, transportation, and construction. Of these 39 %, 11 % of emissions are directly related to materials and construction, commonly referred to as embodied carbon or embodied energy[4]. So, how do we reduce the amount of embodied energy in construction? One method of evaluating the environmental impact is through life-cycle assessment (LCA) of a building, where the extraction, transport, and manufacture of materials is evaluated. Similarly, the University of Bath has made an extensive database for embodied energy and carbon emissions in construction materials, which lists data for more than 200 different materials. Even so, what is considered an "environmental-friendly" material in one part of the world, may be less optimal in another, due to means of transportation and local availability. According to WorldGBC, however, there are some general rules of thumb when it comes to classification of materials and how much they emit. On a global scale, steel and cement are the biggest culprits concerning material-related emissions.

1 WorldGBC. (2019). *Brining Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon.*

2 United Nations. (2015). *Paris Agreement, Article 2 (a).*

3 WorldGBC. (2019). *Brining Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon.*

4 Ibid.

During production, cement and steel require very high temperatures which makes them heavy on energy usage, and as does aluminum and glass. Unfortunately, fossil fuels are still the main source when producing energy for industrial heat on a global scale, albeit use of biofuels is slowly increasing in some parts of the world. Wood is an example of a material that absorbs and stores carbon and this, together with responsible harvesting of timber meant for use in construction, can contribute positively to decarbonisation of the industry.[5]

As architects, we should acknowledge our role and responsibility in the current climate crisis, and strive to reduce the amount of carbon emitted from the buildings we construct. In Svartisen, Norway, architects at Snøhetta have done exactly this. With their hotel project "Svart", they have taken a more climate conscious approach to architecture. Located in close proximity to the Arctic Circle, this hotel is the first building in a Northern climate to be built after the Powerhouse Paris Proof Standard, inspired by the Paris Agreement[6]. During the design process, the architects put a lot of work into limiting the use of materials with a high amount of embodied energy, seeking to avoid materials such as concrete, steel and brick, and instead turning to wood and stone, which have low embodied energy. The circular form and the fluctuating roof slope are designed to optimise the energy gained from the sun, collected via solar panels. By slightly extending the roof and withdrawing the hotel rooms in the facade, the risk of overheating during summer is reduced and hence, the use of energy for artificial cooling is limited. With its circular shape, the hotel is very unlike the archetypal energy-friendly buildings, otherwise often characterised by their compact and box-like bodies. Supported by a slim, wooden structure, the building elegantly conveys its sustainable character by physically, and metaphorically, leaving only a minimal footprint on the ground below and minimising on-site impact. Thus, the building is lifted six metres from the ground, and 70 % of it positioned directly in the water[7]. The supporting structure doubles as a boardwalk for pedestrians and storage space for e.g. kayaks and other maritime gear.

5 Ibid.

6 Snøhetta (n.d.) *Svart.*

7 Thomas, K. (2020). *Interview: Ivaylo Lefterov on the Development of Svart.*

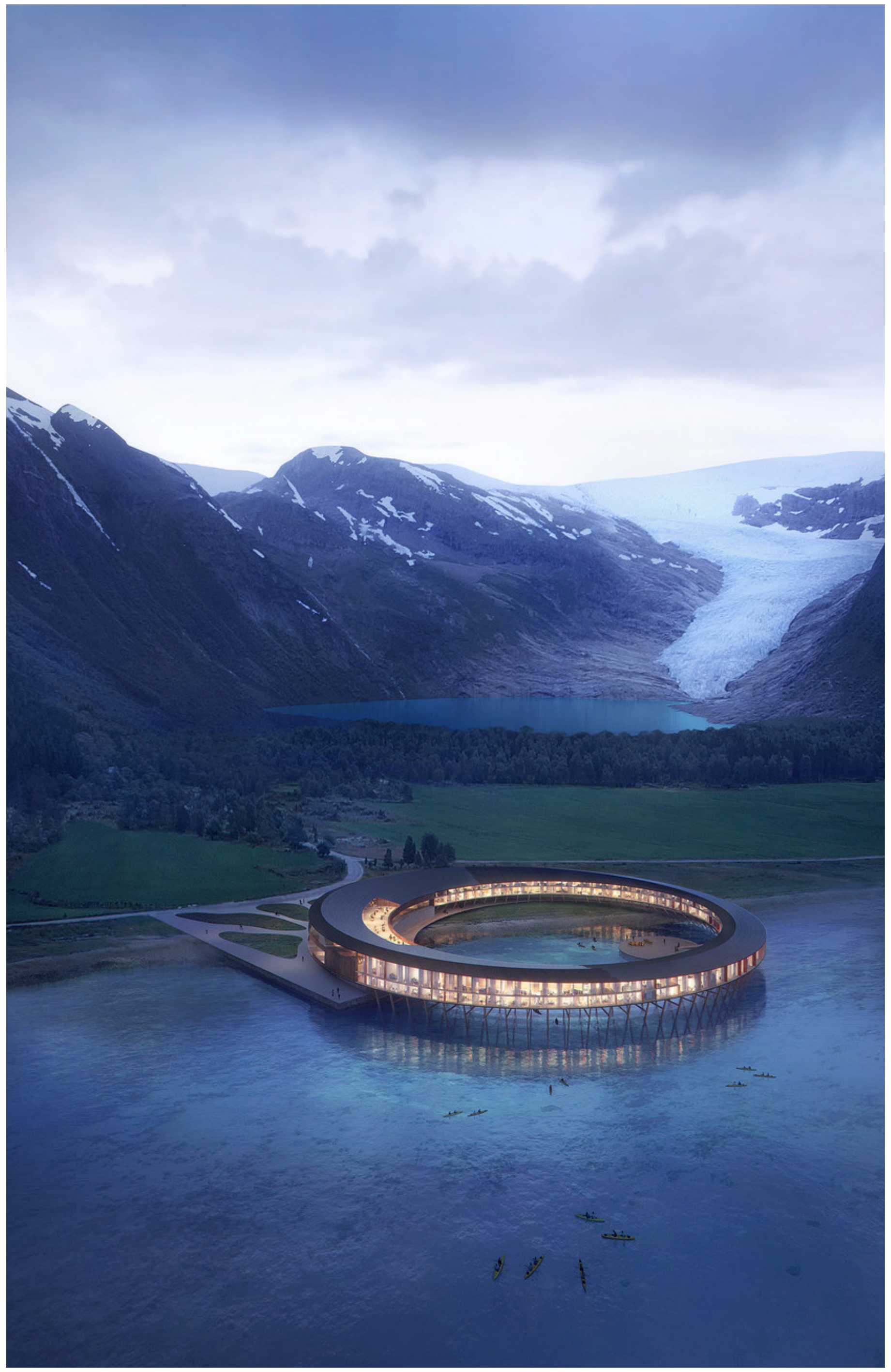


FIG. 6: SNØHETTA, (N.D.) *SVART*

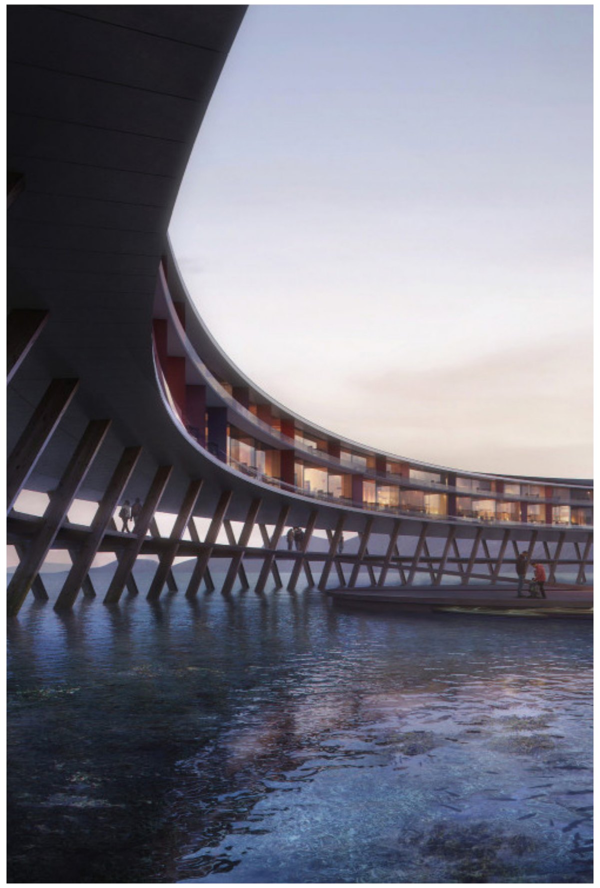


FIG. 7: SNØHETTA, (N.D.) *AN ENERGY OPTIMIZED DESIGN*

Architect: Snøhetta
Location: Svartisen, Norway
Year: 2021 (expected)

4.2 AWARENESS

INTERPRETATION, PRIMING, AND FRAMING OF THE SENSES

Awareness as a general concept, defined as “the knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience”[1] by the Cambridge Dictionary, can be approached in an array of ways depending on the lense one uses to examine it: philosophically, therapeutically, socially, politically, etc. In this text, we aim to examine how awareness plays a role in the built environment and how architecture can influence or even create a certain kind of awareness phenomenologically.

Memorial to the Murdered Jews of Europe, also known as the Holocaust Memorial, is a large urban structure consisting of 2,711 concrete slabs arranged on a grid covering 19,000 square-metres just south of the Brandenbourg Gate in Berlin. The monument is designed by the architect Peter Eisenman and is, as the name suggest, a memorial to the Jewish victims of the holocaust during the second world war. In conjunction with the memorial is a center containing information, names and pictures of the victims[2].

While looking on the memorial from afar, the many concrete slabs seem to be almost the same dimensions as they reach almost similar heights, but entering into the labyrinth reveals that the ground on which they stand is not flat, but undulates, effectively meaning the height of the slabs vary from 0,2 to 4,7 metres. The phenomenological experience of this, as one moves deeper into the memorial, is almost akin to one sinking down into the ground, while the slabs are refusing to conform to the environment. Paradoxically, the changing height is more perceived as the slabs being static and unchanging, while instead it is the observer’s position in relation to them that changes, as they are swallowed by the built environment in a constructed sea of concrete. Many visitors report a moment of giddiness or uncertainty because of this[3].

Just as the memorial plays on and affects the visitors kinesthetic sense spatially, being immersed in the environment also affects the visitors visual senses. The word labyrinth was used before to refer to the monument, which might be misleading as the straight grid lines ensure one can easily find a way out of the memorial again. Phenomenologically the term labyrinth applies very appropriately however in the sense that, once immersed, one is visually lost in the memorial. The big slabs obscure sightlines, prevent one from being able to orient oneself in relation to the world and two people can very easily get lost from one another, despite the lack of barriers or dead ends, that one would find in a traditional labyrinth. This creates a strong feeling of being alone and isolated, which can both be a peaceful experience and allow one to focus on prayer and reflection, but also instill fright and make the user uncomfortable,

1 Cambridge Dictionary, (n.d.), *Awareness*.

2 Visit Berlin, n.d., *Memorial to the Murdered Jews of Europe*.

3 Ibid.

making one empathise with the Jews in the concentration camps. It all depends on the visitors’ mindset when entering the memorial and how they subjectively interpret and perceive their situation, as the memorial can afford different uses and interactions. Fig. 9 and 10 clearly show two different interpretations of what the site is and of how to behave: one showing people in grave remembrance and the other showing a person interpreting the environment as a place to have fun. From personal experience, the same alienating aesthetics of the memorial, that can provide a deep personal experience, is just as frequently used as an interesting backdrop for selfies and taking fun pictures, as the memorial affords both.

The mental phenomenon of interpretation, and that this depends on former experience and priming, also dubbed the Kuleshov effect after Russian/Soviet filmmaker Lev Kuleshov, is very relevant in this case. The name of the memorial, “Memorial of the Murdered Jews of Europe”, primes the visitor into a certain interpretation, but without this - or with a different priming - the monument and how it affects the senses of the visitor is open for being interpreted in a completely different way. This holds true for this text analysing the case as well, which is very much informed by the knowledge of this being a memorial relating to the holocaust. In a conversation with Koolhaas, Eisenman himself reflected on this quality of the monument, as an italian poster had used a picture of it with a star of David superimposed on top to mark the Day of Memorial, the day Auschwitz was liberated.

“What is interesting to me about the poster is that they felt obligated to superimpose the Jewish star over the field of our project in Berlin. Apparently they think no one would be able to read the field without the Jewish star. For me that was significant - I kept saying to myself, why did they have to do that? And I realised that was precisely the point of our project: we forced them to superimpose the Jewish star over the field.”

(Eisenman & Koolhaas (2009) p. 11)

To influence the user of a work of architecture, different strategies can be used in conjunction to affect the users senses. How the senses are affected and which ones, depends on the materiality, spatial composition, volume, etc. of the architectural work. The interpretation of the user however will be subjective, but can be influenced in an intentional direction by proper use of priming and framing.

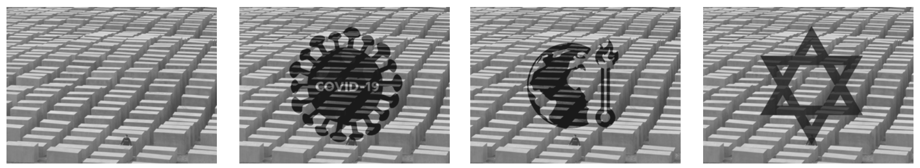


FIG. 8: EISENMAN ARCHITECTS (N.A.) *BERLIN MEMORIAL TO THE MURDERED JEWS OF EUROPE* (ICONS SELF MADE)

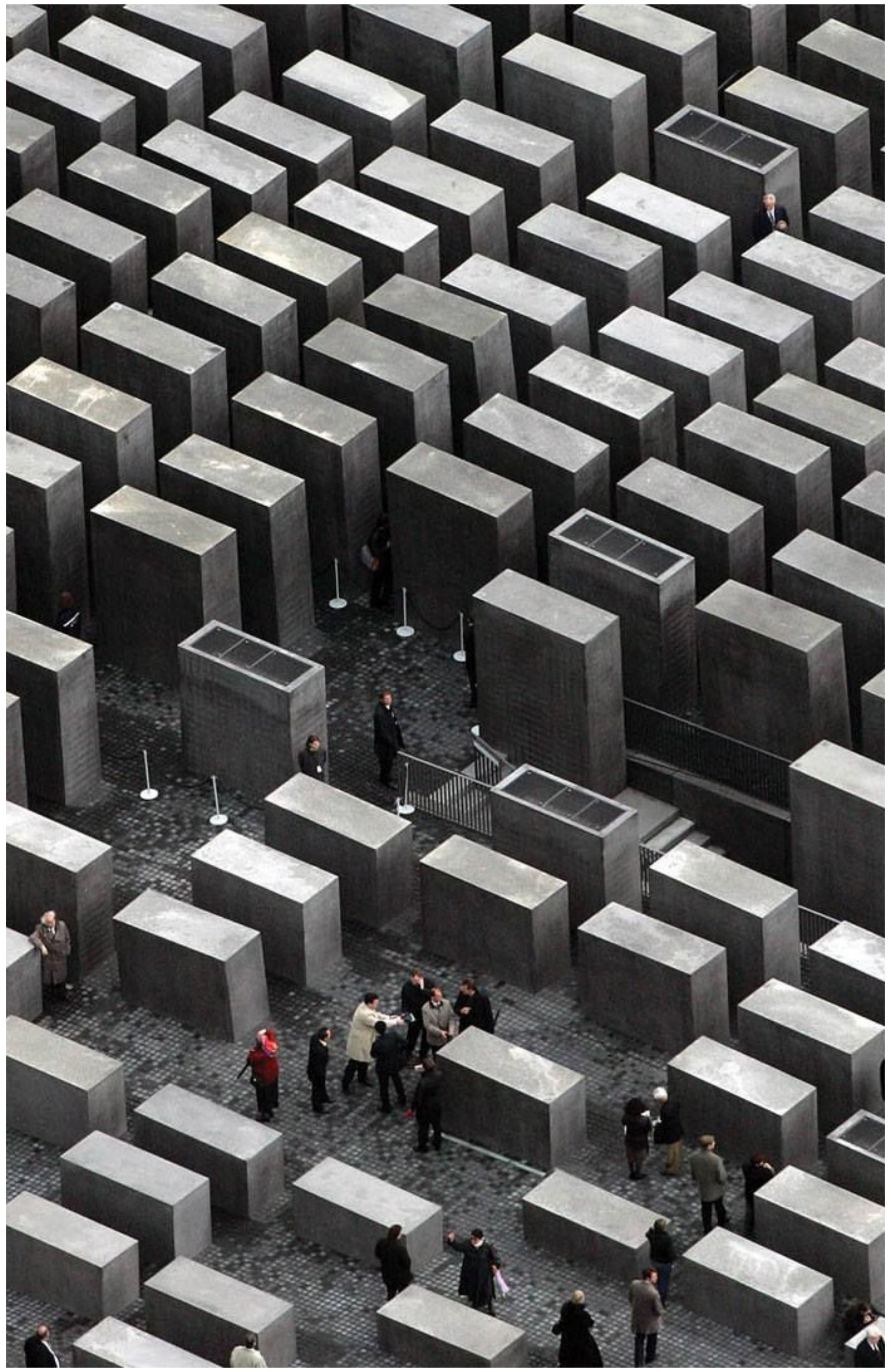


FIG. 9: ARCH STREET JOURNAL (2021), *BERLIN MEMORIAL TO THE MURDERED JEWS OF EUROPE BY EISENMAN ARCHITECTS*

ANALYSIS

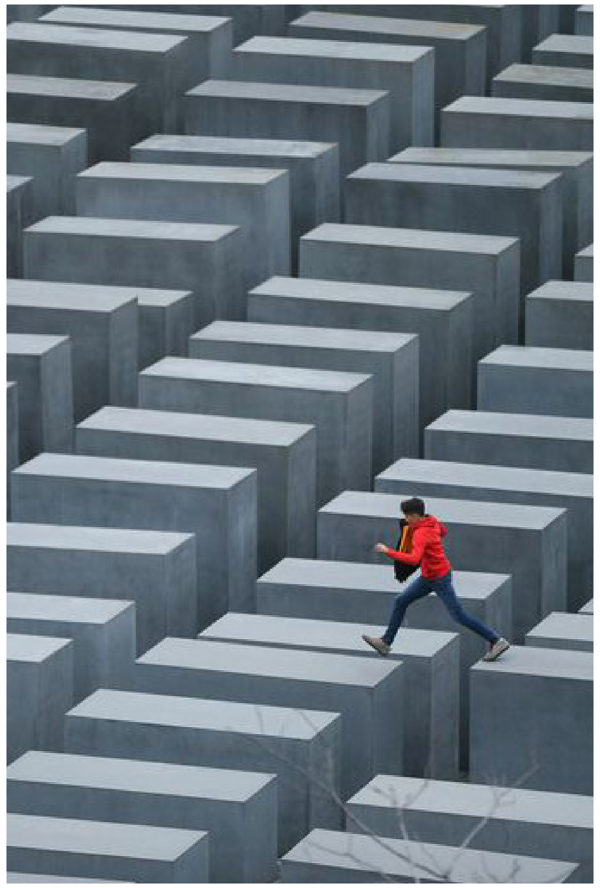


FIG. 10: THE ARCHITECTURAL REVIEW, (N.D.) *THE INEVITABLE BOX*

Architect: Peter Eisenman
Location: Berlin, Germany
Year: 2004

4.3

MEDIATION

THE MAKING OF A NARRATIVE

Central to any space that revolves around communication of a subject is the act of mediation. The transitive version of the term Mediation as this study will focus on, entails in its most basic sense a forthbringing of knowledge or experiences by acting as an intermediary[1]. In this demonstration the intermediary, or mediator, is architecture. The first vital question of this relationship between building and contents is when should the enclosed information speak and when should architecture? The aim is a balance between communication of narrative and knowledge and an effectual architecture. For how can architecture support and emphasise the exhibition rather than consume and dispute it? But in this delicate equilibrium there is a risk that the architecture will become anonymous. An accomplished architectural mediator should be present as itself while engaging its visitors and drawing them into the presented narrative and thus enhance the overall experience.

When it comes to learning one of the most effective strategies is learning through experiences. Naturally, the interior of the building will shape the visitors' experience and thus, in order to be able to learn, visitors must feel safe and at home. This is achieved by allowing them to experience the interiors with their bodies. Yet geometric interiors are considered uninspiring and do not allow for this crucial inhabiting[2] . Therefore shifting spaces and experiences are necessary. Curvilinear forms are a great response to this, as they have been shown to have a soft and pleasant impact on humans[3]. By activating multiple senses and the whole body, visitors will build a personal relationship with the objects, of course based on individual past experiences[4]. The guests' visit can thus be viewed as a journey of exploration through the exhibits. A journey that is most important in keeping the interest of the visitors. A good example of this type of involvement and experience is Moesgaard Museum.

Slightly south of Aarhus, in scenic surroundings, Moesgaard Museum grows out of the ground. The sloped grass roof gently lifts from the terrain inviting visitors to take a stroll to its top. This is an example of a very physical engagement with the architecture where the building and its visitors become acquainted and interact before the visitors even enter.

1 Den Danske Ordbog (n.d.) *Formidle.*

2 Fors, V. (2006) *The Missing Link in Learning in Science Centres.*

3 Vartanian, O. et al. (2013) *Impact of Contour on Aesthetic Judgement and Approach-Avoidance Decisions in Architecture.*

4 Fors, V. (2006) *The Missing Link in Learning in Science Centres.*

The result is an outdoor space of almost equal significance as the indoors. Moesgaard's sloped roof has become its trademark and a public favourite when it comes to walks in nature with family and friends.
Indoors, visitors are met by the spectacular open entry hall containing practical amenities and the cafe. When talking strictly exhibition space, Mosgaard has two; the permanent exhibition and the special exhibition. The permanent exhibition is accessed by descending down the magnificent stone staircase, resembling an archeological excavation. The exhibition is a 12 metre high space for learning and exploring the origin and evolution of humans and daily life from the stone age and up to the middle ages, across literally multiple levels[5]. Through agents such as separation walls and tactile experiences, architecture accompanies the visitors and guides them on their journey through the narrative, strongly exemplified through the exhibition of the Grauballe Man, where lighting, levels, tactility etc. are utilised to recreate the experience of a bog. The result is a figurative translation of the stories encompassed in the exhibited artefacts. The special exhibition however is a more flexible space that can also be rented out for conferences, fairs and fashion shows. Due to its varying purposes the space features high standards of safety, practicality and control of the indoor climate, providing the right conditions for housing international and fragile exhibitions, expanding the possible experiences the museum can provide[6]. Thus the exhibitions at Moesgaard are not static, and the experiences will vary from visit to visit.

The exhibition spaces are rather anonymous in terms of architecture, but allow for a frame in which material, spatial and visual interventions can be used to programme the room to best display the exhibits. This provides a perfect frame for the museum's ever changing exhibitions. But not only the exhibitions at Moesgaard are dynamic. The building was designed to allow for a flexibility and variety of functions, as to accommodate the wish for Moesgaard to be more than just a museum. The architecture supports this vision. It becomes a meeting place, an entertainment and an experience. Moreover it promotes learning on multiple levels as the museum also collaborates with Aarhus University and serves as workspace for more than 300 museum- and university employees[7].

5 Moesgaard Museum, (n.d.) *Permanente udstillinger.*

6 Henning Larsen, (n.d.) *Moesgaard Museum.*

7 Ibid.

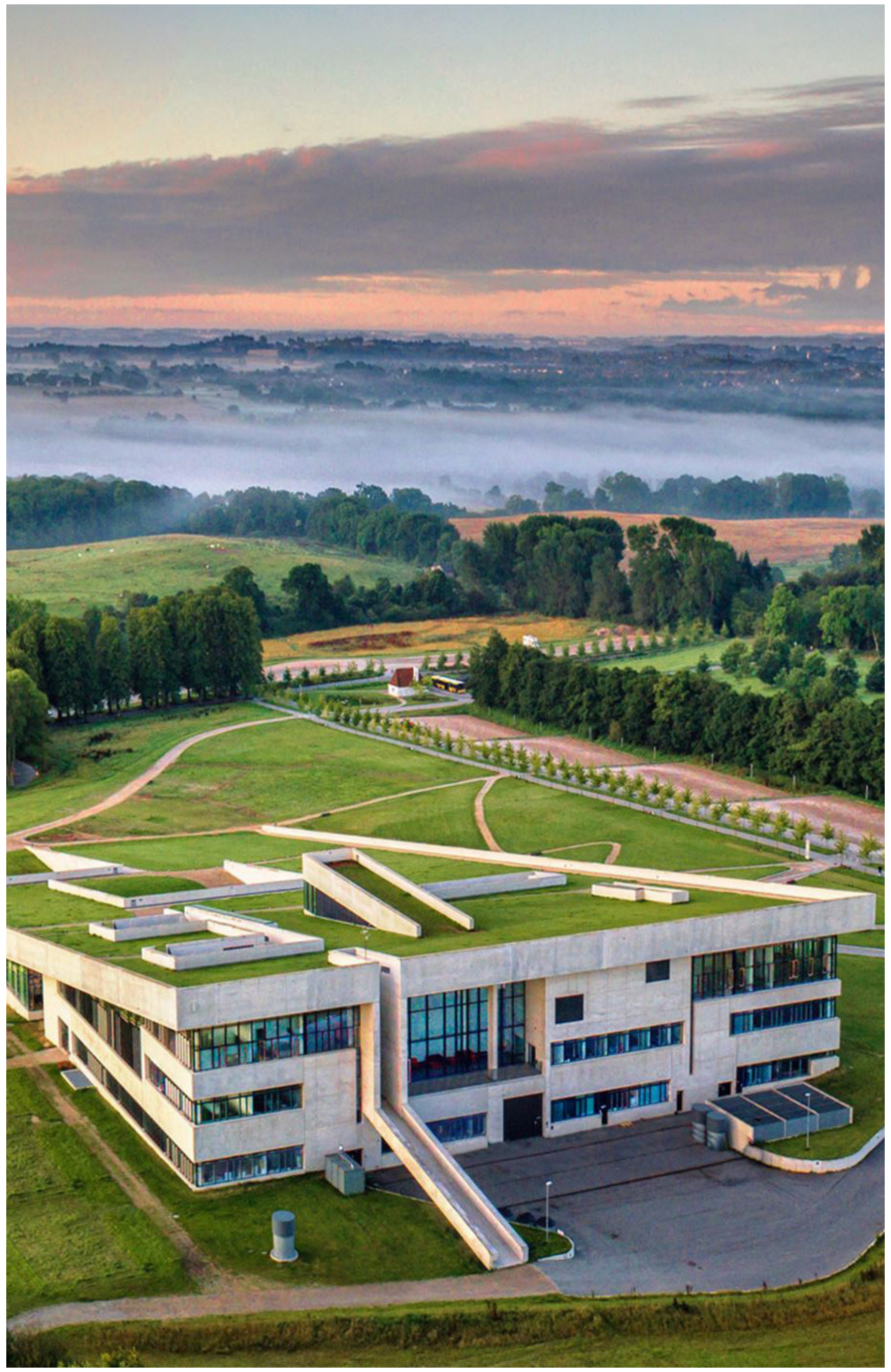


FIG. 11: VISITAARHUS, (N.D.), *THE BIG THINGS TO SEE AND DO*

ANALYSIS

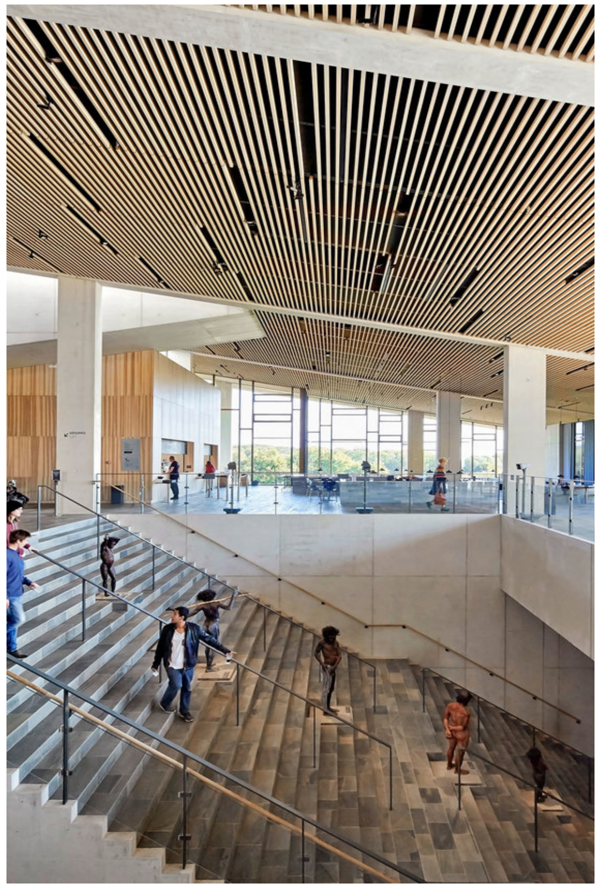


FIG. 12: MOESGAARD MUSEUM, (N.D.) *MOESGAARD MUSEUM*

Architect: Henning Larsen
Location: Aarhus, Denmark
Year: 2014

4.4
A VISIT
EXPERIENCING THE SITE

As you walk towards the future neighbourhood of Kanalbyen, in a perfectly straight line north to south, dictated by Fredericia's distinct grid structure, you leave behind the traditional building blocks. Your back towards the historical ramparts the city is so known for, the water front and Lillebælt straight ahead. Reaching the northern part, the beginning of Kanalbyen where the first apartment blocks in brick stone have already been erected, both the urban strategy and the building typology change. The urban spaces by the canal invite for social interaction and apparitions manifest before your eyes; happy families having potluck dinners, couples walking hand in hand by the waterfront and children playing on the steps at the end of the canal. It seems a postcard from a future summer afternoon.
This new neighbourhood is clearly all about involving and engaging its inhabitants. Even now, long before the residents actually move into their new homes and truly inhabit Kanalbyen, the raised beds for urban gardening, the many tiny shops and workshops provide a sense of community. An anticipation of what will be. Screams from the seagulls remind you how close you are to the waterfront. Moving closer to the site at the south-western corner of Kanalbyen, the terrain opens up and gradually you become more aware of the elements. The cool wind blows through your hair and clothes, no buildings or vegetation to disturb its path and shelter you from the chill. Your positioning makes you feel unprotected, even vulnerable but the breathtaking side-view of the Lillebælt Bridge standing tall in the distance dissolves any unpleasantries. Though the majority of the area is still flat open space you notice that people still take walks along the quayside, already inhabiting and utilising the neighbourhood even before it is built. The magnificent bridge and the soothing presence of the water seems to draw everyone in as if we are affected by some spell.
A loud thud from one of the nearby building sites, snaps you back into the present. The construction work continues, as it will for many years to come; thousands of workers in several professional fields collaborate in developing their proposal for a new sustainable city and Fredericia's future.

FIG. 13: PHOTOS OF THE SITE IN ITS CURRENT STATE

4.5

SITE TOMOGRAPHIES

MATERIALITY, TACTILITY AND ATMOSPHERE

Through a combination of multiple images is sought a representation of the chosen site, its various elements, details and atmospheres. This analysis is based on Martin Krieger's methodology "Urban Tomography"[1] but focuses on the context in close proximity to the site rather than the city as a whole.

A site due to its nature as a physical place is an ever changing constituent. Often only one or two site visits are performed in the duration of a project, which only presents the place under a few weather conditions, specific hours and most likely only one season. When it comes to documentation of a place the most common tool is perhaps the photo. But as a photo is just a slice of space and time, it only ever captures a snapshot. An instantaneous glimpse. Quite like the photo, a site visit only provides an understanding of the site under the conditions present at the given moment. The physical visit does however supply aspects of the place only available to the senses. Urban Tomography attempts to evidence this knowledge by combining multiple photos in a series (source2). The selection of photos bear a narrative, seeking a more satisfactory depiction. Thus the photos selected must be representative of their context in order to provide a comprehensive interpretation of the site's character and atmosphere. Diversity of documentation in angles, motifs etc. is also necessary, as Urban Tomography provides understanding through multiplicity and only then creates an identity. Since Kanalbyen, which the chosen site is part of, is still under development and partially under construction, the current experience when visiting is dominated by large open areas, stacked materials and scattered building sites. The area appears quite eclectic and offers a wide mix of materialities and tactile experiences. Some themes for the future neighbourhood are however evident. Multiple temporary initiatives have sprouted in order to engage Fredericia's inhabitants in the development of this new part of their city, thus involving the inhabitants in a very direct manner. These initiatives include the containers in C-byen where you can find public workshops and cafés, and the garden of rentable raised beds. This very pronounced relation between architectural objective and citizen is evident in several aspects of Kanalbyen. Amongst these are various designs that induce playfulness and interaction with the urban spaces. Whether it be the playground with the small hills or the incorporation of seats into the climate proofing design by the canals it seems a certified goal to create attractive spaces for inhabitants from the whole city to meet with friends and family. Another key concept in the development of Kanalbyen is this close connection to the nearby water and nature, which also supports the aim for the neighbourhood to promote sustainable living. The canals and proximity to Lillebælt provide a feeling of closeness and harmony with the surrounding landscape.

Kanalbyen in Fredericia is an eclectic area under continuous development. However, four design concepts do stand out; engagement, interaction, connection and a rich diversity of materiality and tactility. It may be beneficial for the relation between Kanalbyen and the Visitor Centre to implicate these in the sketching phase. It is worth noting that this analysis is based on a site visit conducted while Denmark was under lockdown, probably resulting in less business related activity than usual.

1 Krieger, M. H (2011) *Urban Tomographies in Site Analysis* in Urban Design: An introductory Reader, Steinø, N.

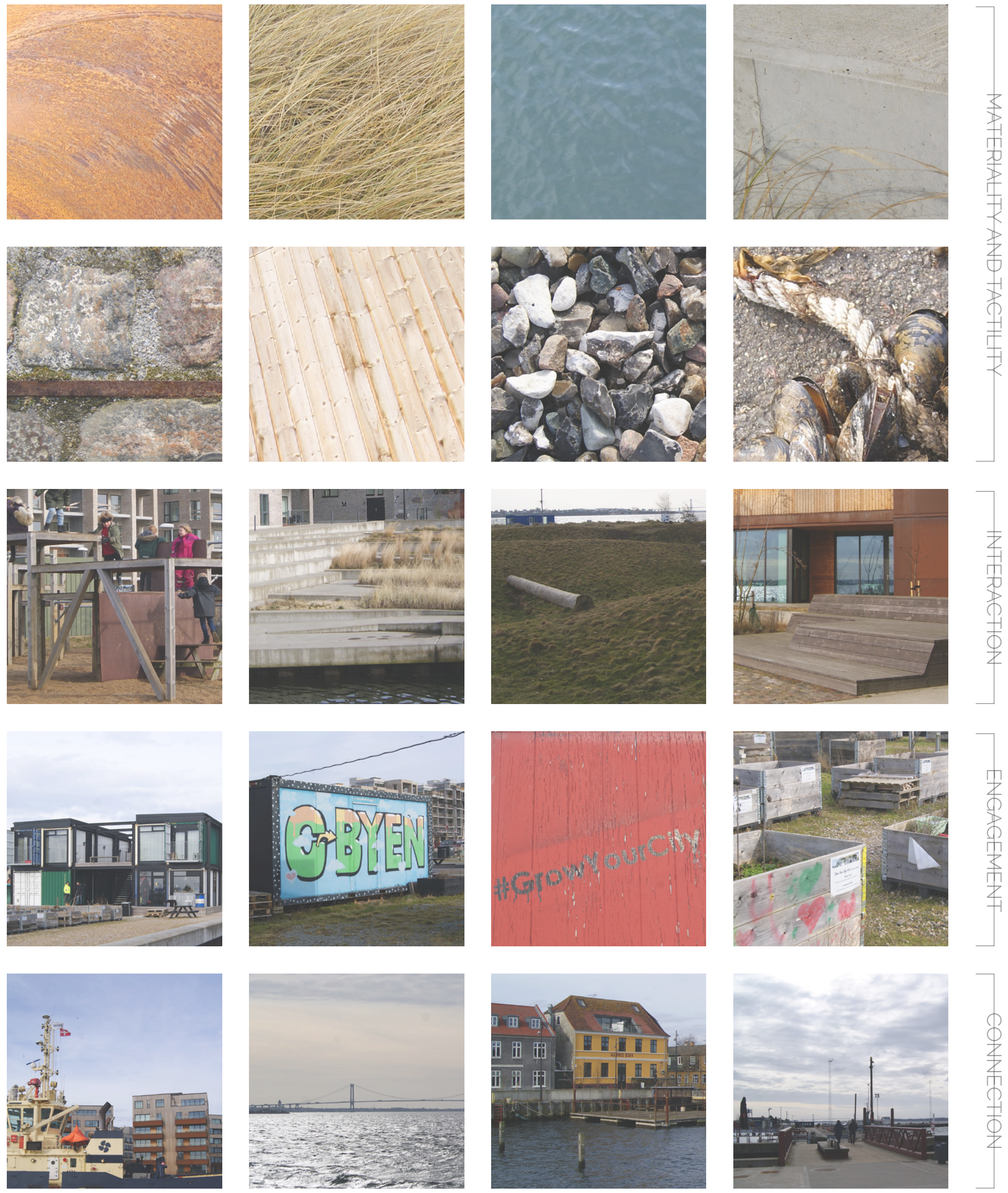


FIG. 14: TOMOGRAPHIC GRID. OWN PHOTOS

4.6
MAPPING
A THEORY OF ANALOGY AND ABSTRACTION

The act of mapping, as described by James Corner, is a method for the uncovering of the potentials of a site, which were previously hidden.[1] The map is a way of re-working what is already present, meaning that it discloses and, in some cases, adds potential for coming acts to unfold. Though it may seem objective, mapping inevitably becomes a subjective act once certain elements are included and prioritised, and others are ignored. Methodologically, mapping can be divided into elements of "fields", "extracts" and "plottings"[2]; the field being the basis, the milieu, from where the mapping itself takes place. Extracts are objects that are singled out or isolated within their original territory, thus revealing any prospective patterns or potentials. Plotting describes the actual graphic indication of interrelations, existing or recent, that exist within the field, essentially setting out the finding and then founding of a project.[3]
Focusing on the location in a larger mobility perspective, the area of Kanalbyen, including its future functionalities and typologies, this analysis aims to clarify the nature and conditions of the site, and reveal any contextual prospectives.

1 Corner, J. (1999) *The Agency of Mapping: Speculation, Critique and Invention in Mappings*, Cosgrove, D. Reaktion Books, p. 213-252

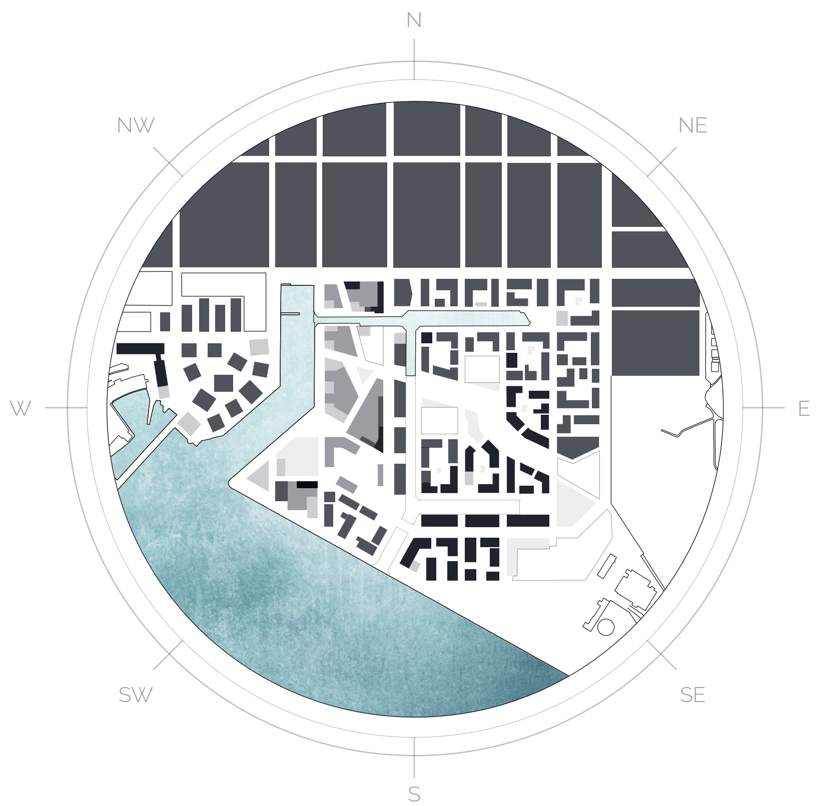
2 Ibid.

3 Ibid.

The infrastructure analysis emphasises the notion of Fredericia as a traffical nerve; the orbital road, which connects to the motorway E20, and the railway going either to Funen, Zealand, or Central or Northern Jutland. It also accentuates the grid structure which is present in central Fredericia, and the partial continuation of the grid in the new Kanalbyen. Around the ramparts, along the Eastern coastline and all the way to and in Kanalbyen are walking paths for pedestrians, essentially connecting the old development with the new.

FIG. 15: INFRASTRUCTURE. 1:50.000

- ORBITAL ROAD
- RAILWAY
- PRIMARY
- SECONDARY
- PEDESTRIANS



The mapping of functions around the site shows the various activities that will be present in Kanalbyen, creating a diverse environment in the future. Closest to the existing buildings, the majority of functions are residential, while the Southeastern part of Kanalbyen is mainly holds commercial functions. The Western part, our site included, primarily concerns cultural functions, together with places for eating and drinking, which will likely result in a lively atmosphere. The functions left of the canal are inspired by the block typolgy as seen in the historic part of Fredericia, while on the rightmost side, the typology is more experimental and contemporary.

FIG. 16: FUNCTIONS. 1:10.000

- COMMERCIAL
- RESIDENTIAL
- RETAIL
- CAFÉ & RESTAURANT
- CULTURE & INSTITUTIONS
- PARKING

4.7

MICROCLIMATE

LOCAL ATMOSPHERIC CONDITIONS

Investigation of the climatic context in which one is designing, provides valuable information on the physical framework of the task at hand. Climate related parameters have potential to be pivotal and may possibly inform and influence the form of the building in the sketching phase. By studying these conditions any crucial challenges can be taken into account early in the design process, resulting in a more durable final proposal.
Being positioned on the corner of Kanalbyen, the site is very open and vulnerable to weather related extremities. Situated in a new neighbourhood so close to the waterfront, it makes sense to take into account the changes that are expected in the near future. By doing so it is possible to ensure building lasting architecture that can withstand changing conditions. This approach makes good sense both in terms of practicality as well as sustainability.

Sun conditions at the site are generally good, although the planned buildings to the south and east may provide some shadow, depending on their height, which remains unspecified. These conditions have been examined in appendix 1. The undisturbed openness to the west may promt attractive placement for photovoltaics.

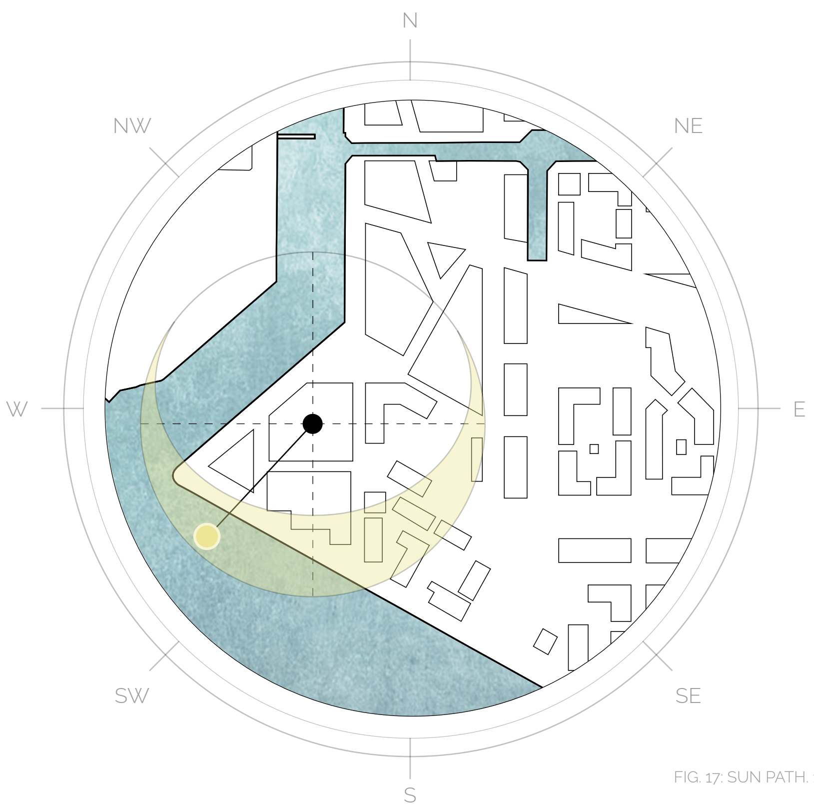
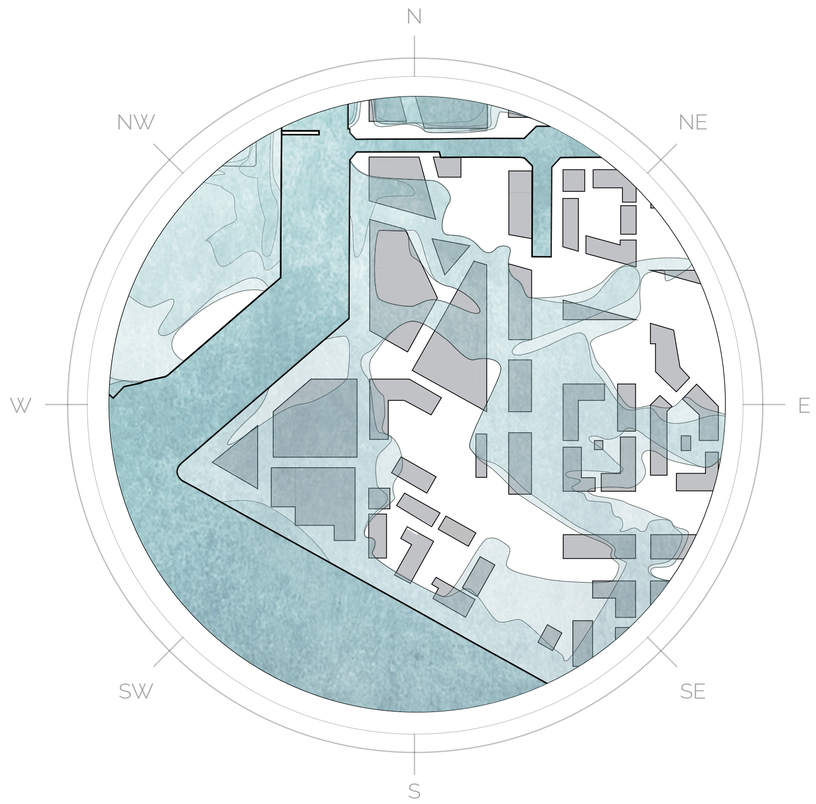


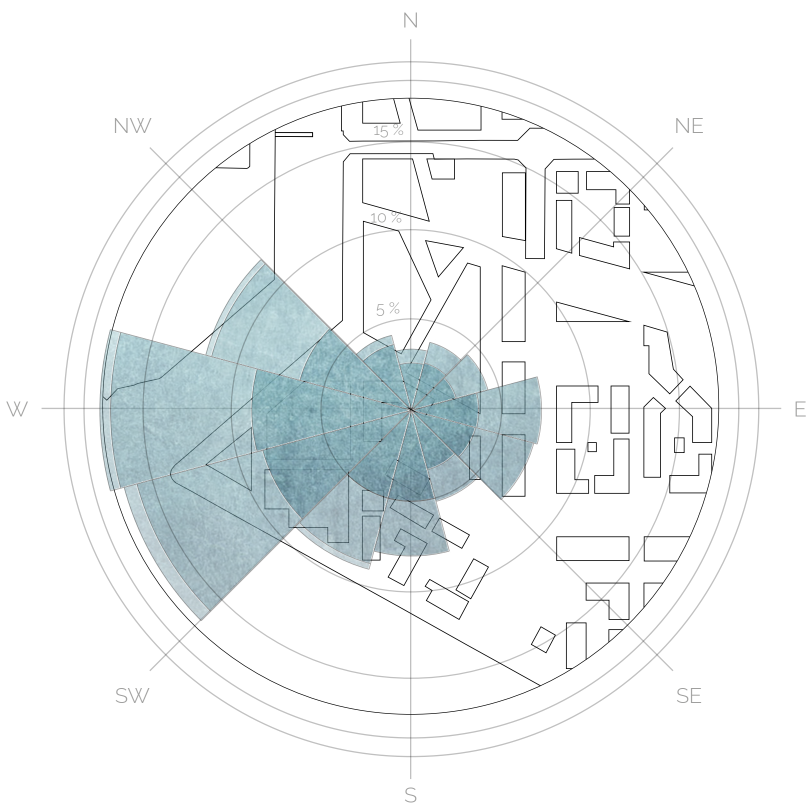
FIG. 17: SUN PATH. 1:5000



Due to its location in the landscape and proximity to Lillebælt, Fredericia is a city in high risk of complications due to climate changes and rising water levels. This mapping accounts for the water levels in case of storm flooding. 10, 20, 50 and 100 year occurrences have been mapped showing that only the 50 and 100 year occurrences should have particular consequences for the chosen site. To accommodate the risk of flooding, Fredericia Kommune has decided that the ground level in the whole of Kanalbyen will be raised to level 2.5 m.

FIG. 18: FLOODING. 1:5000

- 170 CM (50-YEAR FLOOD)
- 176 CM (100-YEAR FLOOD)



The placement on the south-western corner of Kanalbyen leaves the site very unprotected and exposed. The primary wind direction will be west to south-west, and with only open water in this direction, there are no buildings or landscape to shelter the site from the harsh winds. The registered wind speeds indicate that wind will affect the site at most times and it may be necessary to consider creating sheltered spaces for passers-by using the exterior form and disposition of the Centre.

FIG. 19: WIND CONDITIONS. 1:5000

4.8 SUSTAINABLE STRATEGIES

POTENTIAL SUSTAINABLE INITIATIVES ON THE SITE

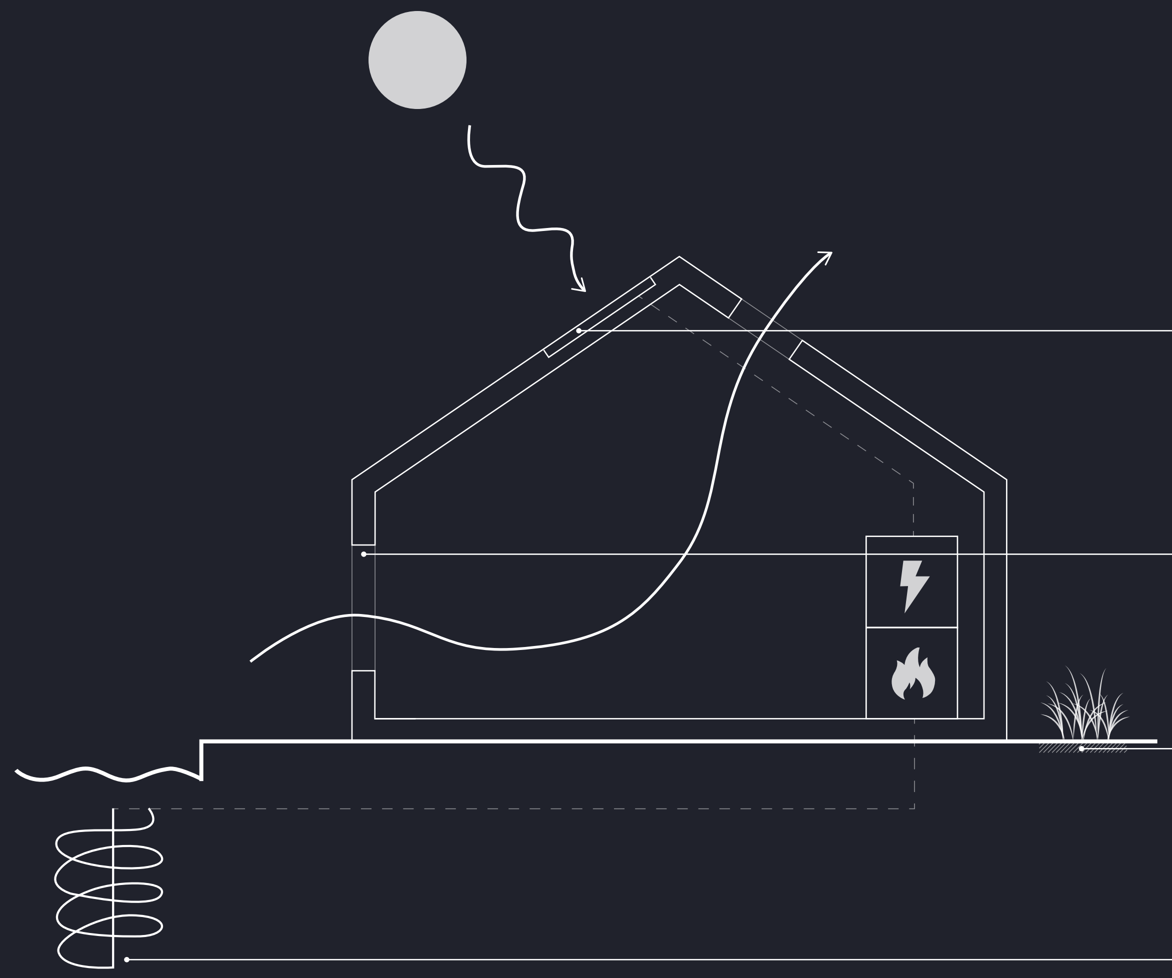


FIG. 20: POTENTIAL STRATEGIES

PHOTOVOLTAICS

The openness to the west can be a suitable orientation for photovoltaics. The east and south can also be considered if placed on the roof to minimise shade from context buildings.

NATURAL VENTILATION

Due to the open area towards the most common wind direction, the driving forces for natural ventilation will have good conditions, which may also be a way to save energy for ventilation in the summer.

VEGETATION

Vegetation can be used to relieve pressure on the sewage system and absorb rain water. This may be desirable due to Kanalbyens position as the lowest point in Fredericia.

HEAT PUMP

Due to the position close to the harbourfront a heat pump in the water should be considered. The brine can be heated or cooled, depending on the needs of the building.

4.9

EXTERNAL ADVISORS

A CALL FOR CHANGE

An important design requirement is the input and desires of the users of a built environment. As this thesis is not developed based on a competition or in collaboration with a specific company, a point of exploration has been on defining user groups, foci and relevant functions for the project as the brief has been developed.

Early in the thesis period, an interview with Christina Aabo, Head of Research and Development at Ørsted, was conducted. The aim of the interview was to reveal any possible desires regarding a new visitor centre, as well as to gain insight into Ørsted's role in the energy industry. Note that the following points and statements reflect the personal opinions of Christina Aabo, and not Ørsted as a company. According to Christina, a future visitor centre should encompass an international appeal that aims to inform both policy makers and the public regarding the impact and implementation of renewable energy and sustainable technologies, on both a micro and micro scale. Another key point was the user experience of the centre, preferably giving the centre a striking aesthetic appeal, making it an experience to revisit, as well as to engage users of different backgrounds and age groups.[1]

As the site is located in Fredericia Municipality they were contacted, and it turned out the municipality is already in the early stages of planning a so-called "science centre" focusing exactly on communication of renewable energy and sustainability. Our correspondent, Gitte Lyager Ryan, project manager on the planned centre, shared their current work and considerations including a preliminary investigation of possible sites, visitors, investors, as well as the general theme for the centre's exhibitions. According to Gitte, the main theme for the exhibitions should be green transition focusing on energy systems, aiming to evoke and sustain an academic interest in natural science amongst youths. Correspondingly, Christina from Ørsted pointed out the need to improve the basis for recruitment in energy companies such as Ørsted, where they are already short of competent staff to manage and succeed in green transition at both a domestic and global scale.[2]
In practice, Gitte Lyager expressed a general desire for providing visitors with hands-on experiences in the exhibition, using a sensuous approach to mediation and learning. Furthermore, an space for hosting school lectures or talks from relevant companies, as well as "lab"-facilities for children and schools to experiment with e.g. robot building would, according to Gitte, be ideal. In terms of its architectural expression, the centre should preferably stand out from its surroundings and act as a landmark for the area of Kanalbyen and Fredericia[3], as an embodiment of their future sustainable strategies.

1 Christina Aabo, (09.02.2021) *online interview by group*

2 Gitte Lyager Ryan, (16.02.2021) *telephone conversation*

3 Ibid.

4.10

USER GROUPS

WHO DO WE DESIGN FOR?

THE GENERAL PUBLIC

This group is broadly defined as civilians from all over Denmark and does not exclusively focus on people living in Fredericia, nor does this group differentiate people into age groups, although distinctions might be useful for a later clarification and definition of this group. As this user group is expected to visit the centre at their own leisure, the centre should cater to the expectations for similar science-centres and museums. The exhibitions should be approachable regardless of age and level of education, while being exciting and promote a curiosity for learning. The overall design of the building should enforce this through the architecture and structural system. Integration into the local environment could aid this experience as well. Thus the design of the centre should be conscious of providing positive experiences for both one-time visitors and the experience of people for whom the centre will be part of their everyday lived environment. Accommodating the user groups needs for a nice afternoon trip, the centre should incorporate proven functions such as a gift shop, a café or restaurant and similar functions to be expected when visiting a museum or science centre.

EDUCATIONAL INSTITUTIONS

This group overlaps with the general public in several ways, as the specific people can be found in both groups. The difference is in for which purpose the centre is visited and the users own role and agency in visiting. School trips and excursions are often planned by an educator and will include pupils who are unmotivated and resistant to engaging in the experience of the centre. As such strategies for creating engagement in the visitor should be explored. As school trips will often include groups of up to 30 people, another focus of the centre could be on an informative layout to help people getting lost and spatially allow for this amount of people to access exhibitions and experiments. The room programme could also include one or more spaces that can be used as temporary class rooms, lectures and guided experiments.

INBVESTORS AND POLICY MAKERS

The last major group is more specifically linked to combating climate change. While informing and including the general public is important, many decisions and policies that have the greatest effect on climate change are dependent on investment in new green technologies and policy making, a statement supported by our interview with Christina Aabo. Thus a requirement of the centre is to be used for developers and companies to have meetings with investors, possibly showcasing their projects and company. Likewise the centre should facilitate both conferences and meetings between policy make and experts, researchers, and the general public. A desire for functions like this was expressed during the interview with Ørsted, although these facilities might only have to be used periodically.

"I WANT THE BUILDING TO ADD VALUE TO MY COMMUNITY"

"I WANT TO LEARN MORE ABOUT SUSTAINABLE BEHAVIOUR"

"IMPRESS ME!"

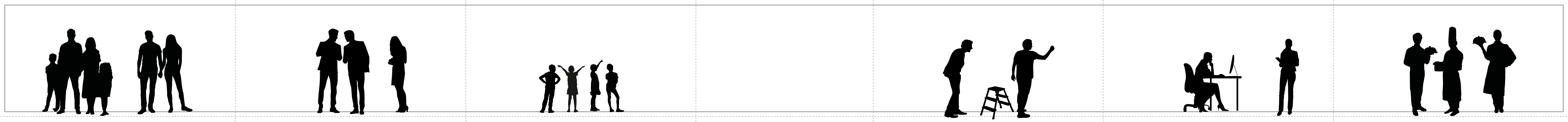
"I WANT AN EXPERIENCE THAT STANDS OUT"

"WE LEARN BETTER THROUGH HANDS-ON EXPERIENCES AND PLAY"

"CURVED SHAPES ARE MORE LEASANT AND INSPIRING"

"I WANT TO PROMOTE SUSTAINABLE DEVELOPMENT"

"OUR FOOD IS GOOD FOR YOU AND FOR OUR PLANET"



	GENERAL VISITORS	STAKEHOLDERS	SCHOOLS		EXHIBITION TEAM	ADMINISTRATION	RESTAURANT STAFF	
USER GROUP								USER GROUP
VISITOR TYPE	CHILDREN ADULTS ELDERLY TOURISTS PASSERS-BY	INVESTORS POLICY MAKERS CORPORATIONS	PRE-PREPARATORY CLASSES PUPILS TEACHERS		CURATOR EXHIBITION ARCHITECT COMMUNICATORS FACILITY MANAGER EXHIBITION WORKERS IT-TECHNICIAN	DAILY MANAGER RECEPTIONIST SHOP MANAGER EVENT COORDINATOR PROJECT MANAGER	MANAGER CHEFS SERVING PERSONNEL	OCCUPATION
ACTIVITY	CLOAKROOM EXHIBITION EXPERIENCE OPEN LECTURES GIFT SHOPPING RESTAURANT VISIT	GUIDED TOURS BUSINESS MEETINGS RESTAURANT VISIT EXHIBITION EXPERIENCE	CLASSROOM LESSONS EXPERIMENTS LUNCH BREAK EXHIBITION EXPERIENCE		MAINTENANCE PLANNING GUIDING TOURS TEACHING	PAPERWORK COORDINATING ORGANISATION PLANNING CUSTOMER SERVICE	PREPARING MEALS HANDLING INGREDIENTS AND TABLEWARE SERVING GUESTS	ACTIVITY
DESIGN STRATEGY	ANALOGUE AND DIGITAL ACTIVITIES KINESTHETIC NARRATIVE INFORMATIVE LAYOUT OUTDOOR INTERACTION	VISUAL AND AUDITORY PRIVACY ANALOGUE AND DIGITAL ACTIVITIES	HIGH CAPACITY DESIGN ANALOGUE AND DIGITAL ACTIVITIES KINESTHETIC NARRATIVE INFORMATIVE LAYOUT OUTDOOR INTERACTION		FLEXIBLE EXHIBITION SPACE CREATIVE WORK ENVIRONMENT	FLEXIBLE WORKSPACE AUDITORY PRIVACY VISUAL CONNECTION	SPACIOUNSESS PRACTICAL SURFACES AGILE WORKFLOW	DESIGN STRATEGY

FIG. 21: USER GROUPS

4.11

CASE STUDIES

CONTEXT, FORM AND STRUCTURE

This study intends to examine the integral relationship between building form, the context in which the building is located and how this form can afford different user interactions and behavior. For this purpose, several cases will be introduced and analysed in respect to the aforementioned relationship. To ensure relevance and similarity with the ongoing development of the project, the selected cases all utilise organic / curved shapes and use wood as construction material for these shapes. This point will be analysed as well in relation to how the qualities of wood influence the design of the buildings.

Through the cases, it is apparent that referencing the context with organic shapes can be used to great effect to create interest and break monotony, as seen with Klimatorium, or inform an overall shape and concept for a structure. All projects incorporate a sense of framing or view point, with different degrees of focus and directionality, which should be translated with care as depending on the desired result and focus. Technically the three projects range from, in order of case; a visible, but less representative solution; a simple, more basic approach; and finally a communicative, but rough expression of the system. These can stand as approaches to be inspired by and as the structural system is fitted to our project.

KLIMATORIUM

ARCHITECT: 3XN
LOCATION: LEMVIG, DENMARK

Klimatoriums location on the waterfront has greatly influenced the overall shape of the building[1]. The design is a two-story structure with a stringent, rectilinear expression. A great amount of glazing is utilised, but the floors are differentiated with the ground floor being completely open and transparent, while a series of dark wood lamella shades the upper. Between the floor, a brand of light wood carves into the southern facade, creating an organic curved pocket, referencing both a wave and the keel of a boat, referencing the historical culture of the city. This element creates a strong identity, as the contrasting colour, shape, and transparency makes it stand out and draws the eye of the user.
Inside the concave shape, a few steps affords a place for the user to sit and observe the harbour and the recreational area next to the building, which uses similar curved shapes in the design of the landscape. Inside the building, the pocket influences how the user perceives and moves, as the convex shape reaches into the room and lays bare the wooden construction. This construction is unique to this part of the building, being a series of beams seemingly made from LVL slabs cut into shaped pieces. This solution is the lesser choice from a tectonic perspective, as bending elements using steam or by laminating them keeps the direction of the grain[2].

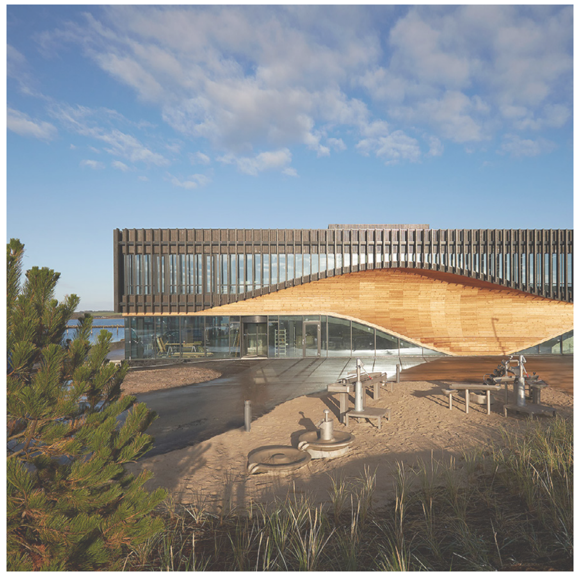


FIG. 22: 3XN, (N.D.) *KLIMATORIUM IN LEMVIG*

FIG. 23: 3XN, (N.D.) *KLIMATORIUM IN LEMVIG*

1 3XN, (n.d.) *Klimatorium in Lemig*
2 Berger, M (2005), *All About Bending Wood*

VISITOR CENTRE NATIONAL PARK MOLS BJERGE

ARCHITECTS: TREDJE NATUR + REIULF RAMSTAD
LOCATION: KALØ, MOLS, DENMARK

The visitor centre is located in the hilly landscape of Mols Bjerge, which is both the focus of the centre and the main inspiration for the overall shape[1]. The centre is constructed as a wavy roof, elevated on a series of massive wooden beams. The roof meets the ground on each end of the longitudinal axis, allowing the user to walk across the building on top. The flow mimics the kinesthetic experience of walking on the hills and leads the user to a view of the landscape and then into it. In the interior, the shape of the roof synergises with the organic path design leading to the different exhibitions.

A vast amount of glazing and beams open up views of the landscape, in particular a view of the Kalø Castle ruin, pointed to by the roof (see figure 25). The structural system is seemling made out of laminated beams and columns, with no visible connections that present the structural frames as singular, massive objects.

FIG. 24: TREDJE NATUR, (N.D.) *VISITORS CENTRE NATIONAL PARK MOLS MOUNTAINS*

FIG. 25: TREDJE NATUR, (N.D.) *VISITORS CENTRE NATIONAL PARK MOLS MOUNTAINS*

1 Tredje natur, (n.d.) *"Visitor center national park Mols Mountains"*

FIG. 26: ARCHDAILY (2015) *THE WARP*

FIG. 27: ARCHDAILY (2015) *THE WARP*

THE WARP

ARCHITECT: OLIVIER OTTEVAERE + JOHN LIN,
LOCATION: ZHAOTONG SHI, CHINA

The Warp is a small-scale project taking inspiration from the surrounding mountainous landscape, with a curved roof that meets the ground on its latitudinal axis[1]. The roof affords the user to walk on top, providing a viewpoint of the landscape and the main road leading to the town, while space is created underneath for resting. The foundation and stairs to the roof is made of a mix of stone and concrete, while the rest of the pavilion is constructed using slender timber elements. The curve of the roof is based on a sine curve, using a structural principle that allows the curve to be constructed using straight, linear timber elements on the lateral axis.

The result is a very smooth curve when viewing the curve from the outside, with the construction exposed underneath. As the construction is light, the inner structural elements can seem a bit flimsy, but the system is very readable and the curvature of the roof is expressed in the smaller stabilising elements. The naked way the building presents itself, results in the project reading more like pure structure, which may or may not be intentional.

1 Archdaily (2015), *The Warp*

4.12
TIMBER STRUCTURES
CONSTRUCTION METHODS AND DETAILING

Within construction, timber is the only true renewable material. As previously mentioned in chapter 4.1, its ability to store and absorb carbon dioxide provides a positive contribution to the battle for a decarbonisation of the building industry. Though it may seem common and familiar to many, wood has an extremely complex cellular structure. Its anisotropic nature means that it has different properties in each direction and no table or formula can fully comprehend its character. Each piece of wood appears different, behaves differently and contains different properties. In its natural habitat, wood is imperfect, flawed and unpredictable. Wood is a living material; it expands when wet and shrinks when dry. It has knots, splits, and warps -- all of which makes it difficult to handle structurally. Nevertheless, wood is a very efficient structural material due to its high weight-to-strength ratio. In tension and relative to their weight, softwoods such as spruce, pine and fir are comparable with structural steel[1]. To accommodate the "flaws" naturally found in wood, engineers have invented solid wood constructions, which allow for greater strength and larger dimensions that what is possible with traditional light wood constructions. The term "engineered wood" thus encompasses a reassembly of small individual pieces of timber that are adhered together to create a manufactured product with properties and strength as if it were one coherent piece of timber, and with less natural imperfections[2] .

Cross laminated wood (CLT) is a type of structure where layers of wood are glued together in an alternating 90 degree angle, which means that the fibre direction of the wood changes with each layer. This minimises the inherent inhomogeneous characteristics that timber elements naturally possess and ensures a more stiff and durable element. CLT elements allow prefabrication and are oftentimes used as solid decks or walls and due to their great strength, they offer a sustainable alternative to concrete elements[3]. As with CLT, glue laminated timber, or glulam, consists of several layers of wood that are adhered together to enhance its strength and minimise irregularities, however each layer has the same fibre direction as opposed to CLT. Glulam elements are often used for beams and columns but can also be assembled into larger panels. Weighing approximately 10 % of the weight of steel and one-fifth of the weight of concrete, glulam is efficient in terms of transportation and production[4]. Laminated veneer lumber (LVL) is a type of engineered wood where thin pieces of wood measuring only 3-4 mm are glued together to form larger panels, columns or beams. In general, the grains of each layer are facing the same direction but it is also possible to orient layers in a 90 degree angle, as in the case of CLT[5]. The large number of layers in LVL makes for a very strong and stable structure, especially parallel to the wooden fibres where it is otherwise weakest.

1 Sandaker, B. N. et al. (2011) *The Structural Basis of Architecture.*

2 Ibid.

3 Mayo, J. (2015) *Solid Wood: case studies in mass timber architecture, technology and design.*

4 Ibid.

5 Ibid.

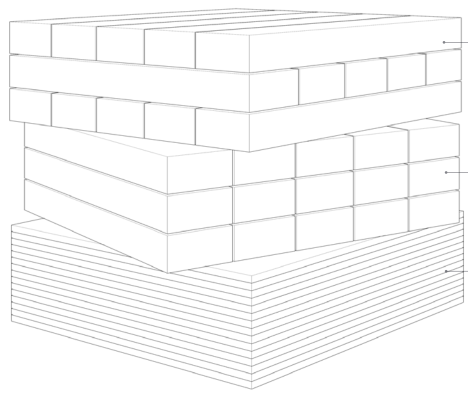


FIG. 28: TYPES OF ENGINEERED WOOD

As stated, wood constructions are living structures that inevitably will be affected by the wear and tear of their surroundings. As our site is located at the very tip of the harbour, it means that the construction will be exposed to moist and salty conditions and needs to be considered. A certain degree of weathering and patina can be preferable and give character when properly orchestrated, but one must differentiate between the terms of weathering and decay[1]. Weathering is primarily caused by exposure to sunlight and moisture from precipitation which affects its appearance, but not necessarily its strength or durability. Moist conditions will expedite the decaying process and can cause wood fibres to erode and loosen, however, some species are naturally more durable than others. This should be taken into account both in terms of the structure itself, but also when using wood as facade cladding. Though various coatings and treatments of the wood can remedy some amount of decay, proper detailing of the design is more efficient. Ensuring proper ventilation, using overhangs, protecting the end-grain and placing the timber elements vertically are all principles that will alleviate protection of the construction. Furthermore, it can be beneficial to distinguish between construction elements; non-structural elements, non-critical structural elements and finally critical structural elements[2]. Non-structural elements have the possibility to be replaced if needed, while critical structural elements should be preserved during the entirety of their lifetime. Thus, it is apparent that close attention needs to be paid when designing timber constructions.

1 Mayo, J. (2015) *Solid Wood: case studies in mass timber architecture, technology and design.*

2 Ibid.

4.13

ROOM PROGRAMME

LIST OF SPACES

VISITOR CENTRE

ROOM	UNITS	AREA (M2 PR UNIT)	CAPACITY (USERS PR UNIT)	LIGHT (DAYLIGHT/ ARTIFICIAL)
FOYER	1	300	85	D/A
TICKET OFFICE	1	20	2	D/A
CLOAKROOM	1	30	15	A
GIFT SHOP	1	40	15	D/A
RESTURANT / CAFÉ	1	200	40	D/A
KITCHEN	1	60	5	D/A
EXHIBITION AREA	1	850	-	D/A
AUDITORIUM	1	250	90	D/A
WORKSHOP	1	120	30	D/A
ADMINISTRATION OFFICE	1	60	8	D/A
MEETING ROOM	1-2	30	10	D/A
BREAK ROOM	1-2	15	6	D/A
TOILETS	10	6	1	A
CHANGING ROOM (INCL. SHOWER)	2	10	1	A
STORAGE	2-3	30	-	A
TECHNICAL ROOM	1	30	-	A
CLEANING ROOM	1	5	-	A

FIG. 29: ROOM PROGRAMME

TOTAL AREA: 2.225 M2

4.14

FUNCTION DIAGRAM

SPATIAL OVERVIEW

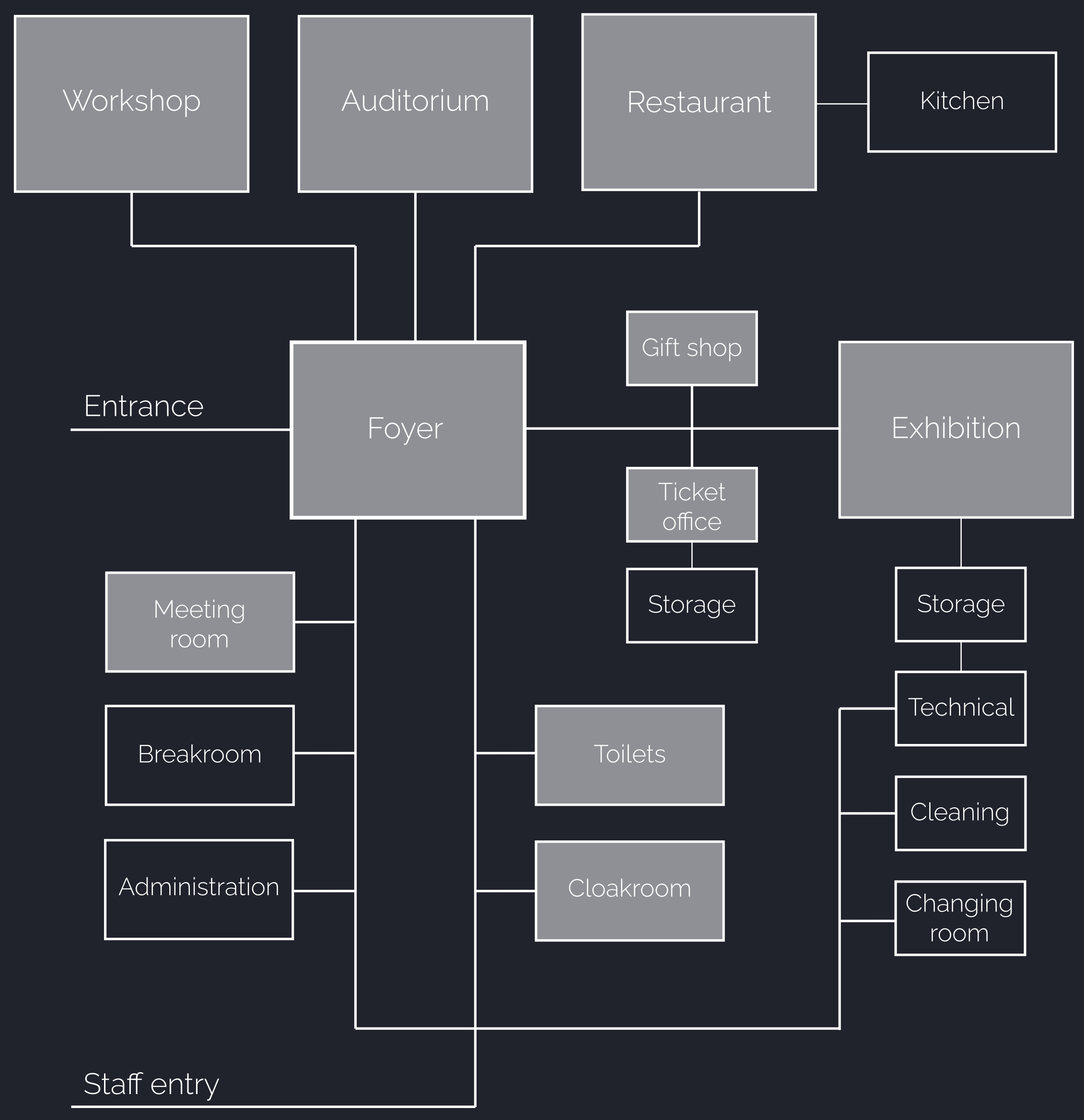
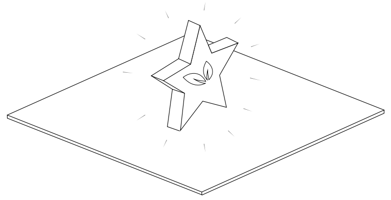


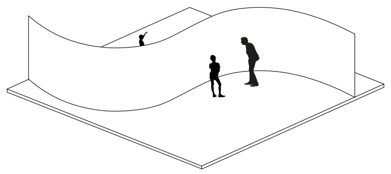
FIG. 30: FUNCTION DIAGRAM

4.15 FINDINGS

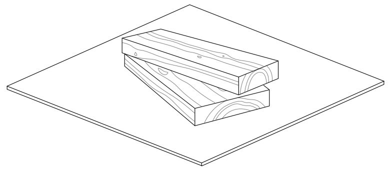
THE BASIS FOR OUR DESIGN



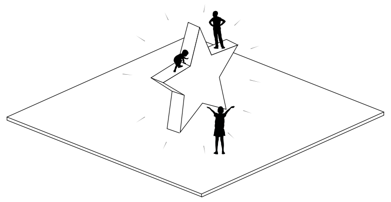
Landmark architecture acting as a beacon for sustainable development



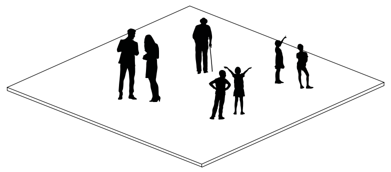
Framing a narrative journey through the building using curvilinear forms



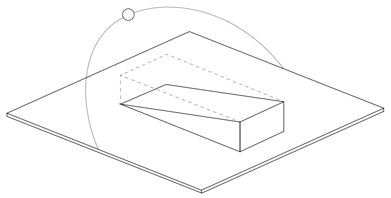
A sustainable approach to selection, processing, and joining of materials with focus on life cycles and optimisation



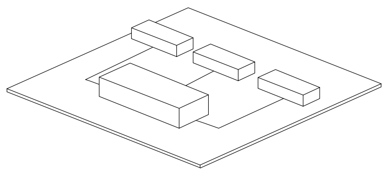
Exterior and interior form allowing use and interaction to inspire a playful approach to architecture and learning



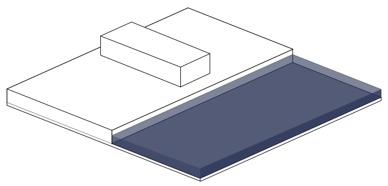
Embracing an engagement with sustainability across different levels of knowledge, influence and age



Implementing passive and active strategies for energy optimisation into the aesthetics and planning of the building



Facilitation of a macro exhibition on energy systems and micro exhibitions on renewable energies



Materials and form responding to the maritime atmosphere and climate at the site

FIG. 31: PROGRAMME FINDINGS

4.16 SCOPE

THE EXTENT OF OUR PROJECT

This thesis revolves around the design of a Visitor Centre focusing primarily on communication and advancement of renewable energy and secondarily on education of sustainable living for the general public. The scope of the communication is intended to incorporate information sharing on different scales, ranging from private visitors, to school excursions, to politicians and investors, taking into account their different pre-understandings. The centre should be between 1500-2000 m^2 including all facilities, and the message of the urgent need for a green transition should be reflected in the architecture itself. Furthermore, the overall focus will be holistic in terms of combining tectonics and sustainability, seeking to create a convergence between the two. The main technical focus will be on tectonics, exploring how this can be used in conjunction with various sustainable strategies, the latter of which will be examined on a conceptual level. Additionally, the project must relate itself to the traditions of nordic architecture by means of materials, contextual relations and aesthetics.
The project will not consider topics such as budget and execution, and calculations of energy consumption and indoor climate will only be examined on a conceptual level.

5.0
DESIGN PROCESS

5.1

DESIGN PRINCIPLES

INITIATING NOTIONS FOR EXPLORATION

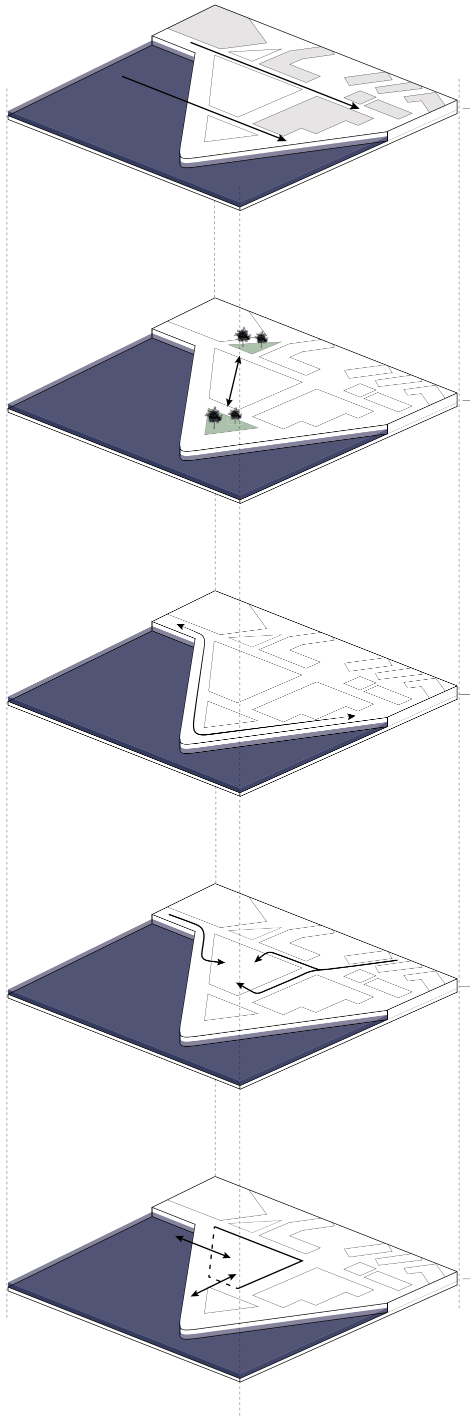


FIG. 32: DESIGN PRINCIPLES

SIGHTLINES

The building site is defined by the gridlines from the city, which create linear sightlines connecting the water and the inner city. A careful and conscious approach should be taken when working with these in terms of views.

RECREATION

Two areas north-east and south-west of the site will be recreational, green areas. The building should relate to and connect these areas as part of the urban scheme.

PROMENADE

The promenade along the water will invite an influx of people strolling in the area, as well as fishermen and people tending to their boats. The building should acknowledge and enhance this flow in the design.

ACCESSPOINTS

People are considered to be arriving mainly from east/south-east and north, which should be reflected in the access points to the building. To the east is located a main road and a parking area.

TRANSPARENCY

Considering the flow of people along the promenade, the facades in these orientations should be open and inviting. Two large buildings are planned to the south and east, result in more closed facades.

DESIGN PROCESS

5.2

TYPOLOGY AND FORM

VOLUMETRIC STUDIES OF FORM

The building shape has been explored through three main typologies in a multiple iterations. The typologies have been judged with a focus on relating the building to the context, while being aware of urban flow; constructing a recognisable landmark, while respecting the development plan for the area; inviting people to engage and interact with the building; as well as considering functionality of the interior spaces. Three iterations for each typology have been selected and judged, and have afterwards been further developed.

The organic forms are inspired by the notions of curvilinear shapes from the programme. As the context almost exclusively uses regtangular footprints, this will efficiently make the building stand out, and the curves inspire curiosity that could provide an organic urban flow. Lowering the building down to the ground makes it possible to utilise the roof top allowing an interesting flow on top of the building and interactivity for the community. Using a linear footprint and realising the curves in the roof instead may be an interesting approach. This form can be realised in several structural ways, fitting the tectonic ambitions of the project, while the linear footprint can make the building easier to realise on the interior.

FIG. 33: TYPOLOGY STUDY

5.3

'THE HYPERBOLIC'

PHYSICAL EXPLORATION OF FORM AND STRUCTURE

Early in the design process, because the undulating building shape was considered, the shape of a hyperbolic paraboloid was explored in terms of its structural advantages and applicability in relation to the roof of the building. A hyperbolic paraboloid (referred to as 'h/p') is a double curved and doubly-ruled surface, meaning that every point on it lies on two straight lines, while that the surface itself is both convex and concave respectively on its two axes. It can thus be constructed using straight elements, while gaining strength from its curved shape, which reduces its tendency to buckle and raises its stiffness.[1] Its utility for the project lies in the shape, which both touches the ground (allowing for an ascending form) and are able to extend over long spans. This allows for a curved shape, which ascends and descends, combining some of the qualities of both the undulating form and the ascending form, as mentioned earlier.

The form was explored in alternate versions using cut models in a series of iterations. The iterations explored to possibility of applying the principle using non-linearity in one or two of the facades and changing the footprint from a square to trapezoid, as to allow for greater flexibility in the shape of the building and better relate it to the footprint of the site. These alternative versions of the h/p still have some of the structural qualities of the 'pure' shape, although alternative construction methods are needed, as the surface is ruled, but no longer doubly-ruled.

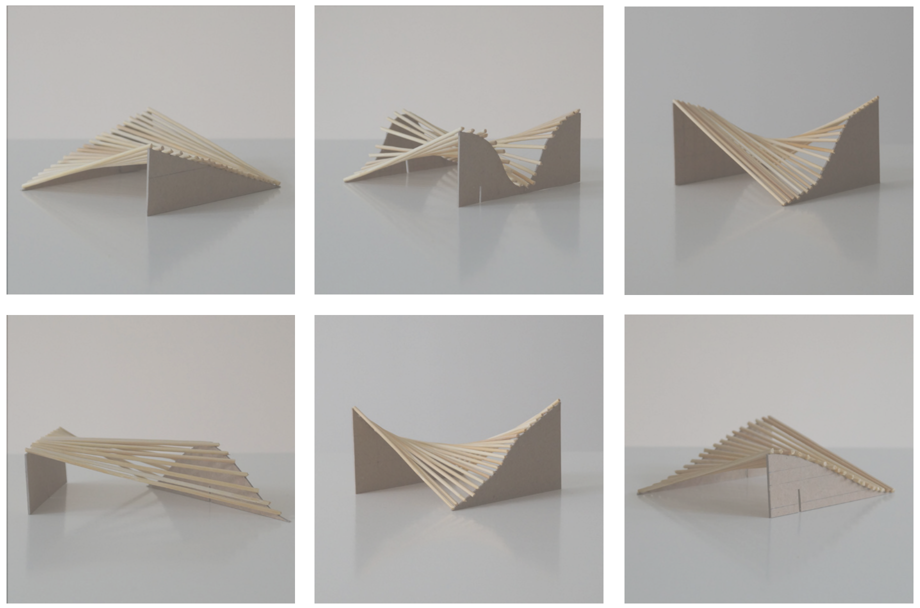


FIG. 34: OWN MODEL PHOTOS

1 Designing Building Wiki, (2020) *Hyperbolic paraboloid in construction*

SURFACE CONSTRUCTION PRINCIPLES

1: A surface constructed through both linear and curved beams, creating a rigid surface

2: A surface constructed through both linear and curved beams, as well as diagonal bracing, creating a rigid structure

3: A surface constructed with bigger linear beams, held together with smaller straight beams which approximate the curve. This type has less rigidity than type 1 and 2

4: A solid, cast surface in which rigidity is ensured due to the h/p form. This type is more suitable for a material such as concrete

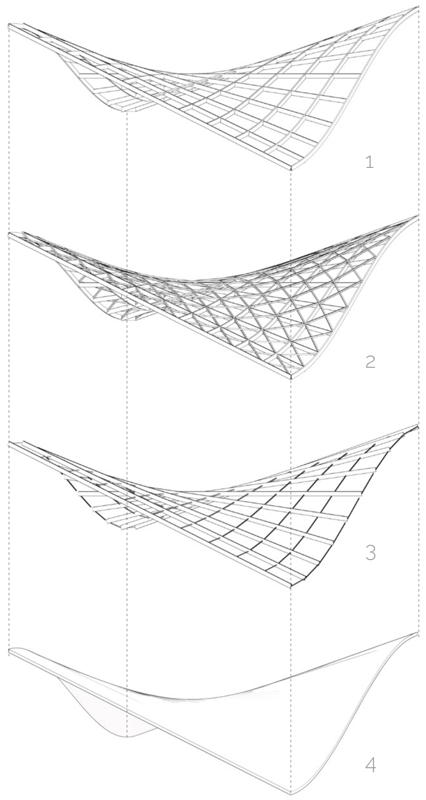


FIG. 36: CONSTRUCTING THE SURFACE

SUPPORT PRINCIPLES

1: Columns placed at all intersections, causing a lack of flexibility internally

2: Randomised placement of columns, however, this requires a completely rigid surface

3: Columns placed at end points of beams, providing flexibility internally, however, this requires large cross sections

4: Stabilising walls providing flexibility internally, however, this requires large cross sections. Possibly requiring concrete or similar material and does not allow for transparency in two of the facades

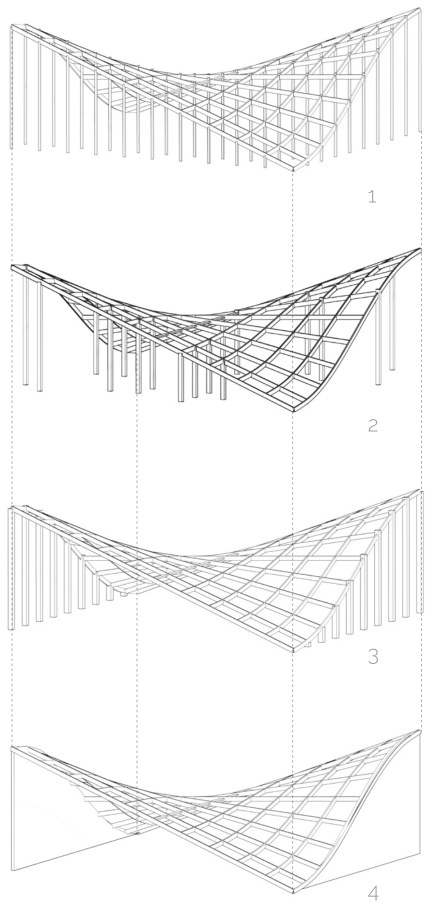


FIG. 35: SUPPORT FOR BEAMS

5.4

FORM EXPLORATION

CONTEXT AND ENCOUNTER

As the undulating roof in general had the most qualities, this section and the coming section will focus on the further development of this shape exemplified in four iterations. An initial exploration was conducted in 3D by exploring how the buildings presented from three directions: north, east and south.

The path from the north along the promenade, is presumably how most people will approach the building. The building needs to look inviting as well being recognisable. All four iterations fulfill this criteria, especially The Ray and The Zaha, of which the wave shape is very pronounced. From the east, the building is obscured by several buildings and it is also where the access to the roof is located. It was thus important that the iterations seemed inviting and led people up on the roof, but without obscuring the view across the canal. The best effect was judged to be when the building does not extend too far towards the north, while at the same time angled such that the surface of the roof is facing the user. This conclusion has been used in future development of the shape. People arriving by boat and walking towards the city along the harbour, will meet the building from the south. In this case it was important that the building communicated its form properly and did not seem too dominating, the latter being the case The Wave 2.0. The roof and the facade of both The Zaha and The Wave dived to meet the user, which counteracted this effect, while the thin roof of The Ray had a lightness and elegance about it, which beautifully leads the eye across the channel and towards the city. Further explorations can be found in appendix 2.

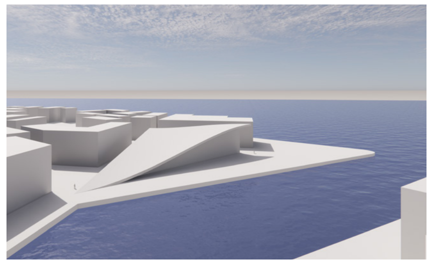


FIG. 37: THE WAVE

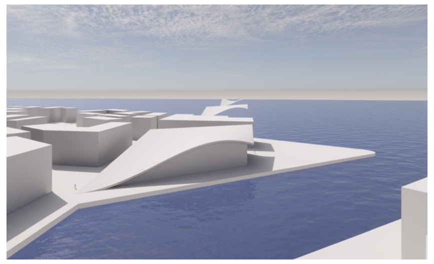


FIG. 38: THE WAVE 2.0

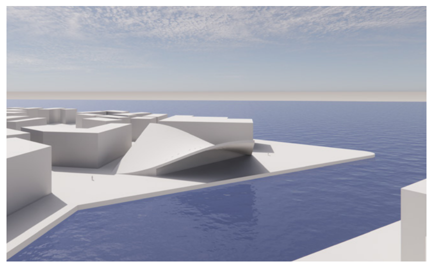


FIG. 39: THE RAY

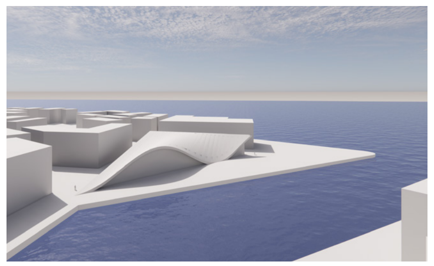
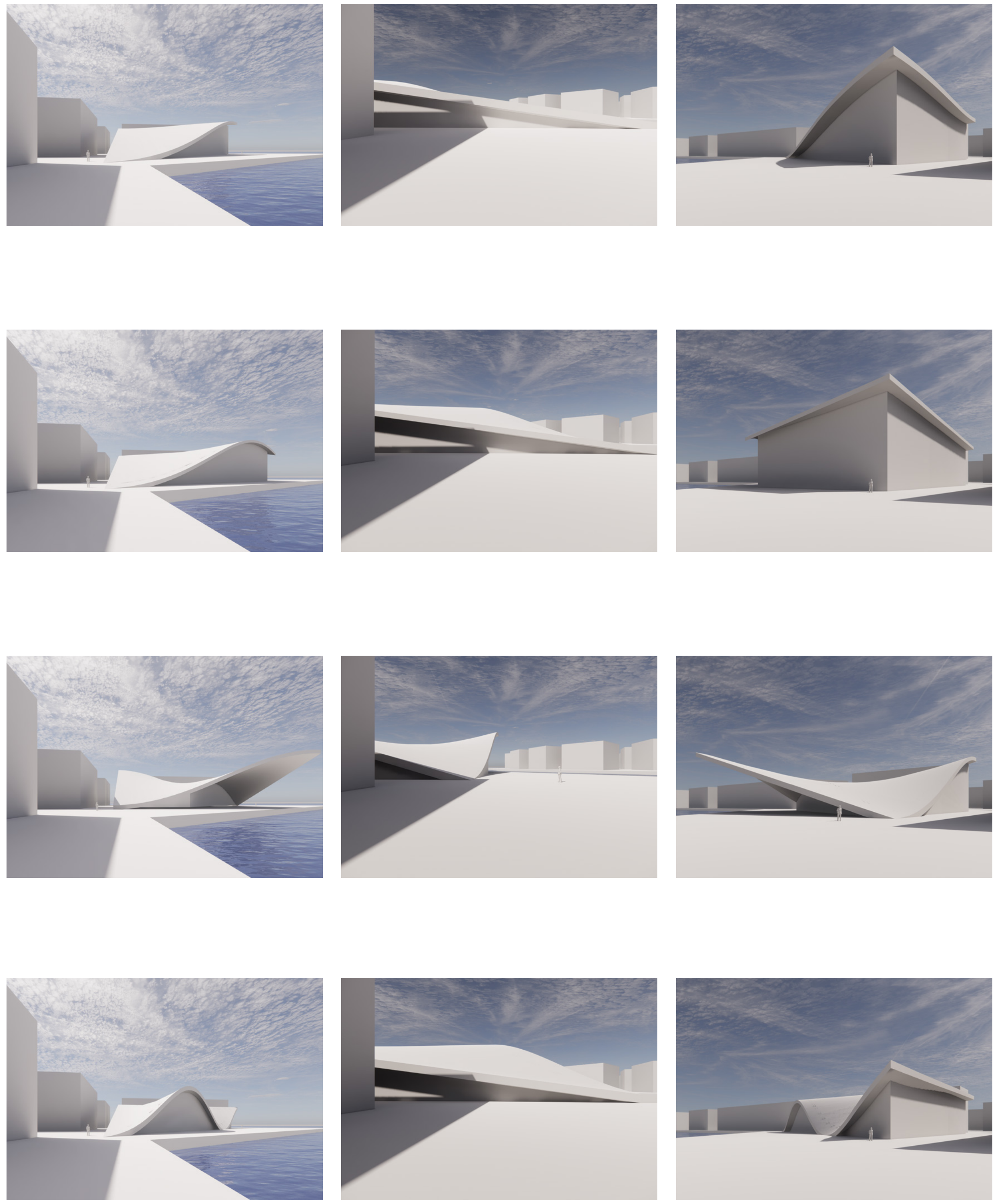


FIG. 40: THE ZAHA

VIEW FROM NORTH | VIEW FROM EAST | VIEW FROM SOUTH



THE WAVE

THE WAVE 2.0

THE RAY

THE ZAHA

FIG. 41: EXPLORING THE RELATION TO HUMAN SCALE

5.5

FORM OPTIMISATION

RADIANCE AND INCLINATION

As a continuation of the previous exploration, the iterations were examined and developed in regards to their angles of the roof. On the exterior, the angles are important for optimizing solar radiation and the yield from photovoltaic panels. To compare the cases, two "base cases" are included: a flat roof and a roof angled 45 degrees south, the latter of which is expected to perform optimally. As it should be possible to walk on the roof with access from the ground from north and south, some areas are angled inefficiently and it is thus not possible to reach the average radiation of the base cases. Thus, a solution which combines optimal inclinations that allow for physical ascent and descent, as well as placement of photovoltaic panels is needed.
A feature of the double curved surface is that its faces are angled in different directions, which might be an advantage in terms of facing the sun more directly both daily and annually. The average results do not reflect this, but it is apparent in the radiation range.
Based on the findings, three new iterations were made based on The Ray. The new iterations were developed in concert with a new plan concept detailed in the next section, while further exploring a route for people to be able to walk and sojourn. These analyses are showcased in figure 43 and 44, while the other analyses are found in appendix 3.

RADIANCE ANALYSIS ITERATION 1 (ILLUSTRATED IN APPENDIX 3)		
CASE	RADIANCE RANGE [kWh/m²]	AVG. RADIANCE [kWh/m²]
FLAT ROOF	914-965	955
ANGLED ROOF	691-1059	970
"THE WAVE"	704-939	866
"THE WAVE 2.0"	737-1001	904
"THE RAY"	655-1089	921
"THE ZAHA"	578-112	829
RADIANCE ANALYSIS ITERATION 2 (FIG. 43)		
CASE 1	-	**906**
CASE 2	-	**898**
CASE 3	-	**895**

FIG. 42: RADIANCE ANALYSIS RESULTS

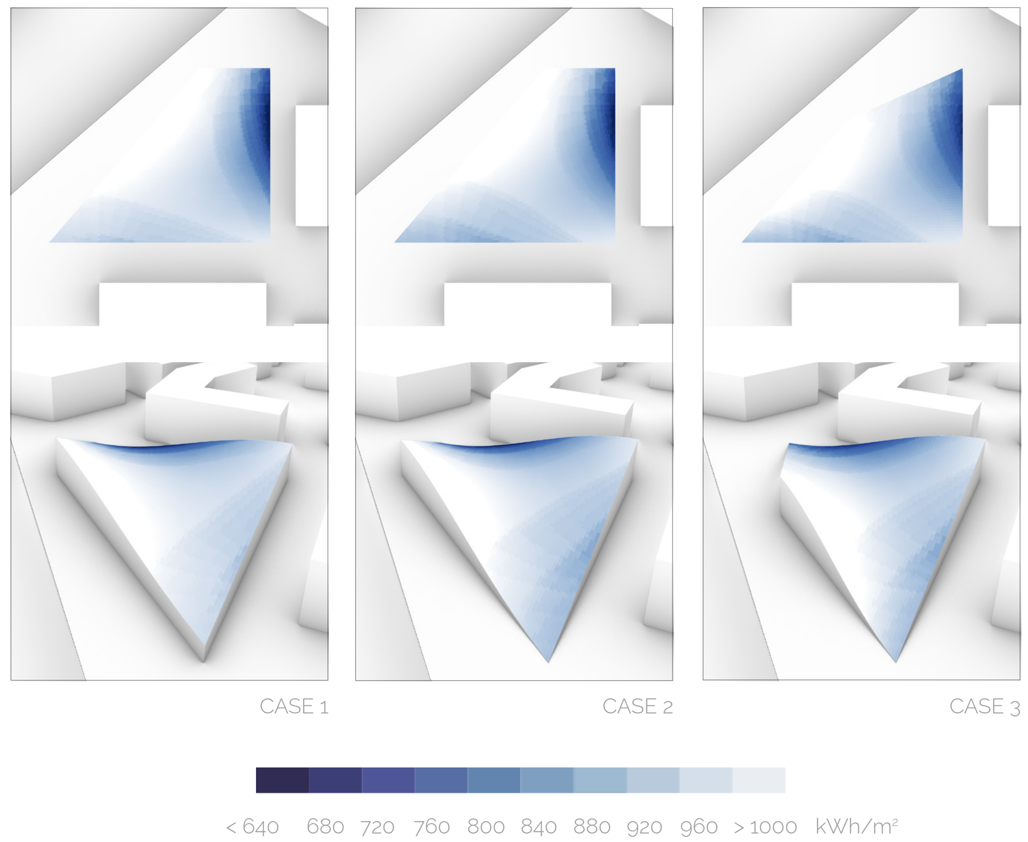


FIG. 43: SOLAR RADIATION STUDY, ITERATION 2

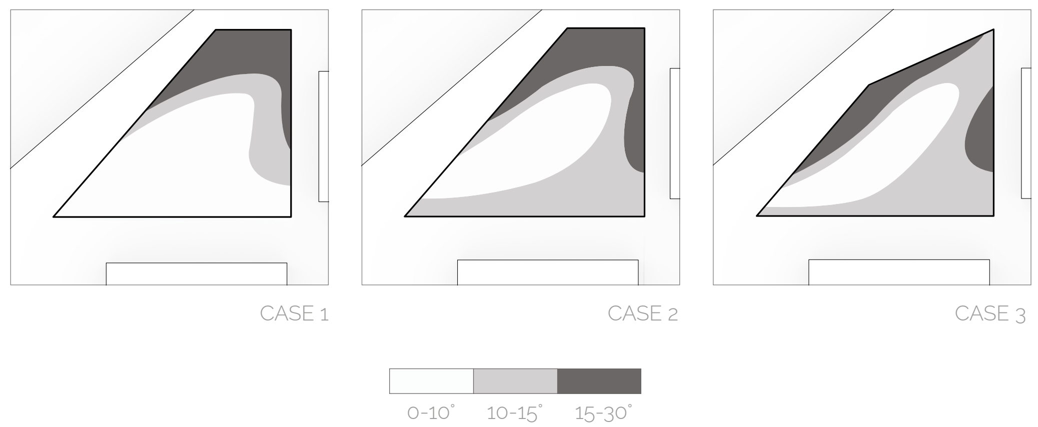


FIG. 44: ROOF INCLINATION STUDY

5.6

PLAN DEVELOPMENT

CONCEPT AND LAYOUT

The initial plan development has been explored and shaped by the existing sightlines of Fredericia, as illustrated in chapter 5.1, fig. 32, resulting in two principled footprints. Generally, the primary explorative foci have been on the orientation of the building, the roof inclination and its impact on ceiling height, as well as the flow between functions. Furthermore, addressing possible concerns with skew and sharp angles has been explored iteratively.

The orientation of the building and its internal and external focus has been important in the layout of the plans. Extrovert functions such as the entrance, foyer and restaurant could benefit from orienting towards the more busy and populated promenade, as opposed to the introvertly focused exhibition and administration that require a higher degree of privacy (fig. 47) The prominent slope of the roof and its effect on interior room height could be solved by digging below ground level, or by extending the roof past an end wall (fig. 46). The lower, sloped ceiling creates a strong directionality for sound and vision, while the lack of transparency creates privacy, which would be suitable for an auditorium. The foyer should act as a hub to make paths easy to read for the user. The entrance and exit of the exhibition should be separate, both tied to the foyer, with the exit leading back to where the user started to foster a sense of journey within the building (fig. 45).

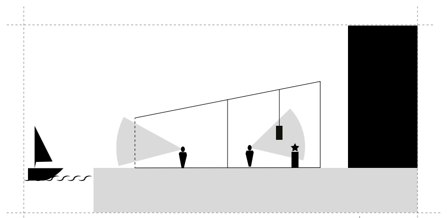


FIG. 47: INTERNAL/EXTERNAL FOCUS

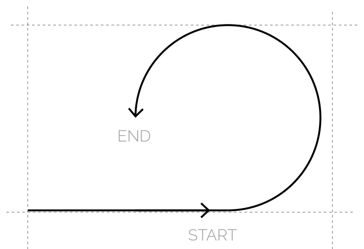


FIG. 48: CIRCURLAR EXHIBITION FLOW

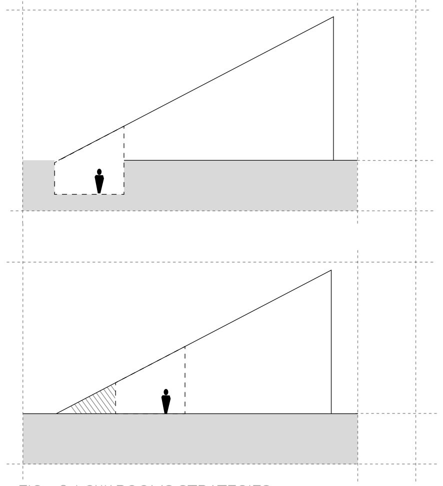


FIG. 46: LOW ROOMS STRATEGIES

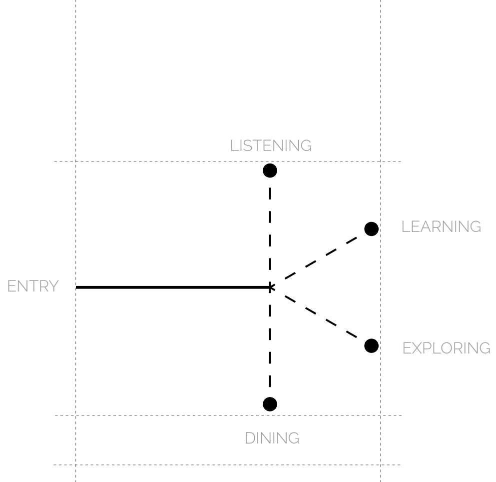


FIG. 45: FOYER AS CENTRAL ROOM FOR FLOW

1 - Exhibition
2 - Functions tied to exhibtion
3 - Visitor areas
4 - Resturant and Kitchen
5 - Meeting room
6 - Administration

Public
Circulation
Staff

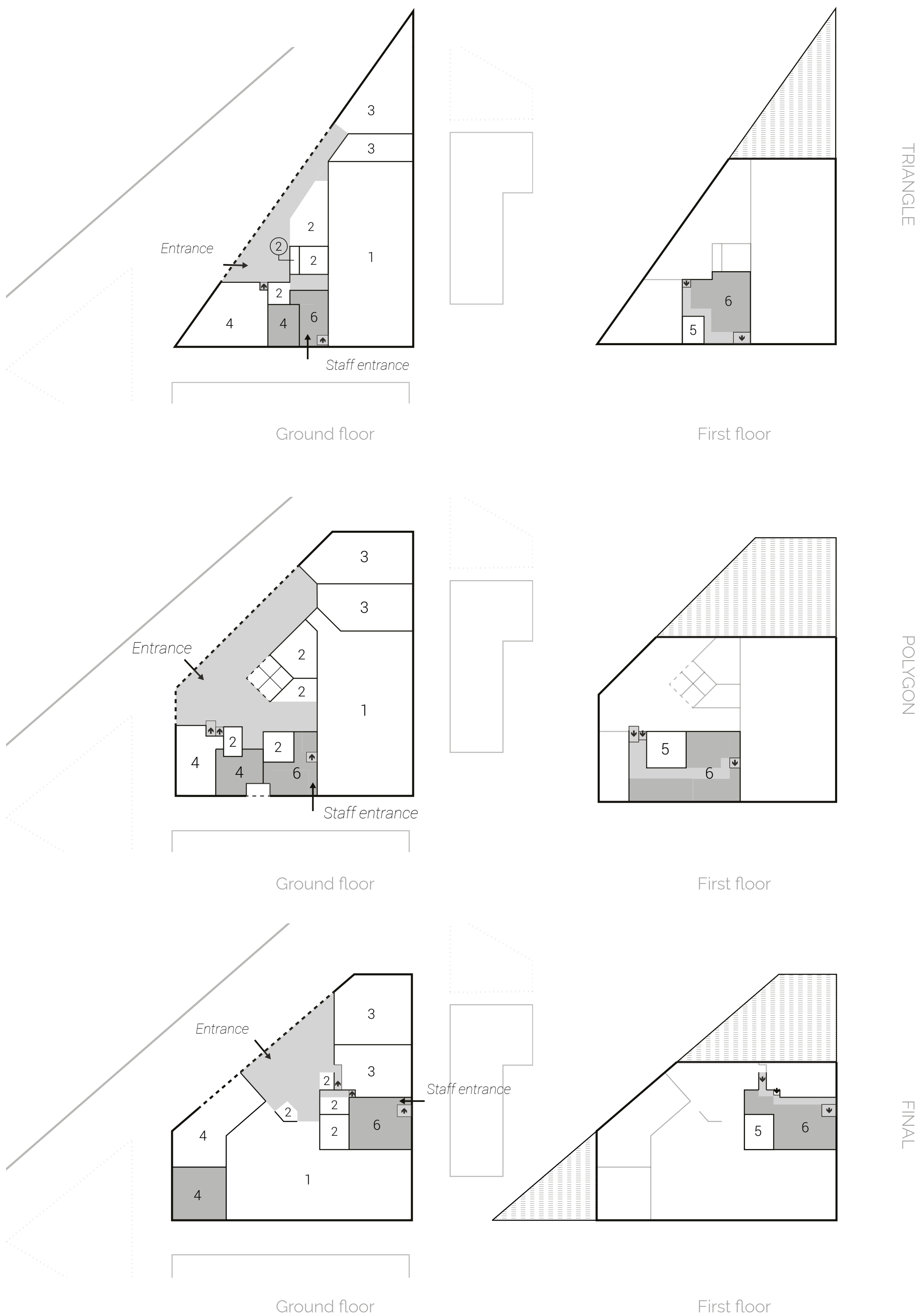


FIG. 49: PLAN PRINCIPLES

5.7

STRUCTURE AND PLAN

GENERATING A STRUCTURAL SYSTEM

While considering how to make the hyperbolic, several options from 5.5 were discarded. E.g. the cast shell required concrete, while the solid supporting walls required a lot of material, both of which were undesirable for sustainable reasons. The system of linear beams in one axis, connected with smaller elements on the curved axis seemed like the most appropriate system, communicating and drawing on the strength of the h/p shape. This system can be realised using one of the different systems as seen in figure 51.

A standard beam case was analysed using worst case scenario load cases (see appendix 4 and 5), which concluded a hard maximum for beam lengths of 25 m and a soft limit of 22 m, to be able to keep the height of the beam below 0.9 m. As the exhibition is 42.5 m long and there is a need for flexibility regarding column placement to allow the desired flow, this poses a dilemma. Inspired by an abacus, a system was thought up, which could allow columns to be moved parametrically along 'beam-lines' and be placed in accordance with the desired flow, while still keeping beam lengths below the limit. This will be detailed in 5.11 The Abacus.

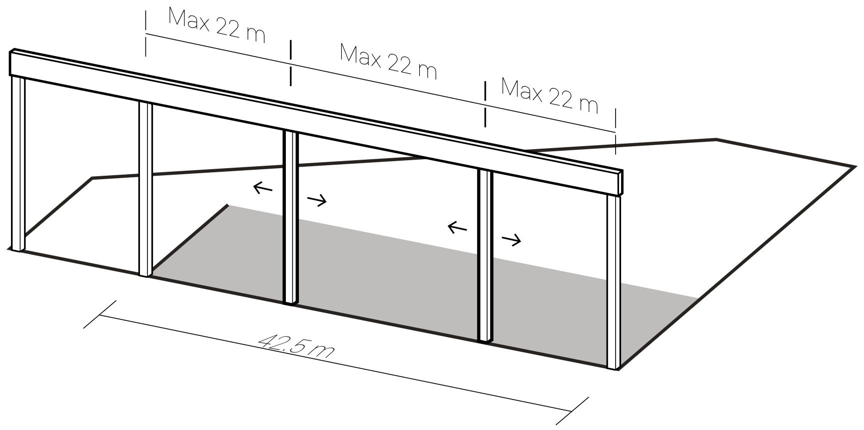


FIG. 50: THE ABACUS SYSTEM

2D STABILITY

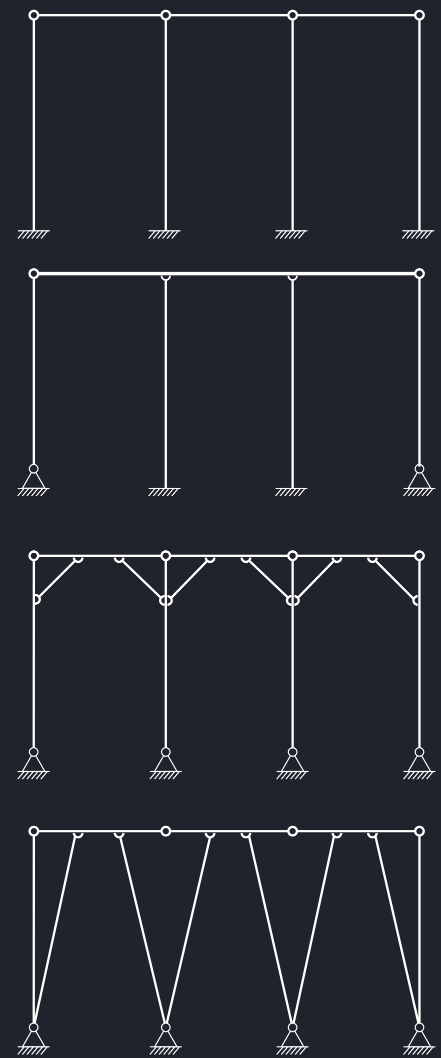


FIG. 51: STATIC SYSTEMS, 2D

3D STABILITY

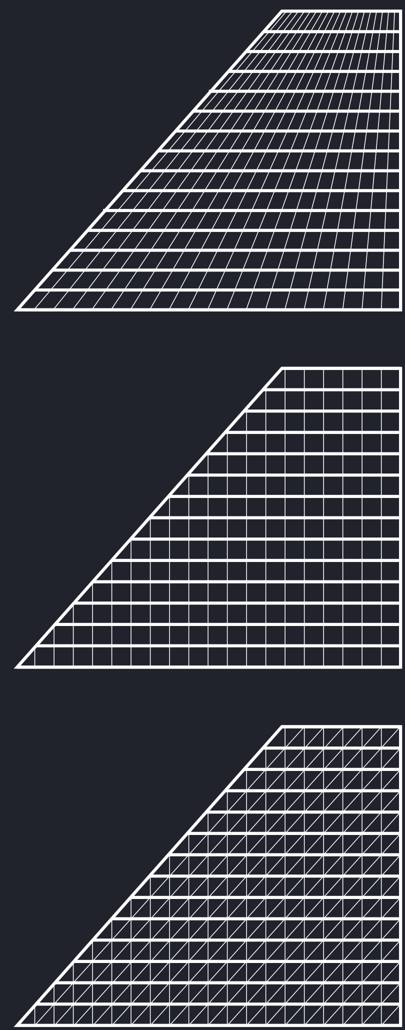


FIG. 52: STABILISING BEAMS SYSTEMS IN THE ROOF

The static schemes in 2D have been examined using the Karamba plugin for Grasshopper and Robot Structural analysis. It is desired to reveal the beams as clean, linear elements in the ceiling, best realised through system 1 and 2, although these cannot be realised without using fixed joints or supports somewhere. Through the analysis, it was determined that the best solution, determined by balancing stability and aesthetics, was to fix the supports of some of the interior columns.

Stability in the roof will be ensured with smaller, linear elements connected to each of the larger beams. Three systems has been examined using Karamba, The first case, in which the elements meet in rectilinear connections was, albeit possible due to the curvature of the roof, the least effective. Of the two remaining, the second system was chosen, as it was the most genuine realisation of the h/p shape. Further stabilisation will be incorporated with bracing in the facades.

5.8

EXHIBITION THEMES

A JOURNEY OF EXPLORATION

While the overall plan arrangement is one thing, the organisation of the exhibition journey is another. Since the user groups will have very different backgrounds and pre-understandings, it will be suitable to have a flow where exhibitions can be investigated or passed by according to the interest of the individual visitor.

In order to design a continuous exhibition journey and thus keep the interest of the visitor, it will be necessary to still maintain a natural flow throughout, even if micro exhibitions can be circumvented.
This flexibility can be accommodated by having one exhibition entrance, a main route and one exit but with smaller side tours providing enough internal freedom for users to make individual choices and shape their own experience.This principle will enable one macro exhibition journey which each micro exhibition can elaborate on. These micro exhibitions will each educate visitors on a topic within renewable energy; solar energy, wind power, bioenergy, hydropower and finally relate to the visitor’s own daily life by exemplifying environmental friendly habits and inspire sustainable living.

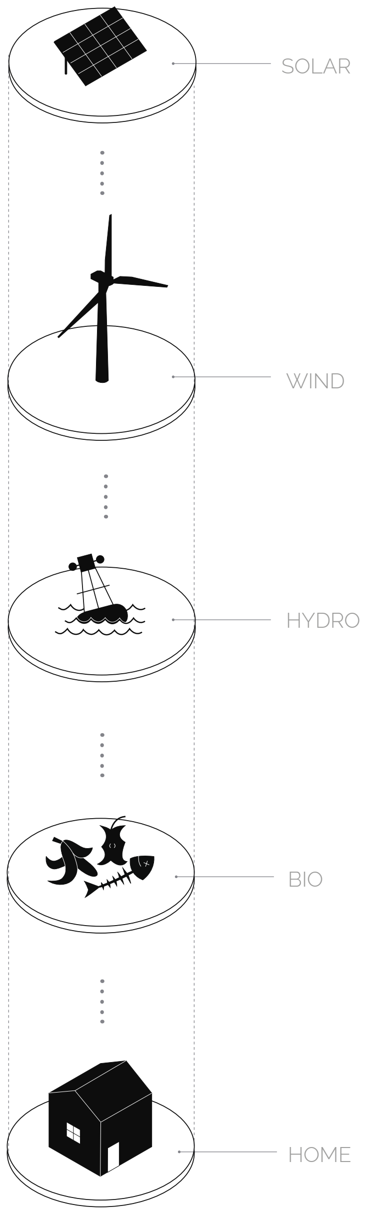


FIG. 53: EXHIBITION THEMES

5.9

EXHIBITION PRINCIPLES

EXPLORING ACCESS AND CONNECTIVITY

LOW INTERNAL INTERCONNECTIVITY

Stronger sense of curated journey and more control.

HIGH INTERNAL INTERCONNECTIVITY

More diffuse and less sense of control. More user choice.

MULTIPLE ACCESSPOINTS

Several entrances/exits to different parts of the exhibition. More freedom to choose your own path.

FEW ACCESSPOINTS

One entrance, one exit. Stronger differentiation between entering and exiting the exhibition

SEPERATION OF EXHIBITS

One room acts as a mini-hub and provides access to exhibitions. Strong division of themes or topics.

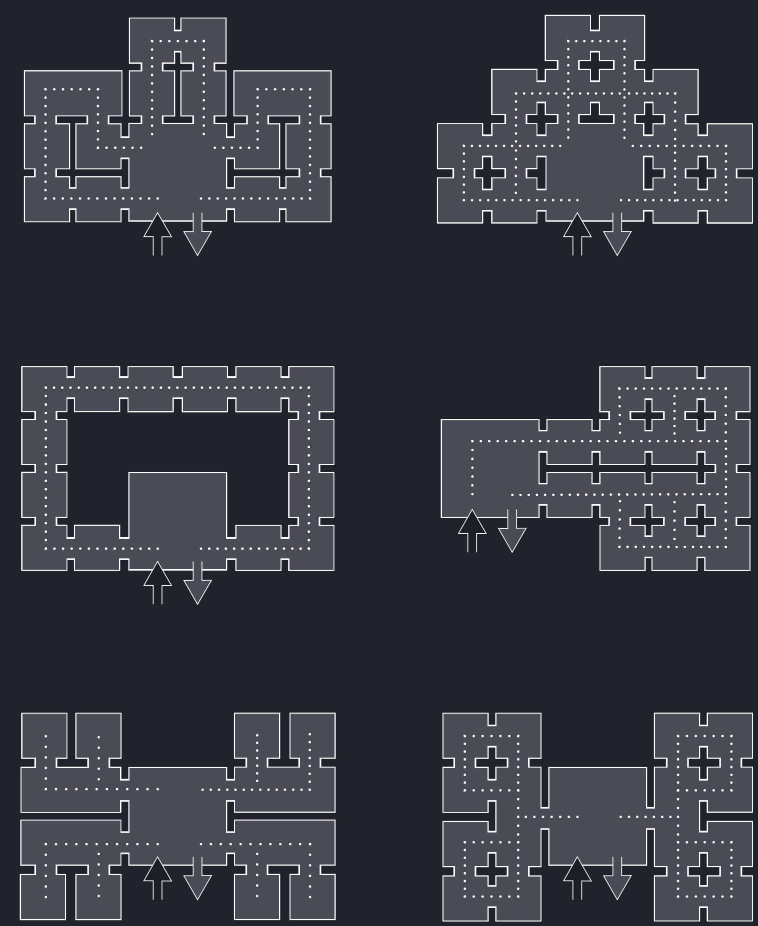


FIG. 54: EXHIBITION PRINCIPLES

5.10
FLOW
JOURNEY AND MOVEMENT

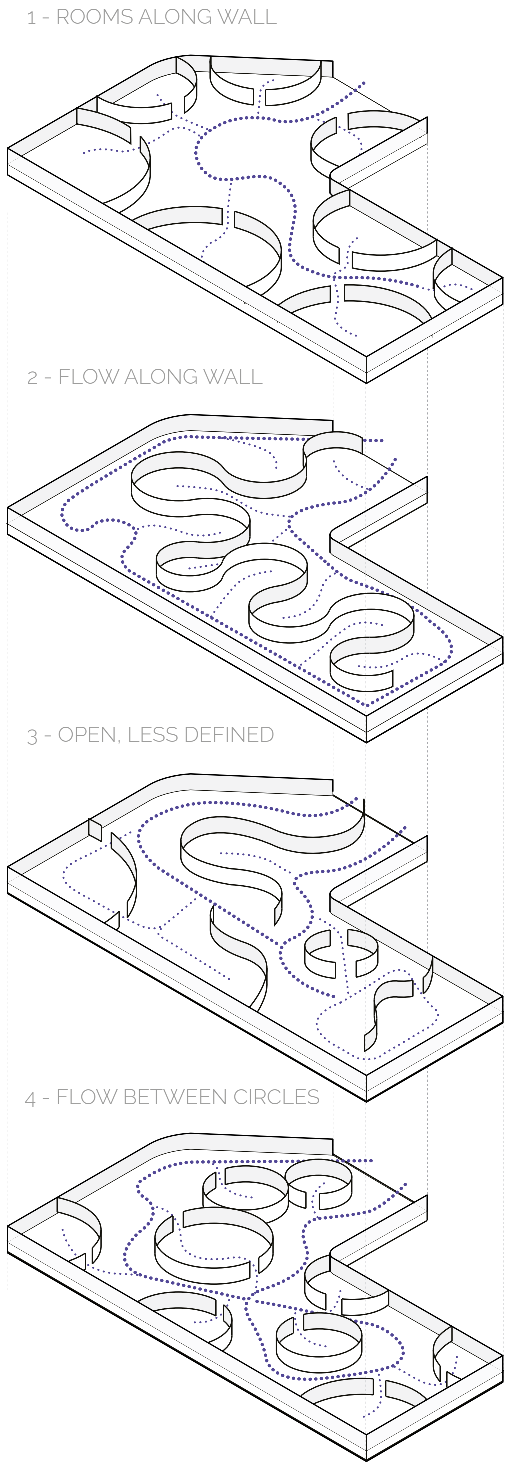


FIG. 55: FLOW ITERATIONS

The flow should lead the visitor along a main path, while gesturing to the micro exhibitions along the way. This will be mediated by curvilinear walls, which, beside separating the different areas, should stimulate the user's curiosity and create a smooth experience. The circulation has been explored through a series of iterations using curves and circles to define the flow. In figure 55 four of these principle iterations have been shown, each with different qualities.

The final flow is highly inspired especially by the second diagram, as this one has a clearly defined journey, with the micro exhibitions spread along the way. It does not however activate the outer walls and the flow can become a bit monotonic, which the bubbles in the other iterations address. As shown on figure 56, the walls that define the final flow have been developed together with the load bearing columns, which are needed for the beams and the abacus system. The flow, inner walls and construction thus inform and shape each other interdependently, such that one part cannot be changed without affecting the others.

5.11
THE ABACUS
CONSTRUCTING AN OPEN PLAN

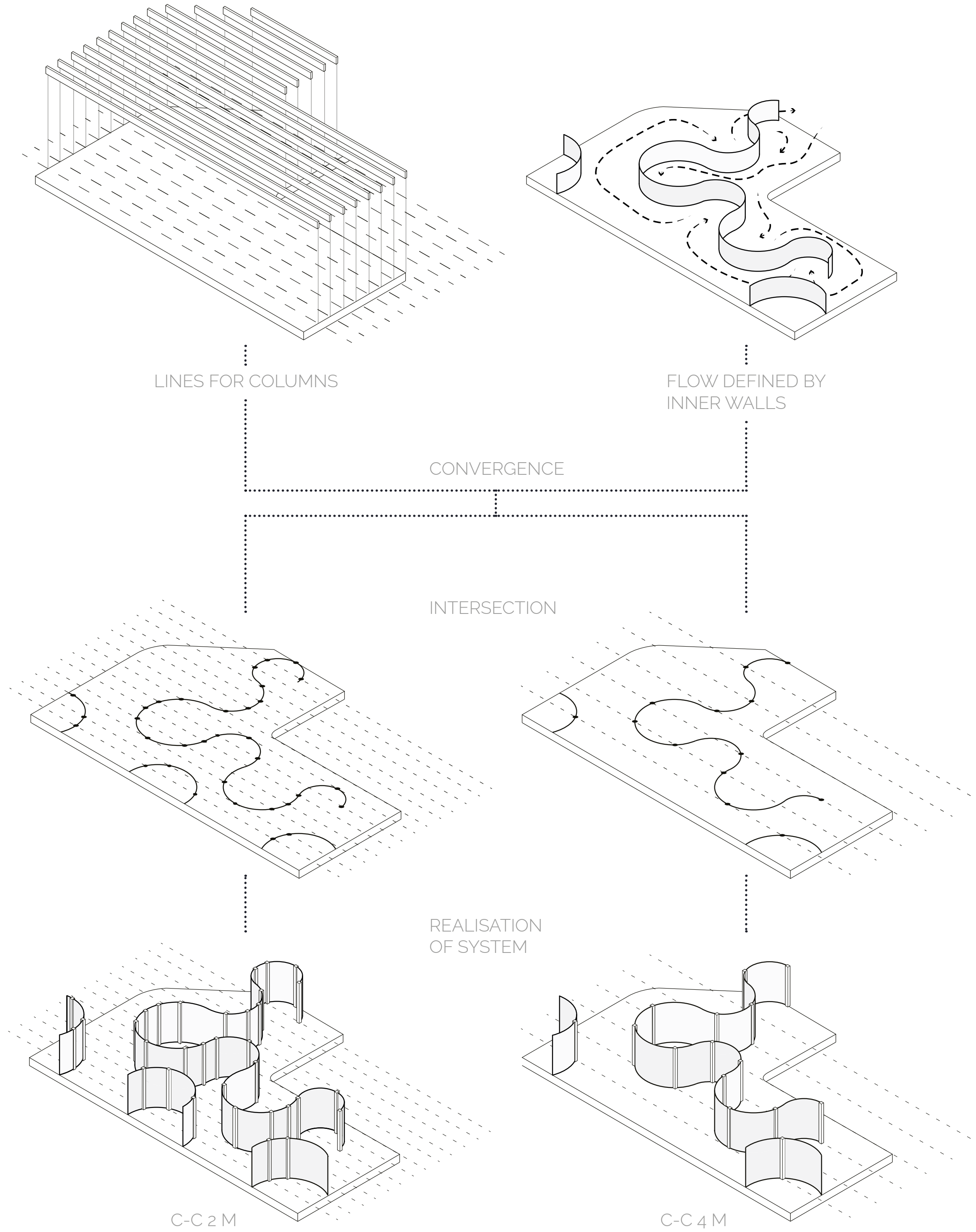


FIG. 56: REALISATION OF THE ABACUS PRINCIPLE

5.12

LOCOMOTION

EXPERIENCING THE EXHIBITION

When examining the kinesthetic experience of walking in a room defined by curvilinear walls, an interesting quality emerges. Compared to a rectilinear geometry, in which turning a corner creates sudden visual reveals, the experience is more gradual with curves. New visual information is continuously revealed for the user when walking, making them much more aware of their changing surroundings. For the exhibition, this experience is coupled with a degree of changing transparency by introducing lamella as some of the wall, which is an extension of the of the strategy in the ceiling. This creates a flow, during which areas are in a constant state of revealing and veiling. Two strategies, one with lamellae radiating from a midpoint and one with parallel lamellae, have been examined in both plan and perspective, as seen on figure 57-60. Structurally and visually, the project will use the parallel solution, as it creates the most interesting experience.

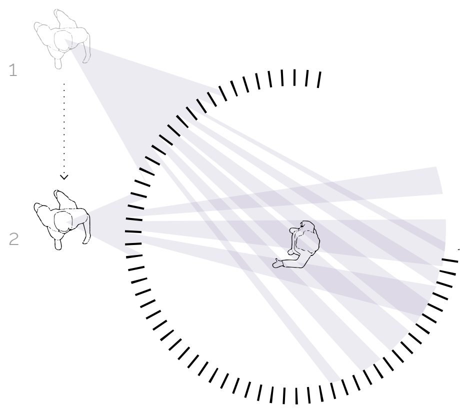


FIG. 57: RADIATING PATTERN

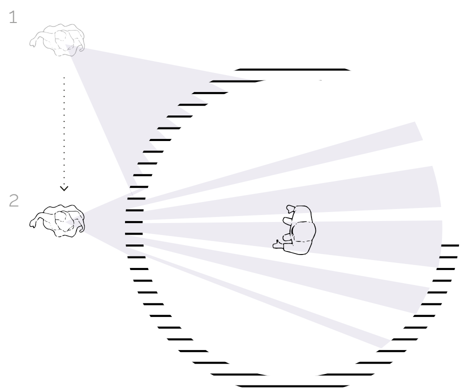


FIG. 58: PARALLEL PATTERN

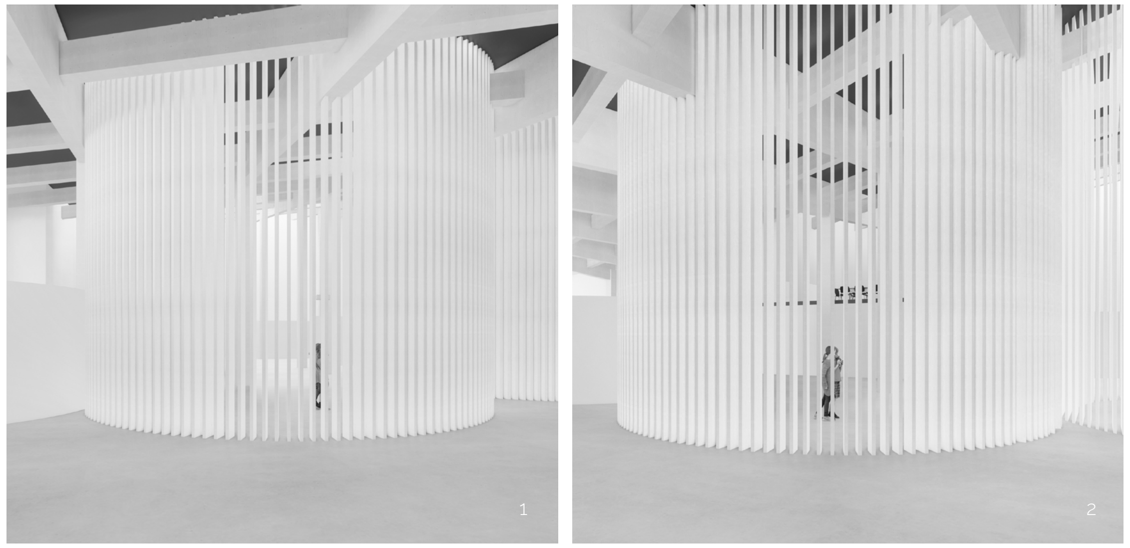


FIG. 59: PERSPECTIVE OF RADIATING PATTERN

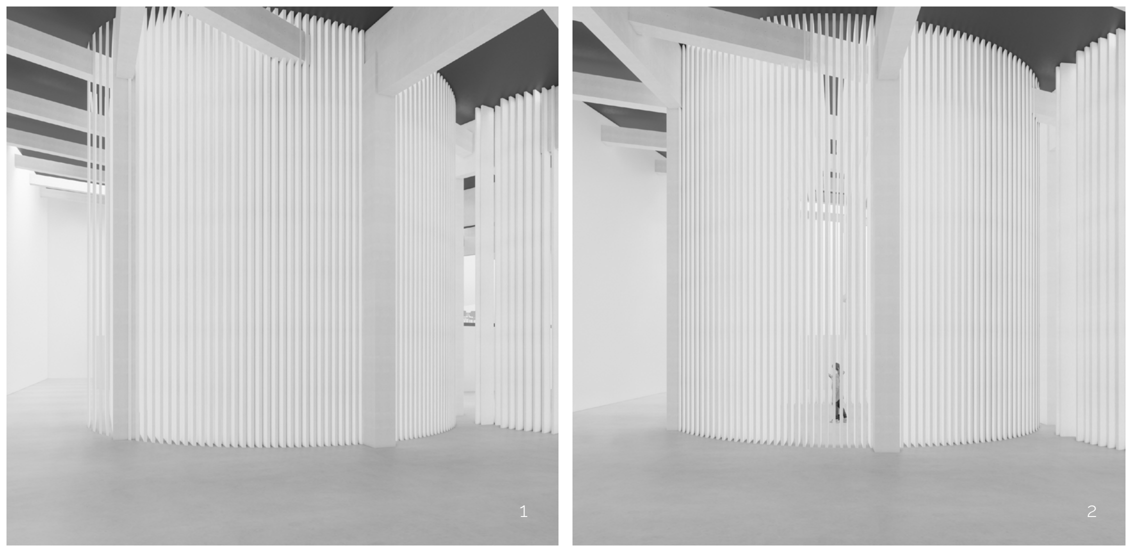


FIG. 60: PERSPECTIVE OF PARALLEL PATTERN

5.13 INSPIRATION

AESTHETIC AND ATMOSPHERE


FIG. 61: FERNANDO GUARRE (2015) *CARE IMPLANT DENTISTRY*


FIG. 62: EDMUND SUMNER (2015) - *GLOUD GARDEN*


FIG. 63: INT.DESIGN (N.D.) *VITRINE ETUDIANTE*


FIG. 64: 3XN (N.D.) *COPENHAGEN CHILDREN'S HOSPITAL*


FIG. 65: WANG NING (2017) *ROCKERY-FOR-PLAY*


FIG. 66: JOSÉ HEVOA (2019) *LAS BUTACAS Y SILLONES BASIC*

5.14 AFFORDANCES

FRAMING AN ARCHITECTURAL LANDSCAPE

Addressing the act of inhabiting, earlier described as crucial for the sense of safety and homeliness for the visitors, a set of principles have been developed as to how architecture can afford interaction and through that encourage learning. Implementation of these in the final design will activate multiple senses and thus allow the visitors to build a personal relationship with the spaces and interiors. The diverse user groups will inevitably experience the affordances differently and thus themselves play a part in shaping their individual experience.

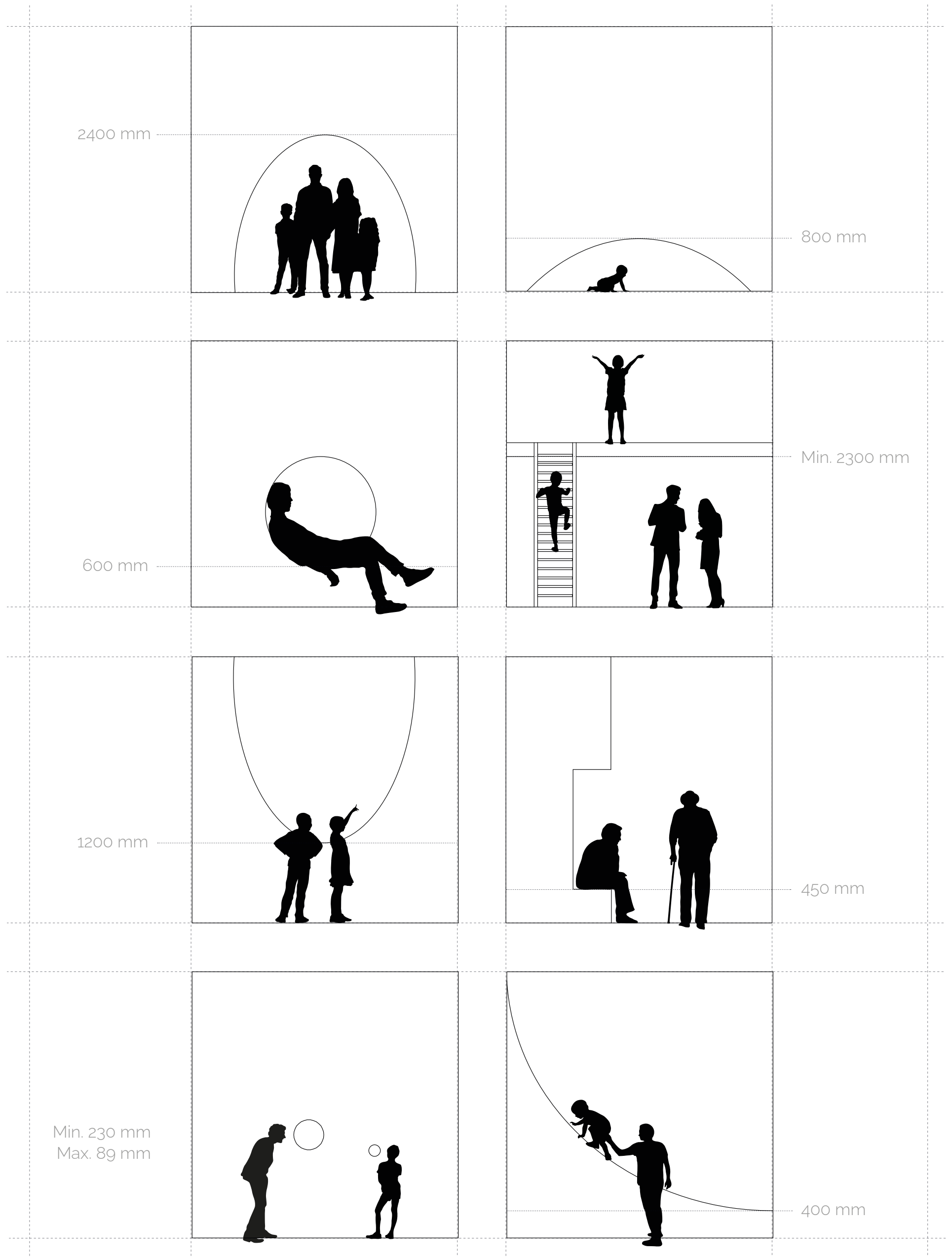


FIG. 67: ARCHITECTURAL AFFORDANCE PRINCIPLES

5.15

DAYLIGHT CONDITIONS

ENSURING A GOOD VISUAL ENVIRONMENT

Only a few of the rooms in the Visitor Centre will be used as offices or classrooms and are therefore regulated in terms of daylight. The building requirement calls for 300 lux from daylight on half of the floor area in half of the daylight hours[1]. Appropriate daylight can be demonstrated either by having 10 % of the floor area as glass, factoring in any shadow conditions or by analysis proving a 2,1% daylight factor, which in Danish conditions should correspond to 300 lux. The analyses presented here are two examples, and analyses for other rooms can be found in appendix 6.

The most challenging spaces are the meeting rooms, as they are placed in the center of the building, precluded from the facade. Even though they both have glass walls that allow light to pass through from other rooms, their central placement means that skylights are necessary to ensure a DF above 2,1%.

The administration office is considered one of the most important rooms in regard to daylight, since it will be used as a daily work space as opposed to the meeting rooms, which are only in use for shorter periods. The placement on the second floor facing east is very good and the analyses show no need for skylights.

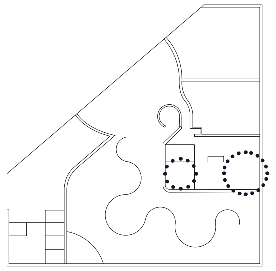


FIG. 71: LOCATION OF ROOMS

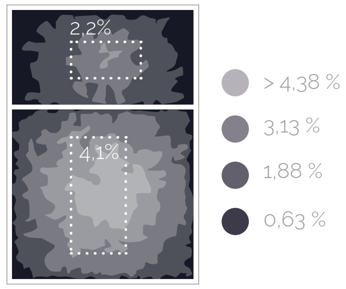


FIG. 68: MEETING ROOMS: AFTER IMPLEMENTATION OF SKYLIGHTS

FIG. 69: OFFICE: TWO SMALLER WINDOWS

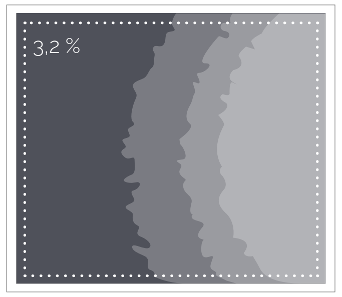


FIG. 70: OFFICE: ONE LARGE WINDOW ABOVE TABLE HEIGHT

1 Bygningsreglementet (2018), *Lys og Udsyn*

5.16

VENTILATION STRATEGY

CONCEPTUAL VENTILATION PRINCIPLES

The chosen building form and structure uses a system of parallel timber beams, and the idea from the beginning has been for the beams to be visible in the interior spaces. Therefore one of the main questions regarding ventilation is how the ducts should go across the beams in order to reach all necessary rooms. A good solution for this could be a cavity wall. The idea is the same as a suspended ceiling, where the ducts run in an enclosed space between the interior cladding and the construction, but using a wall instead of the ceiling.
Working with a cultural building, the amount of visitors in the building is expected to vary extensively through the day and week. This variation in ventilation needs is ideal for a VAV system where air flow in individual areas can be adjusted and controlled separately and this will save energy in the long run. Due to the curved roof shape, most of the interior spaces will have a very high ceiling, making displacement ventilation an excellent option. This method supplies air from a low point, closer to the visitor. Displacement ventilation is also ideal for floor heating, which will aid thermal buoyancy. For smaller rooms with lower ceiling height e.g. employee areas, mixing ventilation can be used. As this project only considers ventilation on a conceptual level, only strategies have been considered and no duct dimensioning has been done. A conceptual ventilation plan can be found in appendix 7.

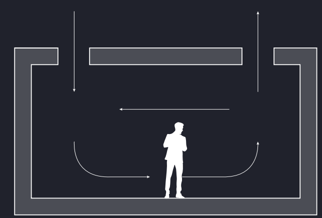


FIG. 72: MIXING VENTILATON

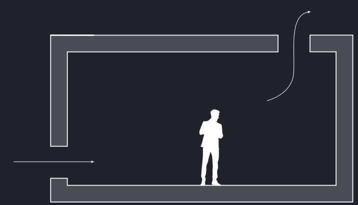


FIG. 73: DISPLACEMENT VENTILATION

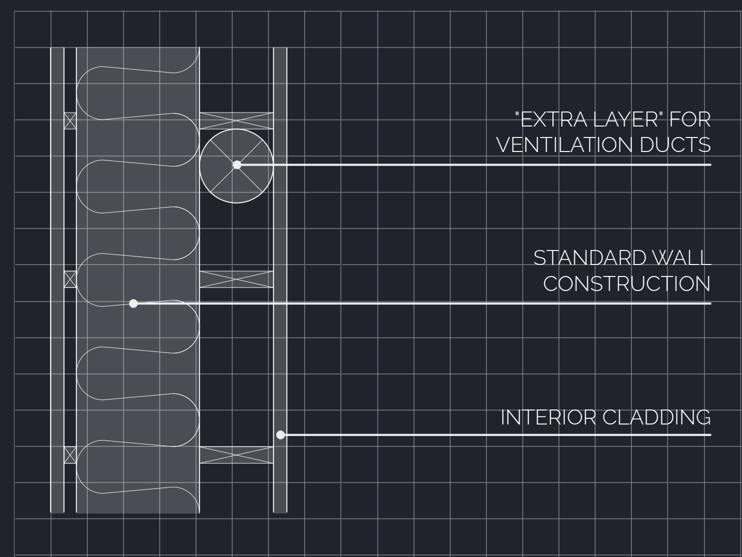


FIG. 74: CAVITY WALL STRUCTURE

5.17

ENERGY OPTIMISATION

BE18 PROCESS AND ENERGY SAVING INITIATIVES

As the Visitor Centre aims to teach renewable energy forms and be a beacon for sustainable development, this also sets certain expectations for the building's own energy consumption. Based on the initial notion of transparency towards north-west and west due to both the harbourfront promenade and the tall buildings planned straight to the south and east, an estimate of the total energy consumption was therefore done using the calculation programme BE18. The goal for this process was to gain knowledge of energy related consequences of design proposals and thus also possible methods of optimising the final design. The starting point included a full glass facade to the north-west. Even though this facade is not facing a critical orientation, large glass facades can always entail issues such as overheating, and should be implemented with care. Since the Centre will entertain large groups of visitors, who supply internal heat gains, excessive heat and the associated penalties in the energy calculation were viewed as one of the main challenges. By using the results from BE18, lamella dimensions and frequencies in the glass facade have been evaluated and used as a shading technique (see appendix 8 for elaboration). In order not to reveal too much of the building's interior prior to entering, whilst also limiting the excessive heat, the amount of glass in the north-western facade was then minimised. By adding mechanically controlled natural ventilation in the summertime in rooms where possible, most of the remaining excessive heat can be removed. This solution will also be comfortable for the visitors as a natural flow of air is usually considered rather pleasant. As the Visitor Centre is considered in use more than the standard 45 hours a week, the BE18 calculation takes into account a supplement for extended usage time. This raises the total energy consumption demand to 45,7 kWh/m2 which is thus fulfilled in step number 4. Two active strategies have then been implemented to minimise the energy consumption even further. A heat pump in the water and photovoltaic panels on the roof demonstrate accountability while including the building itself as an educational element into the experience of the exhibition journey.

The analyses of the daylight conditions that were already introduced have also been done in collaboration with this exploration of the building's energy consumption. The energy calculation makes sure to allow for an appropriate amount of window area, while taking into account parameters such as increased risk of overheating or higher transmission losses.

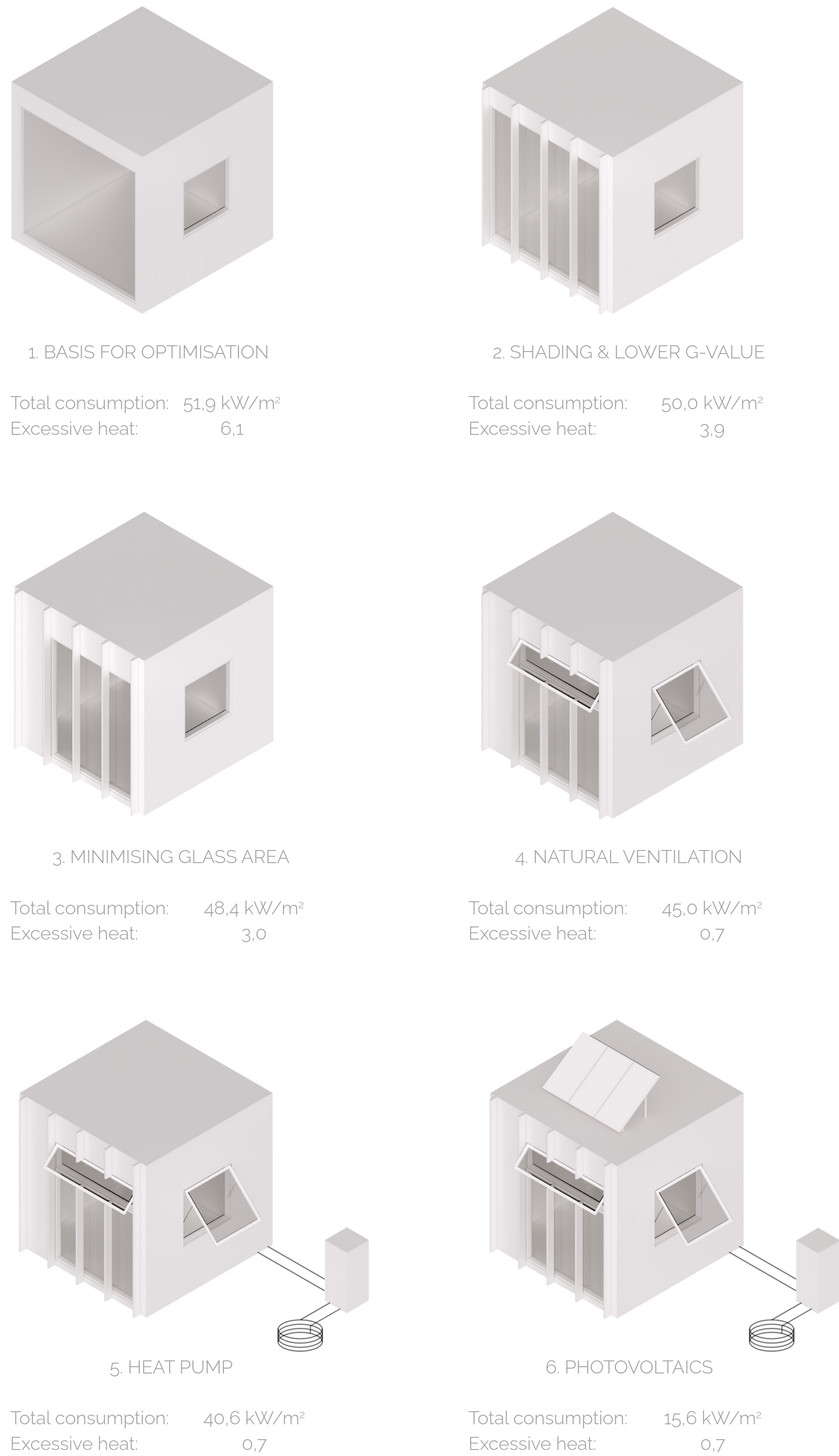


FIG. 75: BE18 ITERATIONS

5.18

FACADE

TRANSPARENCY, STABILITY AND EXPERIENCE

Since bracing in the facade is one of the main factors in the 3D structural stabilisation, the performance of different solutions has been analysed principally. Three of the best performing options have then been further investigated in terms of aesthetic interplay between bracing, beams and the curved roof as well as the experienced relation to the ground and the user. The V-shape bracing is preferred as it seems to enhance the roof curve more, while still allowing an open view to the promenade and canal. More of these studies can be found in appendix 9 where the architectural experience of single or double columns also has been examined. Adding onto the bracing study, the facade The wish has been a facade design that can accommodate both the need for openness towards the promenade, and provide a noteworthy experience along the more closed facades. Vertical lamellae have been examined as a solution as they can divide the long facade, and provide a sense of depth and tactility. The lamellae contain a captivating ability to conceal or reveal the interior and create a shifting experience based on the position of the viewer, whilst subtly signaling the entrance. The facade thus imitates the motif of the lamella walls in the exhibition and can also supply a bit of shade on the large glass facade.

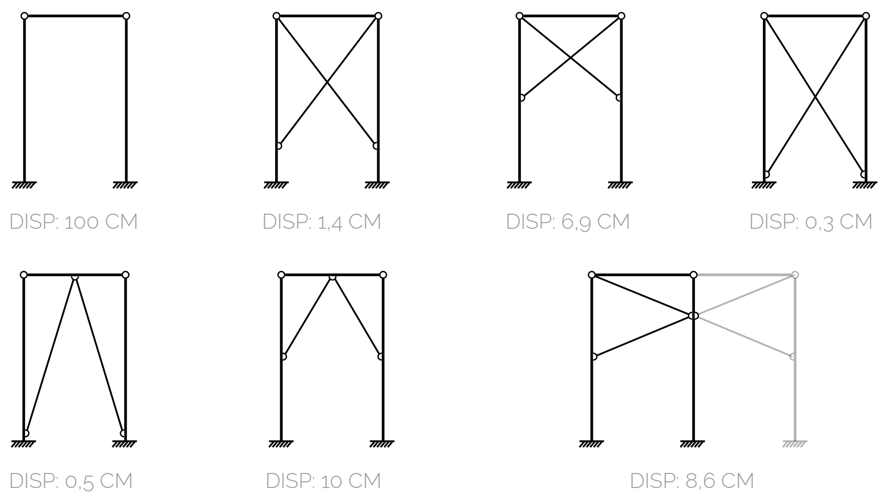


FIG. 76: BRACING ANALYSES

FIG. 77: BRACING EXPERIENCE

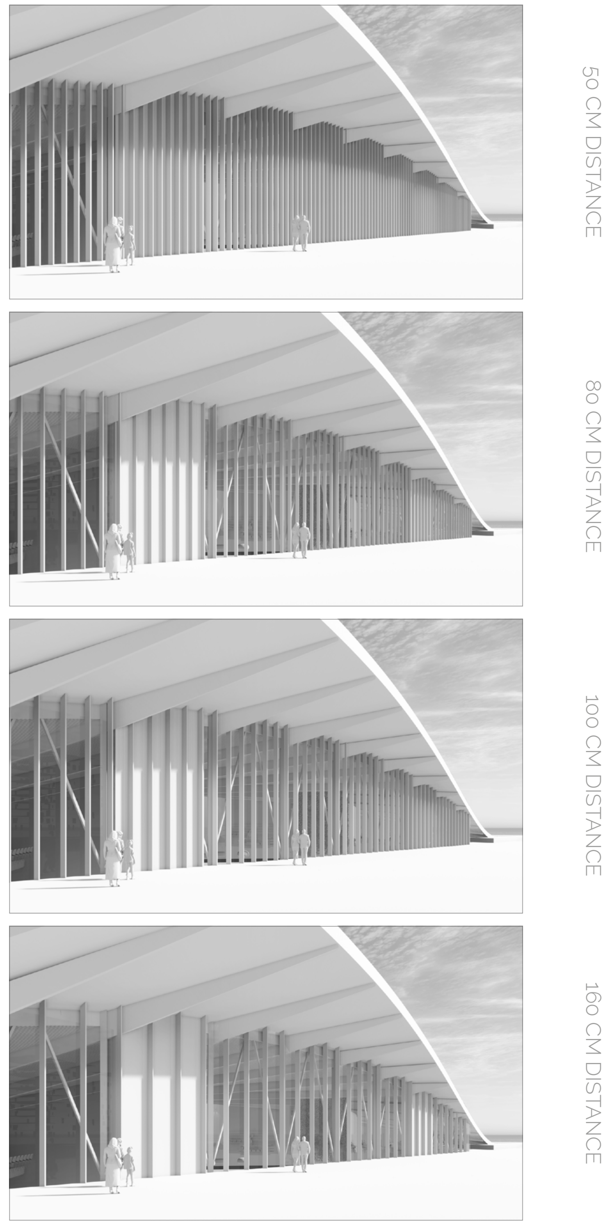


FIG. 78: FACADE SHADING

5.19

STRUCTURAL ANALYSIS

CONCEPT AND LAYOUT

The system has been verified using Robot Structural Analysis and the load cases calculated in appendix 4. After the initial verification, the system was optimised by repeatedly modifying cross sections and verifying the structure, until some of all the major elements were approaching a utility ratio of 100 %. In a complex system, the loads affect the elements differently, which means that while some of the large beams approach a utility rate of 100 %, some of them are less utilised. Optimising every single element is somewhat of an sisyphean endeavor, requiring most elements to be unique. Instead the structure was further optimised by incorporating some of the strategies as shown on figure 79.

The beams were originally calculated as spanning from post to post, but optimisation was possible by first calculating them as singular long elements spanning across the whole building and then dividing them based on their bending moment. Doing this reduced the internal forces and thus allowed for smaller cross sections. Similarly, the cross sections were modified in the cantilevered beams, such that the height of the section approached the width, as the moment approached 0 at the end of the beams. In the restaurant and kitchen, the cross sections of the beams could in general be reduced, as their utility radio was quite low, which also improved the spacial qualities of the rooms. Lastly two column cases were examined: double or single. The double columns make for a more clean hinged joint with the beams and because of the improved moment of inertia, the cross section could be reduced.

SAVINGS BY OPTIMISATION

Material reduction by first phase: 123.5 m^3 material reduction
= 25,261 kg CO_2 e.q reduction

Material reduction by optimisation strategies: 92.5 m^3 material reduction
= 22,581 kg CO_2 e.q reduction

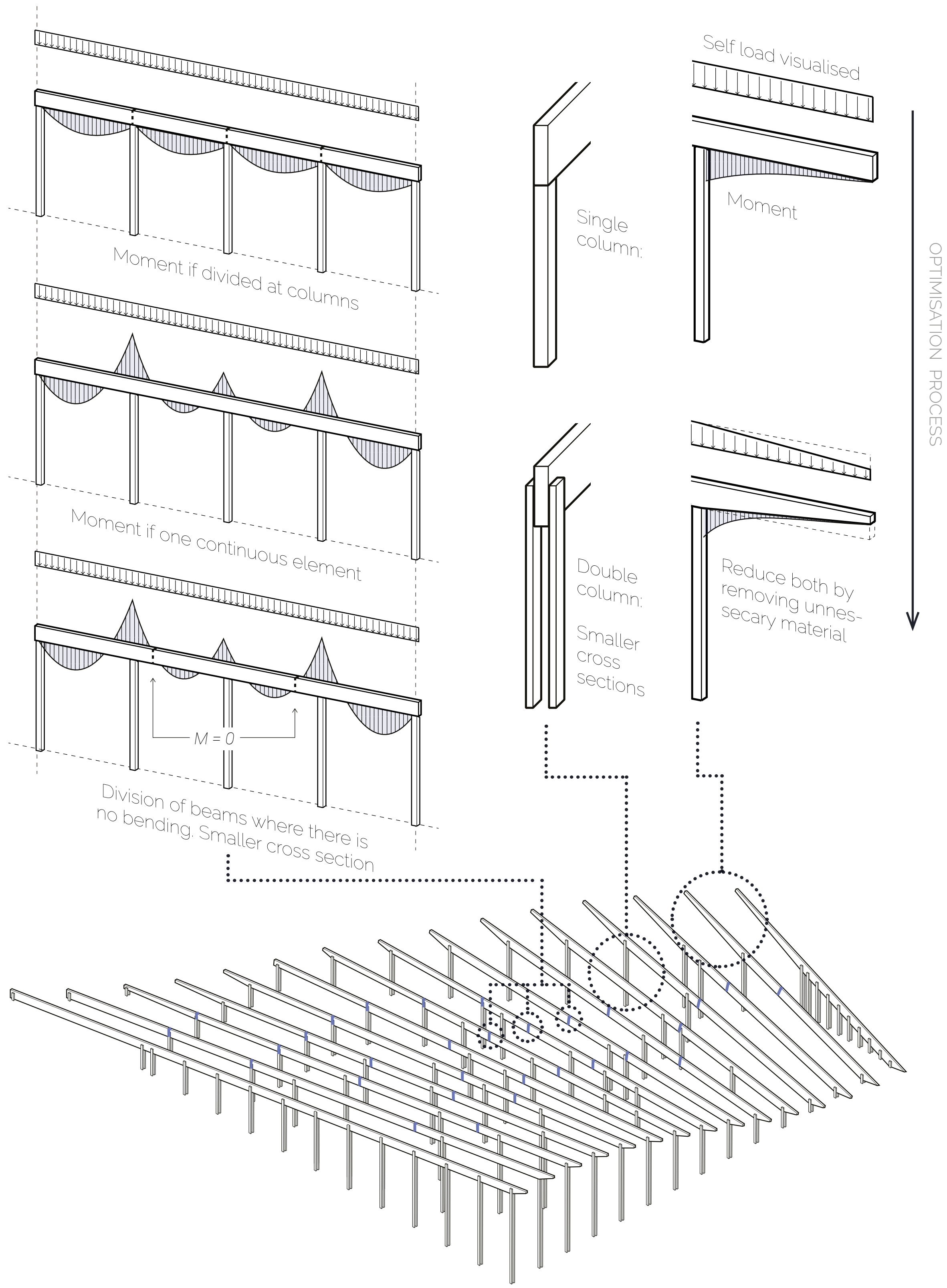


FIG. 79: OPTIMISATION STRATEGIES

5.20

MATERIALS AND GWP

USING LCA-BYG AS A DESIGN TOOL

Hoping to lead by example, materials and construction elements for the Visitor Centre must be chosen responsibly. Wood is generally prefered over concrete or steel due to its ability to store CO_2 which lowers the material's embodied carbon or GWP (Global Warming Potential). More complex compositions with several layers have been assessed using LCA-Byg in order to choose the least CO_2-emitting solution. The programme has thus been used as a tool to compare solutions by their final GWP. For these simple comparisons energy costs related to transportation have not been considered.

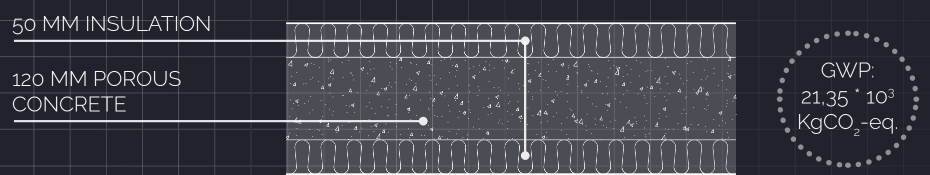


FIG. 80: CONCRETE FLOOR SLAB

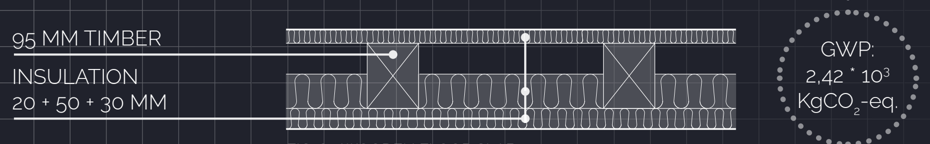


FIG. 81: WOODEN FLOOR SLAB

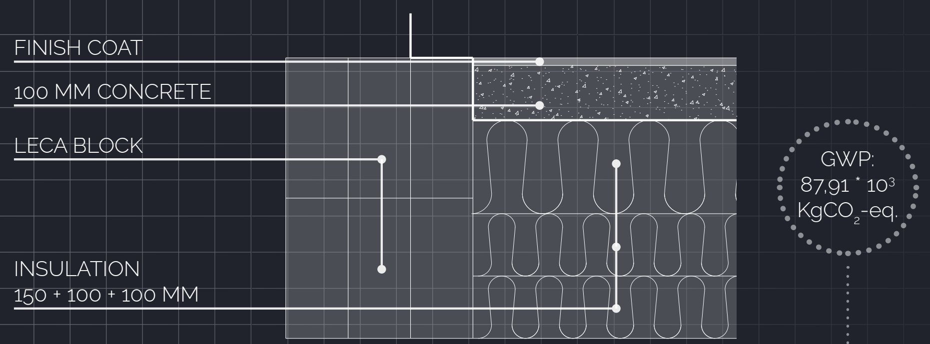


FIG. 82: GROUND DECK CONCRETE FLOOR

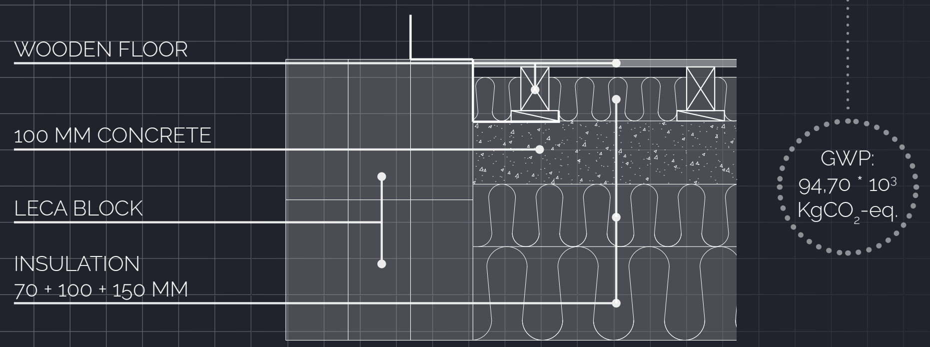


FIG. 83: GROUND DECK WOODEN FLOOR

5.21

URBAN PRINCIPLES

FACILITATING URBAN ACTIVITY

One important focus of the Visitor Centre has been to engage and connect with its neighbourhood and context. The situation alongside the attractive harbour promenade provides an exceptional level of presence and opportunity to draw attention to our environmental challenges, and maybe even induce more sustainable choices for passers-by. The wish is for the sustainable initiatives to be a visible and natural part of the urban experience providing appealing areas for activities, stay and recreation. Principles for activating the two recreational areas and the rooftop have been applied to the urban scheme, employing a playful approach.

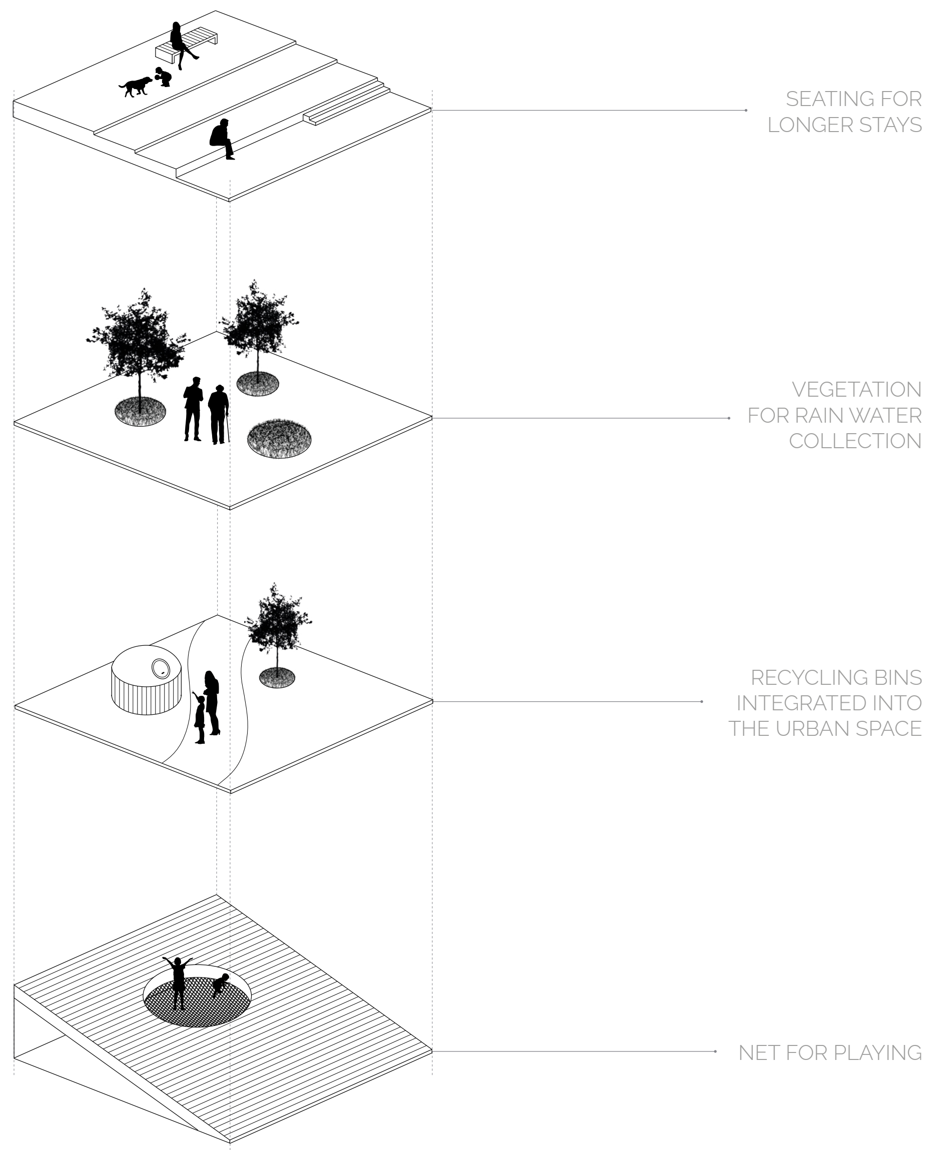


FIG. 84: URBAN STRATEGIES

6.0
PRESENTATION

6.1

A NARRATIVE JOURNEY

EXPERIENCING SUSTAINABLE TECTONICS

Located in the new development of Kanalbyen in Fredericia, the Visitor Centre for Renewable Energy emerges towards the brink of the harbour. With its distinctive curvilinear form, the centre stands out from its surroundings, while still relating itself to the historic sightlines of Fredericia. The gentle yet dynamic sloping of the roof invites passers-by to ascent and engage with the architecture while enjoying the breathtaking and scenic view over Nature Park Lillebælt. Once on the roof, visitors gain firsthand access to experience the large photovoltaic panels, gently unveiling the sustainable nature of the building and revealing a peek into the interior function of the centre.

Lying parallel to the canal, the centre engages with the long promenade and provides recreational spaces to sojourn. Once entering the centre, visitors are met by a large, open foyer that acts as a central hub and provides access to public functions such as the auditorium and restaurant, as well as the centre's large exhibition space. Here, a flow of curvilinear walls shape the physical scope of the exhibition and serves as a continuous element of surprise to visitors in locomotion. A set of carefully constructed walls afford an interplay between solidity and transparency, providing visitors with a spatial landscape in constant renewal. The exhibition curates a journey through an overall macro exhibition that branches out into smaller micro exhibitions, each of which is focusing on renewable energy sources; solar energy, wind power, hydropower, bioenergy and lastly a home exhibit showcasing a range of everyday sustainable initiatives.

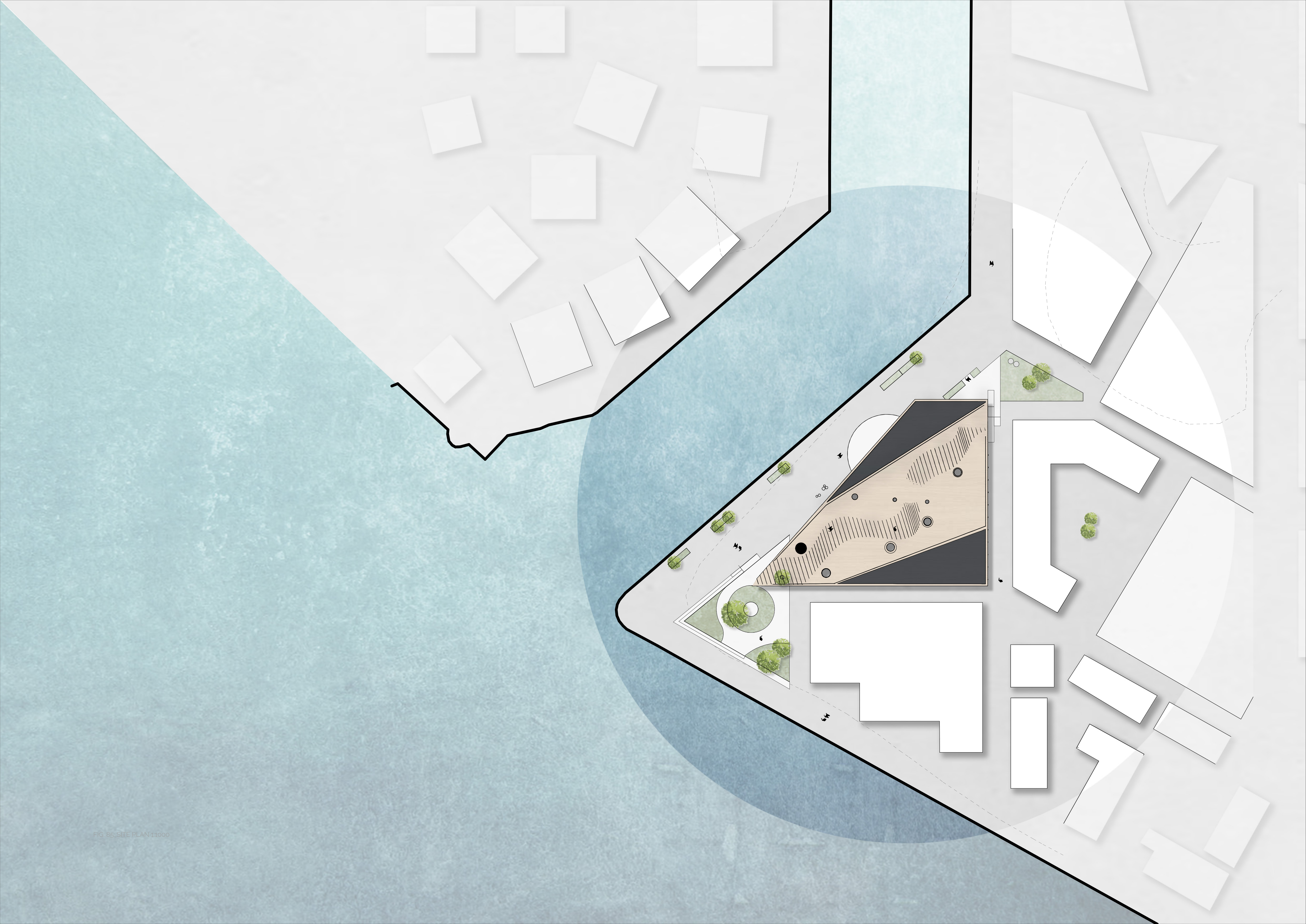


FIG. 85: SITE PLAN 1:1000

FIG. 86: GROUND FLOOR PLAN 1:500

1: Foyer
2: Exhibition
3: Restaurant
4: Auditorium
5: Workshop
6: Cloak Room
7: Changing rooms
8: Toilets
9: Storage
10: Technical Room
11: Kitchen
12: Storage
13: Toilets
14: Break Room
15: Reception
16: Gift shop

PRESENTATION

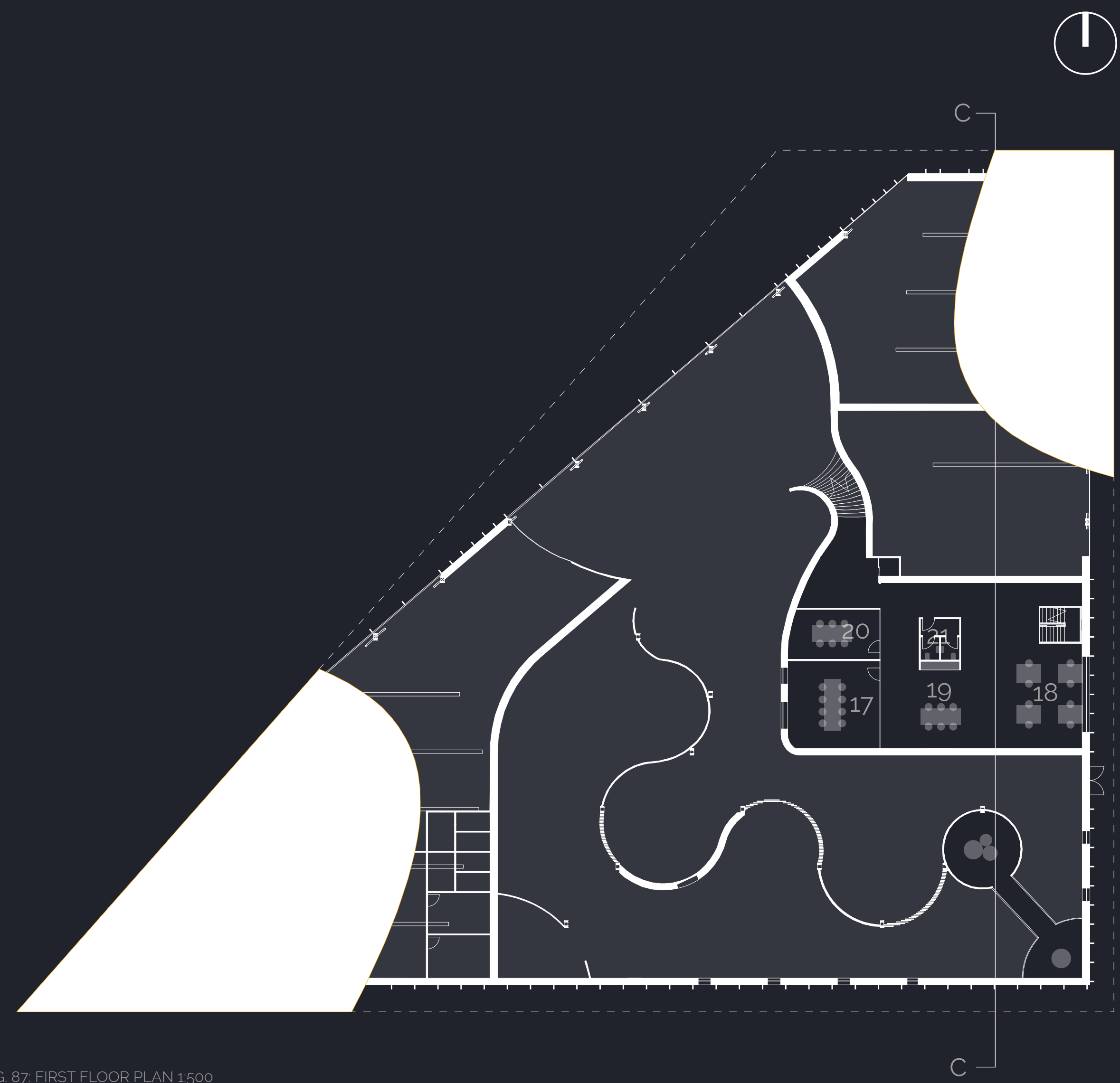


FIG. 87: FIRST FLOOR PLAN 1:500

17: Meeting Room
18: Office
19: Break Room and Kitchenette
20: Meeting Room
21: Toilets

5.19

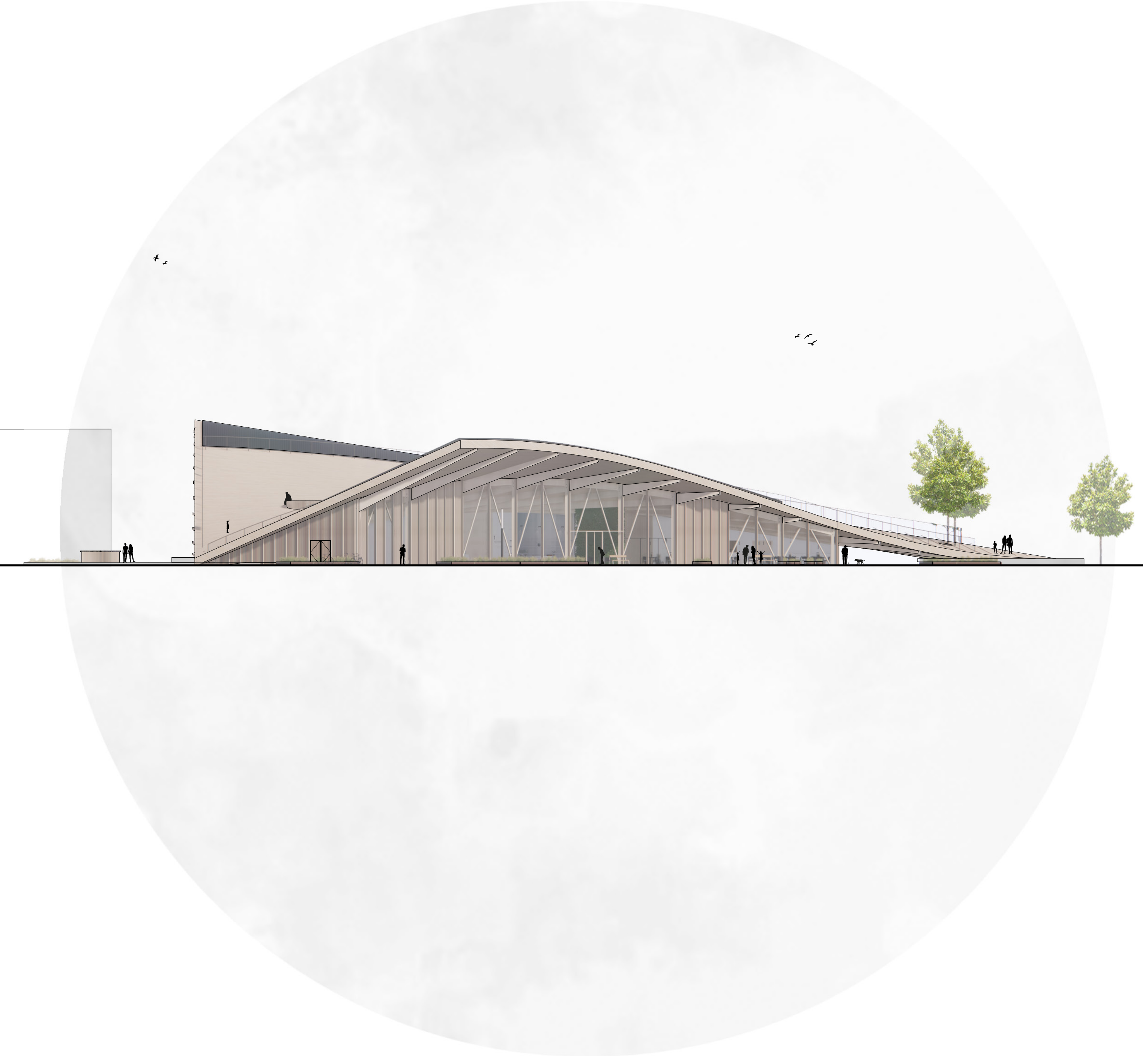


FIG. 88: NORTH ELEVATION 1:500

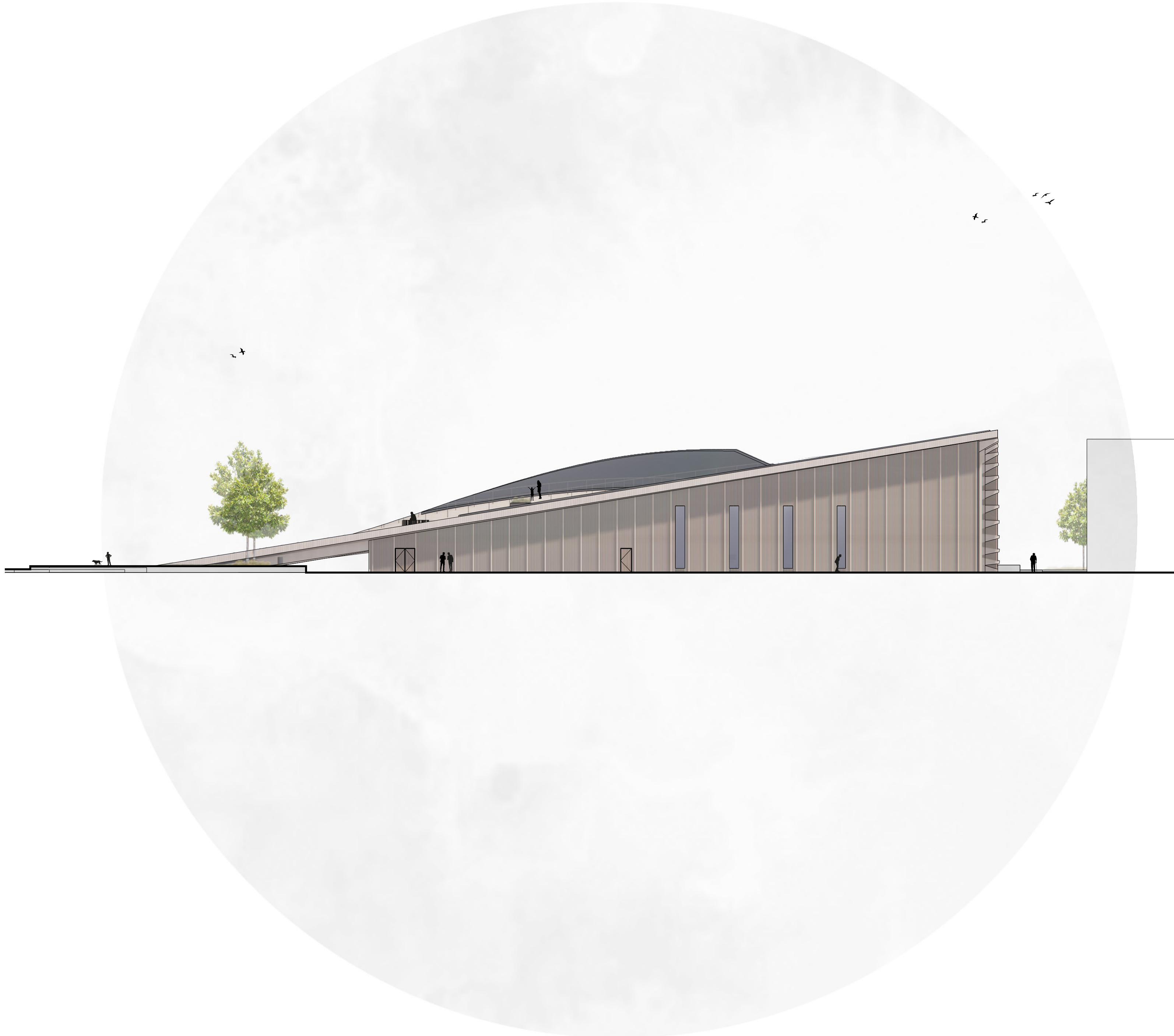


FIG. 89: SOUTH ELEVATION 1:500

FIG. 90: EAST ELEVATION 1:500

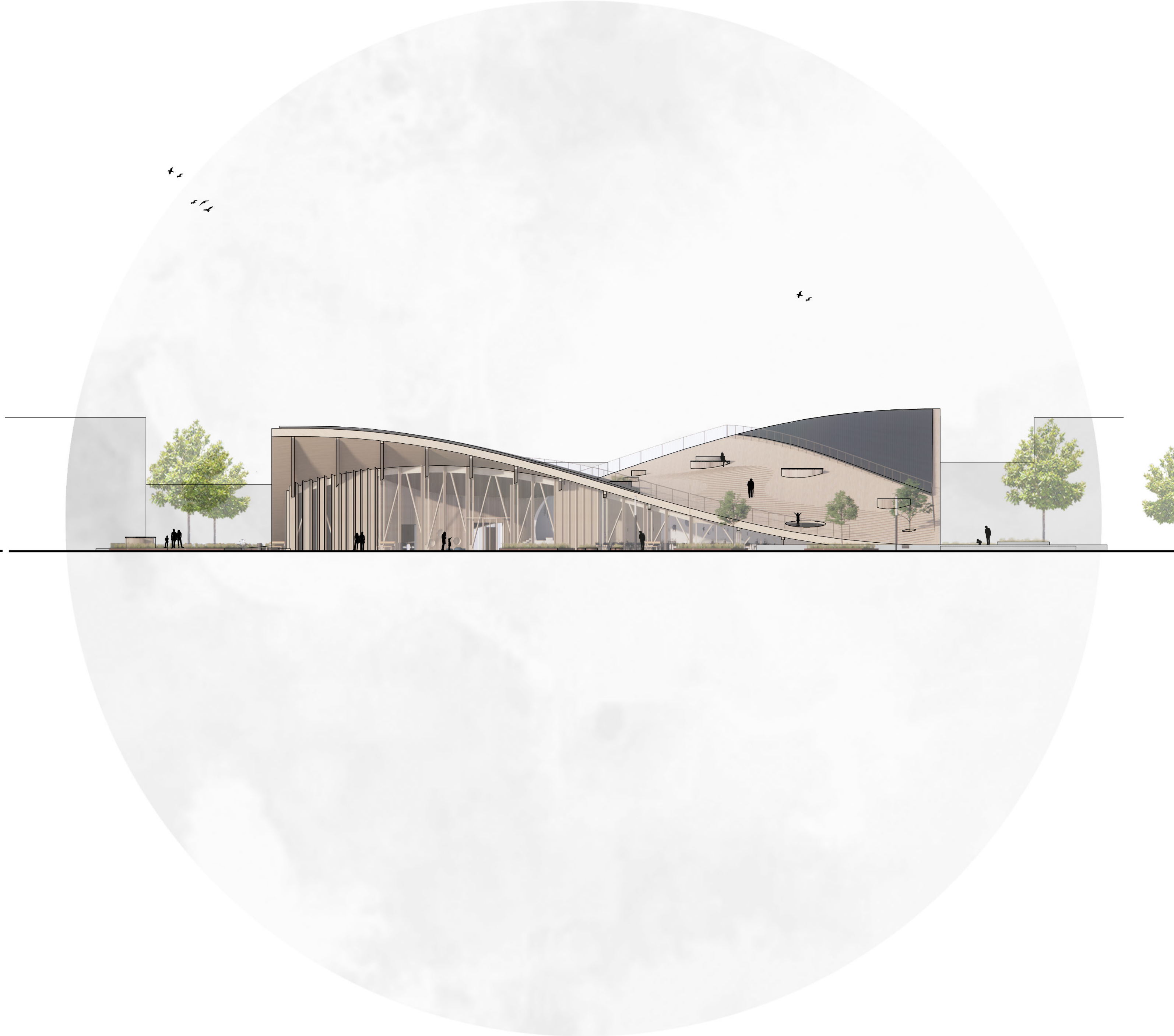


FIG. 91: WEST ELEVATION 1:500

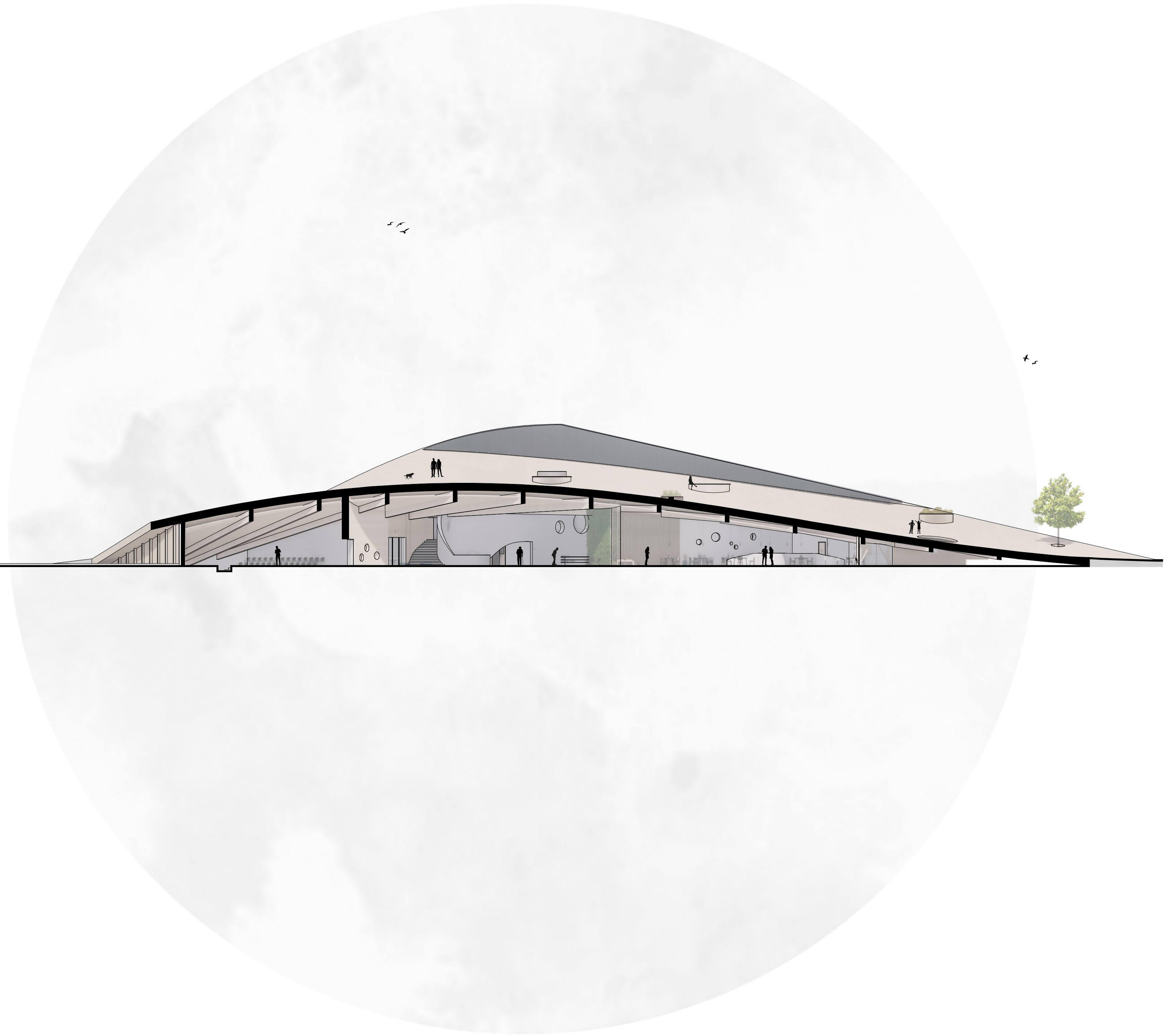


FIG. 92: SECTION A-A 1:500

FIG. 93: SECTION B-B 1:500

FIG. 94: SECTION C-C 1:500

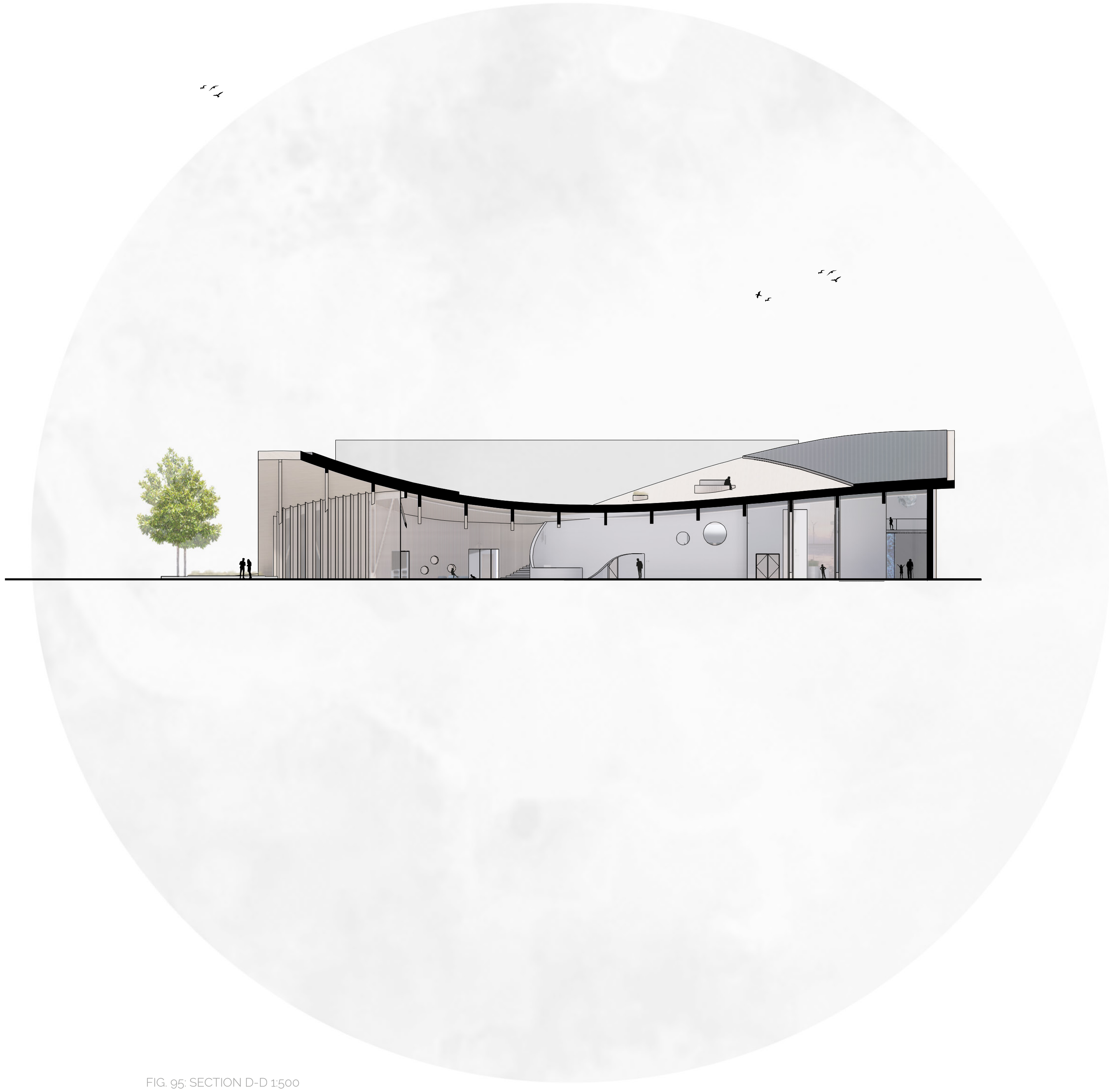


FIG. 95: SECTION D-D 1:500

FIG. 96: FOYER

FIG. 97: RESTAURANT

FIG. 98: MICRO EXHIBITION ON SOLAR ENERGY

PRESENTATION

PRESENTATION

FIG. 99: MICRO EXHIBITION ON WIND POWER

PRESENTATION

FIG. 100: MACRO EXHIBITION

FIG. 101: SMART GRID EXPERIENCED IN VR

6 . 2

CIRCULATION

BUILDING FLOW

About the flow: The Visitor Centre is designed to accommodate various flows and paths for different user groups depending on the reason for their visit. All routes begin in the foyer, in which all further entrances are visible, including the auditorium, the restaurant and the exhibition for general users, while the administrative unit with meeting rooms and the staff's workstations are located on the first floor. The foyer thus acts as a central node from where all paths diverge.

- PUBLIC ROUTE
- AUDITORIUM
- WORKSHOP
- MEETING ROOM
- EXHIBITION
- RESTURANT

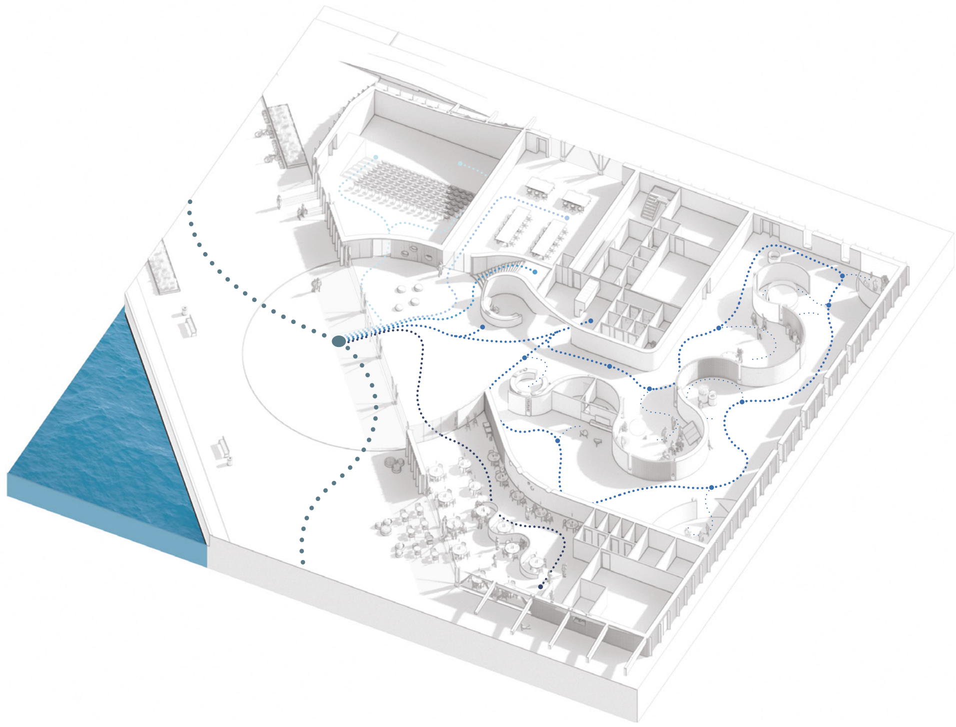


FIG. 102: FLOW DIAGRAM

6 . 3

STRUCTURAL SYSTEM

EXPLODED VIEW OF CONSTRUCTION ELEMENTS

The diagram shows the four construction layers in the building. The posts and the big beams are the primary load carrying elements, while the smaller beams and the diagonal bracing in the facade are stabilising elements. On top is the roof structure, here represented as a surface.

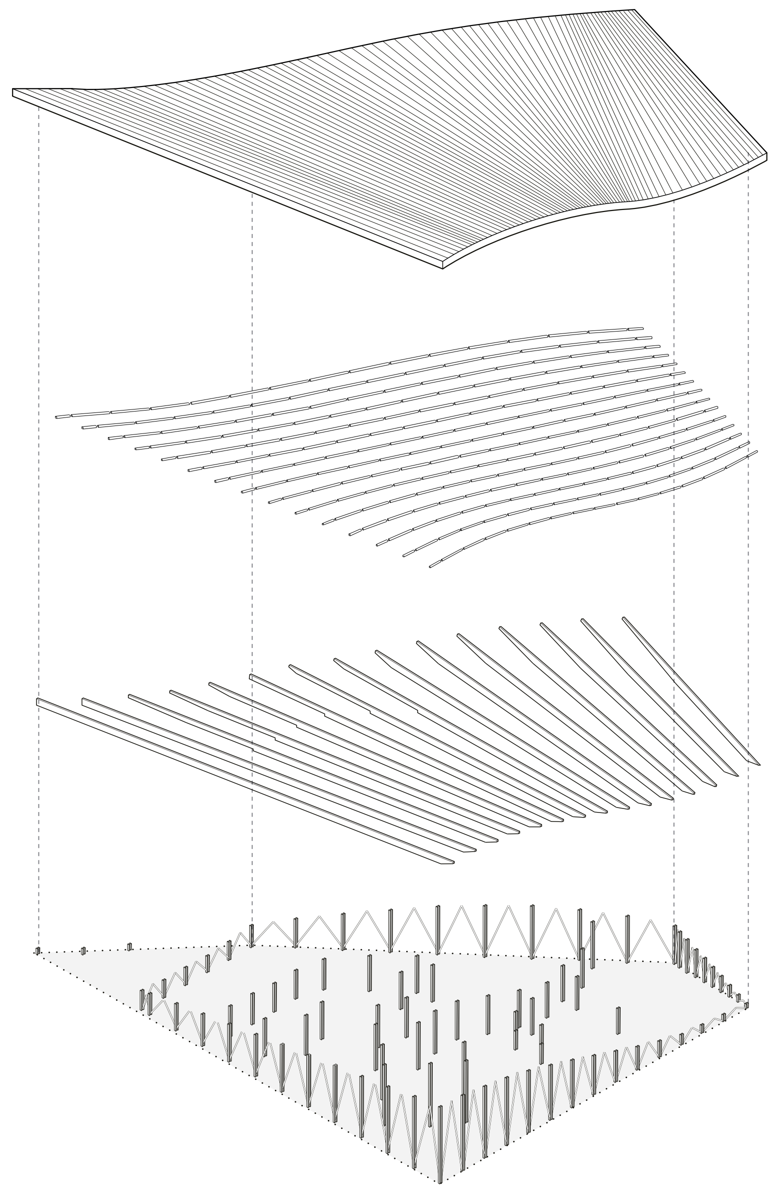


FIG. 103: STRUCTURAL SYSTEM

6.4

CONSTRUCTION OF ROOF

1:10 DETAIL OF THE ROOF

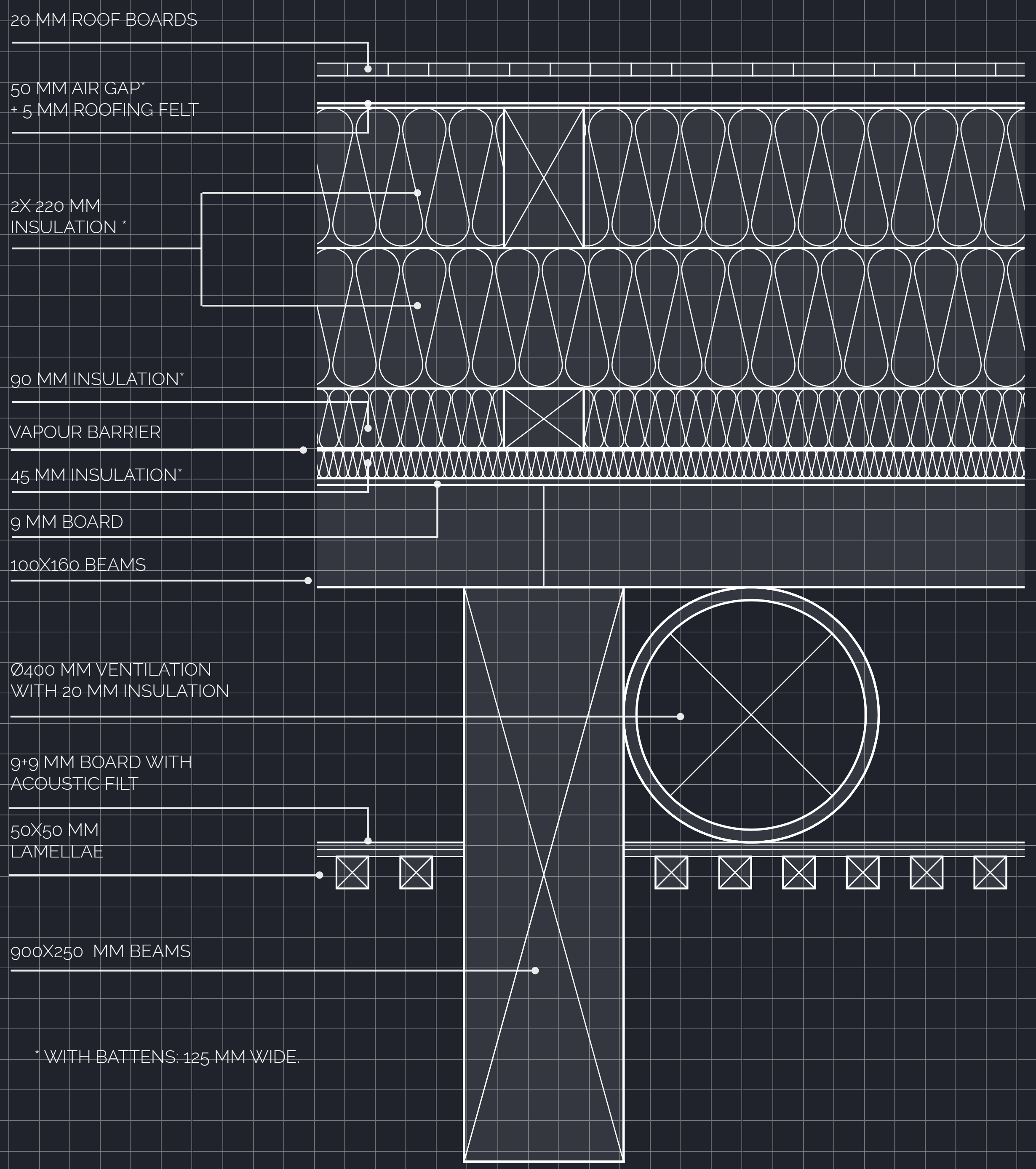


FIG 104: ROOF DETAIL, 1:10

6.5

ENERGY CONSUMPTION

FINAL RESULTS FROM BE18

ENERGY FRAME BR 2018		
Without supliments	Supplements for special conditions	Total energy frame
41.4	4.3	45.7
Total energy requirement		15.6

ENERGY FRAME LOW ENERGY		
Without supliments	Supplements for special conditions	Total energy frame
33.0	4.3	37.3
Total energy requirement		15.6

CONSTRIBUTION TO ENERGY REQUIREMENT		NET REQUIREMENT	
Heat	2.8	Room heating	14.3
EL for operation of building	6.6	Domestic hot water	5.5
Excessive in rooms	0.7	Cooling	0.0
SELECTED ELECTRICITY REQUIREMENTS		HEAT LOSS FROM INSTALLATIONS	
Lighting	10.0	Room heating	0.0
Heating of rooms	0.0	Domestic hot water	0.2
Heating of DHW	0.2		
Heat pump	3.4	OUTPUT FROM SPECIAL SOURCES	
Ventilators	6.2	Solar heat	0.0
Pumps	0.2	Heat pump	12.8
Cooling	0.0	Solar cells	29.3
Total el. consumption	35.9	Wind mills	0.0

6.6

CONCLUSION

FINAL REMARKS

The Visitor Centre for Renewable Energy exhibits the final design proposal for an innovative centre that addresses a broad group of users, and is designed to accommodate several approaches in informing and pushing for a more sustainable future. In its mediating form, the
centre seeks to invoke a greater sense of sustainable consciousness and awareness amongst its users and the inhabitants of Fredericia.

The exhibition is designed around a composition of themes that touches on a range of different aspects in relation to sustainable technologies and renewable energy, as well as their history, implementation, and potentials. The use of curvilinear shapes and flow creates a spatial, kinesthetic and visual architectural experience that seeks to engage, inform and awaken curiosity in visitors. The grand roof of the building gives the centre a distinctive appeal in the new developing area of Kanalbyen in Fredericia and activates the urban space for recreational use while physically showcasing sustainable technologies related to the interior functions.

Using a tectonic approach, the proposal has resulted in a structure developed to enhance the mediating role of the centre, as the structural elements help define the flow and narrative journey. In terms of sustainability, the project primarily uses environmentally friendly materials in its construction and has been projected to reach the low energy Building Class 2020. Energy requirements have been met by a conscious approach to the building envelope and implementation of passive and active strategies to help save and produce renewable energy.
With the Visitor Centre, the city of Fredericia will lead the way and set an example for a new approach to the furthering of green initiatives, serving as a platform for exploring, learning, listening, and discovering.

6.7

CONTEMPLATION

REFLECTING ON OUR PROCESS

It is our opinion that every project invites the designer to take a step back and reflect on their process and its relation to the final design. How was the initial problem informed, which tools were available, how were they applied and which solutions arose? This final section of the report will be an attempt at such an evaluation.

One cannot properly evaluate the design process without addressing the external situation surrounding it. The covid-19 virus and the implemented measures to contain it, has meant that two thirds of the design process has been conducted separately and digitally, as the university has been closed for most of the project period. Work has been carried out using video chat and screen sharing as the main way of communication. As designers of visual artefacts and concepts, this has required alternative methods, as the collaborative sketching, model making, discussion of concepts and sharing of sources of inspiration has been impaired, in short: the development and communication of the design. Countermeasures have been used in the form of online feedback and critique, using screen sharing and digital whiteboards for sharing sketches and day-long video sessions while working. While these have been valuable tools, they are not a suitable replacement for working physically together. Complex ideas and concepts are more difficult to explain, misunderstandings are prone to happen, while inspiration and issues alike do not get communicated. These are issues in every design process, but they are only worsened in this situation.

This, for us, goes to show how important tools analogue sketching and concept development can be, as complex ideas require advanced means to communicate. This had been an issue in the early design process e.g. when collaboratively developing the structure and when assessing scale, space and volume. Which tools are available is in general one of the important factors when developing a design. This has been very apparent throughout the development of the project, as some programmes have certain limitations to be ware off. For the development of the design, Rhino with the Grasshopper and Karamba3D plugin have been used for the overall shape and structural stability, Robot Structural Analysis has been used for dimensioning and verification, while Revit has been used for modelling the final building, based on the imported geometry from Rhino. These programmes function very differently and, with an exception for Grasshopper, in which the basic geometry was made, they do not handle working with curved or double curved surfaces very well. In addition to making the process a challenging experience, this also limits how far the shape can be developed. When one is choosing which tools to work with, one is also, consciously or not, choosing what solution space is available.

This point is also relevant for the focus and approach one holds for the design. The three main pillars, as stated in the programme, for the project has been sustainability, tectonics and phenomenology and the approach has been to use integrated design to create a holistic whole. The process has birthed some interesting solutions when all three foci worked together, which especially has been developed in the exhibition space. It has also served as a criteria for rejecting solutions, which only addressed one of the foci or of which the implementation would negatively impact one of the others. While serving as a guideline for the design, this approach has also felt like a leash. As the design grew more complex and solutions became interdependent, the solution space very rapidly diminished. This has been challenging, as minor issues could not be solved by conventional or simple means, as one change would have a ripple effect throughout the design and thus huge consequences.

Finally, we would like to address the role of the architect. As the last project of our masters, this thesis and its focus, the type of building we wanted to design and its functions have been completely up to us. We have chosen to build a learning and science centre with a focus on sustainability, as we deem this an ever increasingly important topic to address on a global scale because it allowed us to pursue an interest in phenomenology, tectonics and affordances. This is thus a completely internally motivated project, without a client or competition to set the limits, functions or direction. We have thus independently contracted external advisors to better inform the project. All advisors brought us a wide range of functions and considerations, which have been great at informing the project, but ultimately it has been up to us to define and detail the different spaces. A concrete example of this is the exhibition: With our focus on affordances and the phenomenological experience, a ‘blank canvas’ approach was quickly ruled out. The exhibition should be designed for the artifacts it is meant to contain and the flow that should tie them together, but as we had no exhibition pieces, we have had to design this ourselves. We are not curators and therefore, detailing the narrative of the exhibition has been challenging and time consuming, as this type of creativity is not something we have had any previous experience with. We do believe however that the principles it has been designed upon can be used to create a different experience, albeit with room for modifications to follow. This is one element we would have liked to continue developing, preferably with a curator, exhibition team or client. Another aspect is LCA and the exploration of alternative sustainable materials. As we were all, until working on this thesis, inexperienced with the theory, knowledge and programmes relating to these aspects, we are aware that there is much more to learn. As we are soon to enter the professional workspace, we will hopefully learn more regarding this and a range of subjects not touched on in this thesis as we continue to develop as architects and designers in the future.

7.0 EPILOGUE

7.1 SOURCES

INTERNET SOURCES:

3XN (n.d.), Klimatorium in Lemvig, accessed 16.04.2021, available at: https://3xn.com/project/lemvig-climatorium

Archdaily (2015), The Warp, accessed 16.04.2021, avaiable at: https://www.archdaily.com/771023/the-warp-olivier-ottevaere-and-john-lin-plus-the-university-of-hong-kong

Berger, M (2005), “All About Bending Wood”, accessed 17.04.2021, avaiable at: https://www.finewoodworking.com/2005/09/12/all-about-bending-wood

Brody, R. (2012) The Inadequacy of Berlin’s “Memorial to the Mudered Jews of Europe in The New Yorker, July 12, 2012
Available at: https://www.newyorker.com/culture/richard-brody/the-inadequacy-of-berlins-memorial-to-the-murdered-jews-of-europe [Accesed 20.02.2021]

Bygningsreglementet (2018), Lys og Udsyn, Available at: https://bygningsreglementet.dk/Tekniske-bestemmelser/18/Krav/379_381 [Accessed 19.05.2021]

Cambridge Dictionary, n.d., Awareness. Available at: https://dictionary.cambridge.org/dictionary/english/awareness [Accessed 20.02.2021]

Den Danske Ordbog (n.d.) Formidle https://ordnet.dk/ddo/ordbog?query=formidle [Accessed 20.02.2021]

Designing building wiki (2020) “Hyperbolic paraboloid in construction”, Available at: https://www.designingbuildings.co.uk/wiki/Hyperbolic_paraboloid_in_construction [Accessed 17.03.2021]

DinGeo (n.d.) Havvand på land. Available at: https://www.dingeo.dk/kort/searise/?type=havstigning [Accessed 26.02.2021]

DMI (1999) Technical report 99-13. Available at: https://www.dmi.dk/fileadmin/user_upload/Rapporter/TR/1999/tr99-13.pdf [Accessed 26.02.2021]

Fredericia Historie, n.d. Fredericias Historie. Available at: https://www.fredericiahistorie.dk/side/fredericias-historie. [Accessed 25.02.2021]

Fredericia Historie, n.d. Industrialisering og transport. Available at: https://www.fredericiahistorie.dk/side/industrialisering-og-transport. [Accessed 25.02.2021]

Fredericia Kommune (2014) Kommuneplantillæg nr. 4: Klimatilpasning. Available at: http://fredericia.viewer.dkplan.niras.dk/media/214290/samlet_kommuneplantillaeg-nr4-vedtaget-kopi.pdf [Accessed 26.02.2021]

Golsteijn, L. (2018) LCA Basics: life cycle assessment explained. Available at: https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/ [Accessed: 19.02.2021]

Henning Larsen, (n.d.) Moesgaard Museum, https://henninglarsen.com/da/projects/featured/0716-moesgaard-museum, [Accessed 04.02.2021]

Klima- Energi- og Forsyningsministeriet n.d. Vedvarende energi. Available at: https://kefm.dk/energi-og-raastoffer/energiforsyning/vedvarende-energi. [Accessed 20.02.2021]

Koch, C. (2018) Kanalbyen i Fredericia: Udviklingsplan. Available at: https://kanalbyen.dk/media/f4cpjger/65989_kb_udviklingsplan_a4_r25.pdf. [Accessed 20.02.2021]

Moesgaard Museum, (n.d.) Permanente udstillinger https://www.moesgaardmuseum.dk/udstillinger/permanente-udstillinger/oldtidsudstillinger/, [Accessed 04.02.2021]

Snøhetta n.d. Svart. Available at: https://snohetta.com/projects/366-svart. [Accessed 21.02.2021]

Sørensen, B. J. (2021) Unikt samarbejde: Trekantområdet som internationalt produktionscentrum for grønne brændstoffer. Available at: https://www.trekantomraadet.dk/viden-nyheder/presserum/trekantomraadet-som-internationalt-produktionscentrum-for-groenne-braendstoffer. [Accessed 25.02.2021]

Thomas, K. (2020) Interview: Ivaylo Lefterov on the Development of Svart. Sleeper. Available at: https://www.sleepermagazine.com/stories/originals/interview-ivaylo-lefterov-on-the-development-of-svart/. [Accessed 18.02.2021]

Tredje natur,(n.d.), “Visitor center national park Mols Mountains”, accessed 16.04.2021, available at:

United Nations. (2015) Paris Agreement, Article 2 (a). Available at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf. [Accessed 19.02.2021]

Vartanian, O. et al. (2013) Impact of Contour on Aesthetic Judgement and Approach-Avoidance Decisions in Architecture, Available at: https://www.pnas.org/content/110/

Supplement_2/10446 [Accessed 05.04.2021]

Visit Berlin, n.d. Memorial to the Murdered Jews of Europe. Available at: https://www.visitberlin.de/en/memorial-murdered-jews-europe [Accessed 20.02.2021]

Wanscher, H. M. (2020) Fakta om Danmarks udledning af drivhusgasser samt energiforbrug. Danmarks statistik. Available at: https://www.dst.dk/da/Statistik/bagtal/2018/2018-12-06-fakta-om-danmarks-udledning-af-drivhusgasser-samt-energiforbrug. [Accessed: 21.02.2021]

Wanscher, H. M. (2020) Fakta om Danmarks udledning af drivhusgasser samt energiforbrug. Danmarks statistik. Available at: https://www.dst.dk/da/Statistik/bagtal/2018/2018-12-06-fakta-om-danmarks-udledning-af-drivhusgasser-samt-energiforbrug. [Accessed: 21.02.2021]

WorldGBC (2019) Brining Embodied Carbon Upfront. Available at: https://www.worldgbc.org/news-media/bringing-embodied-carbon-upfront. [Accessed 21.02.2021]

BOOKS AND PAPERS:

Bech-Danielsen, C. (2014) An Abstract Culture's Search for Concrete Roots in Towards an Ecology of Tectonics: the need for rethinking tectonics in architecture, Beim, A. & Madsen, U. S., Edition Axel Menges, p. 55

Christiansen, K. (2015) The Paradox of Tectonics - Mortensrud Church in Reader: Tectonics in Architecture, Foged, I. W & Hvejsel, M. F, Aalborg University Press, p. 345

Corner, J. (1999) The Agency of Mapping: Speculation, Critique and Invention in Mappings, Cosgrove, D. Reaktion Books, pp. 213-252

Drake, J. (1979) "The primary generator and the design process" in Design Studies, vol. 1, no. 1 (July 1979): p. 36-44
Available at: https://www.sciencedirect.com/science/article/abs/pii/0142694X79900279

Eisenman, P. & Koolhaas, R. (2009) Supercritical. Aa Publications, pp 8-11

Foged, I. W. (2018) Environmental Tectonics: Convergences Between Six Causalities in Reader: Tectonics in Architecture, Foged, I. W & Hvejsel, M. F., Aalborg University Press, p. 379.

Fors, V. (2006) The Missing Link in Learning in Science Centres, Luleå University of Technology, pp. 47-62 and 137-154.

Gibson, J. J. (2015) The Ecological Approach to Visual Perception. Taylor & Francis

Hvejsel, M. F. (2018) Gesture and Principle: Tectonics as a critical method in architecture in Reader: Tectonics in Architecture, Foged, I. W & Hvejsel, M. F., Aalborg University Press, p. 395.

Knudstrup, M.-A.. (2004). Integrated Design Process in Problem-Based Learning in The Aalborg PBL Model : Progress, Diversity and Challenges, Kolmos, A. : Fink, F. K. : Krogh, L., Aalborg University Press. pp. 221-234.

Krieger, M. H (2011) Urban Tomographies in Site Analysis in Urban Design: An introductory Reader, Steinø, N., Aalborg University, pp. 154-173.

Mayo, J. (2015) Solid Wood: case studies in mass timber architecture, technology and design. Routledge.

Lawson, B. (2005) How designers think: the design process demystified. 4.ed, Oxford: Architectural Press, Elsevier

Sandaker, B. N. et al. (2011) The Structural Basis of Architecture. 2nd ed. Routledge.

Sekler, E. F. (1965) Structure, Construction, Tectonics in Reader: Tectonics in Architecture, Foged, I. W. & Hvejsel, M. F., Aalborg University Press, p. 71.

OTHER

Christina Aabo, online interview by group, Aalborg, 09.02.2021, sound file can be accessed by: https://tinyurl.com/whsrtt47

7.2
LIST OF ILLUSTRATIONS

ALL ILLUSTRATIONS NOT ON THIS LIST WAS MADE BY THE GROUP

GRÖN

A VISITOR CENTRE FOR RENEWABLE ENERGY

APPENDIX

MSc04-ARK9, MAY 2021
CAMILLA CHRISTINA EDEN, CAROLINE TORDRUP ELKJÆR, CHRISTIAN IRMING FRIIS BUHL

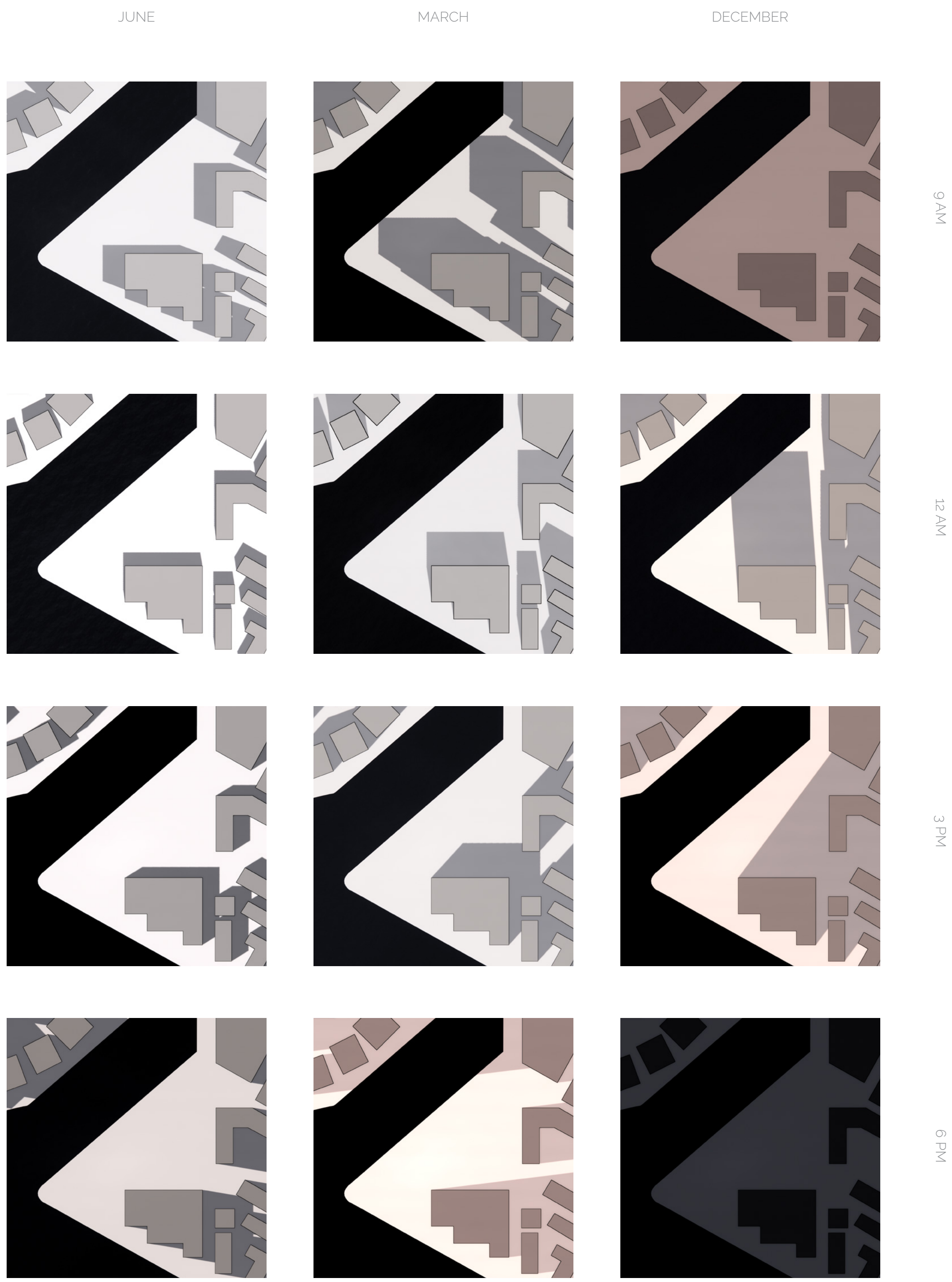
CONTENTS

A.1

SHADOW ANALYSES

SHADING FROM CONTEXT

Since there is currently no distict plan for the southern part of Kanalbyen, the shadow analyses presume the context buildings' height to be 15 m. This is a height that is common elsewhere in Kanalbyen where construction has already started.



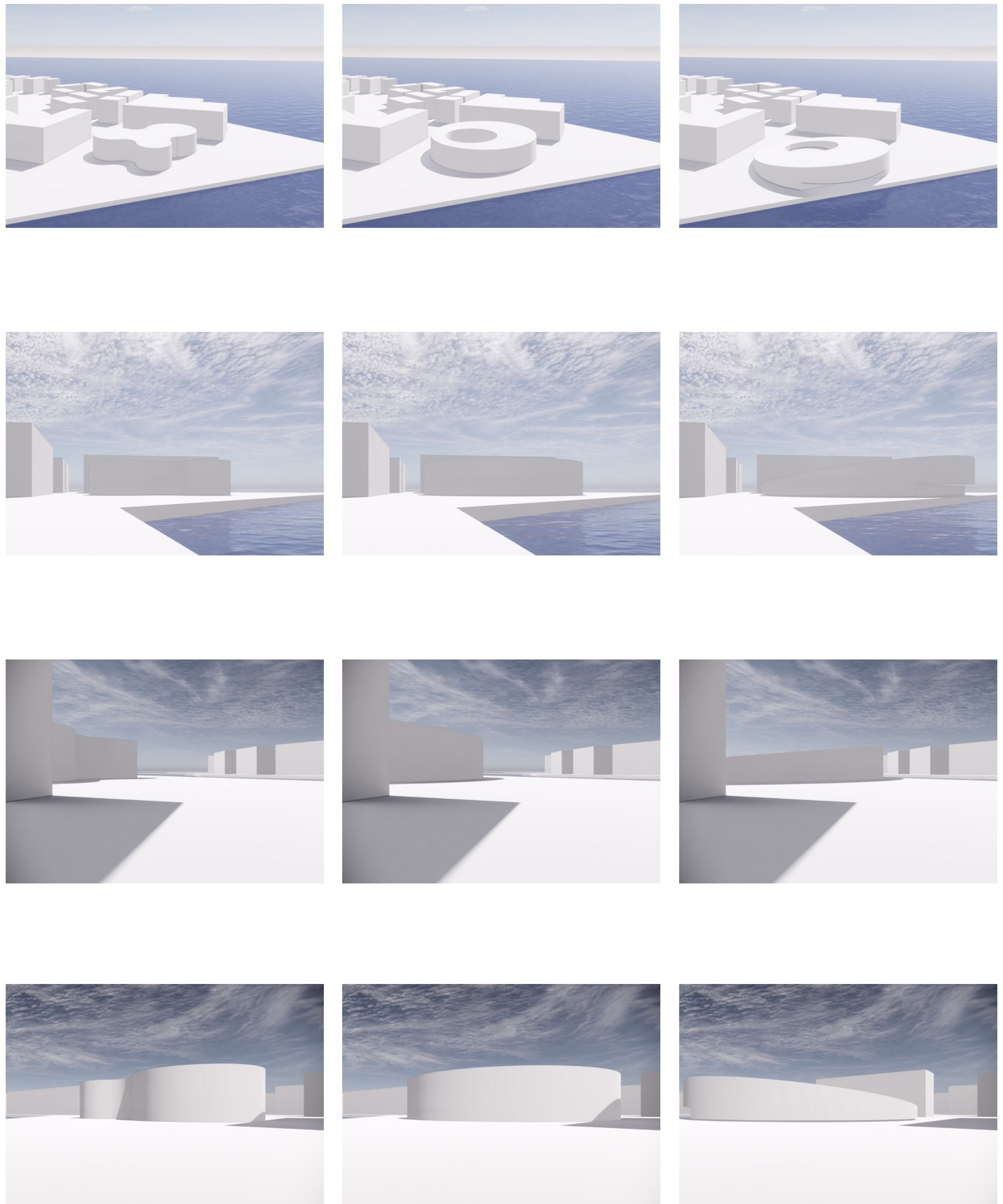
A.2

VOLUME STUDY

TYPOLOGIES

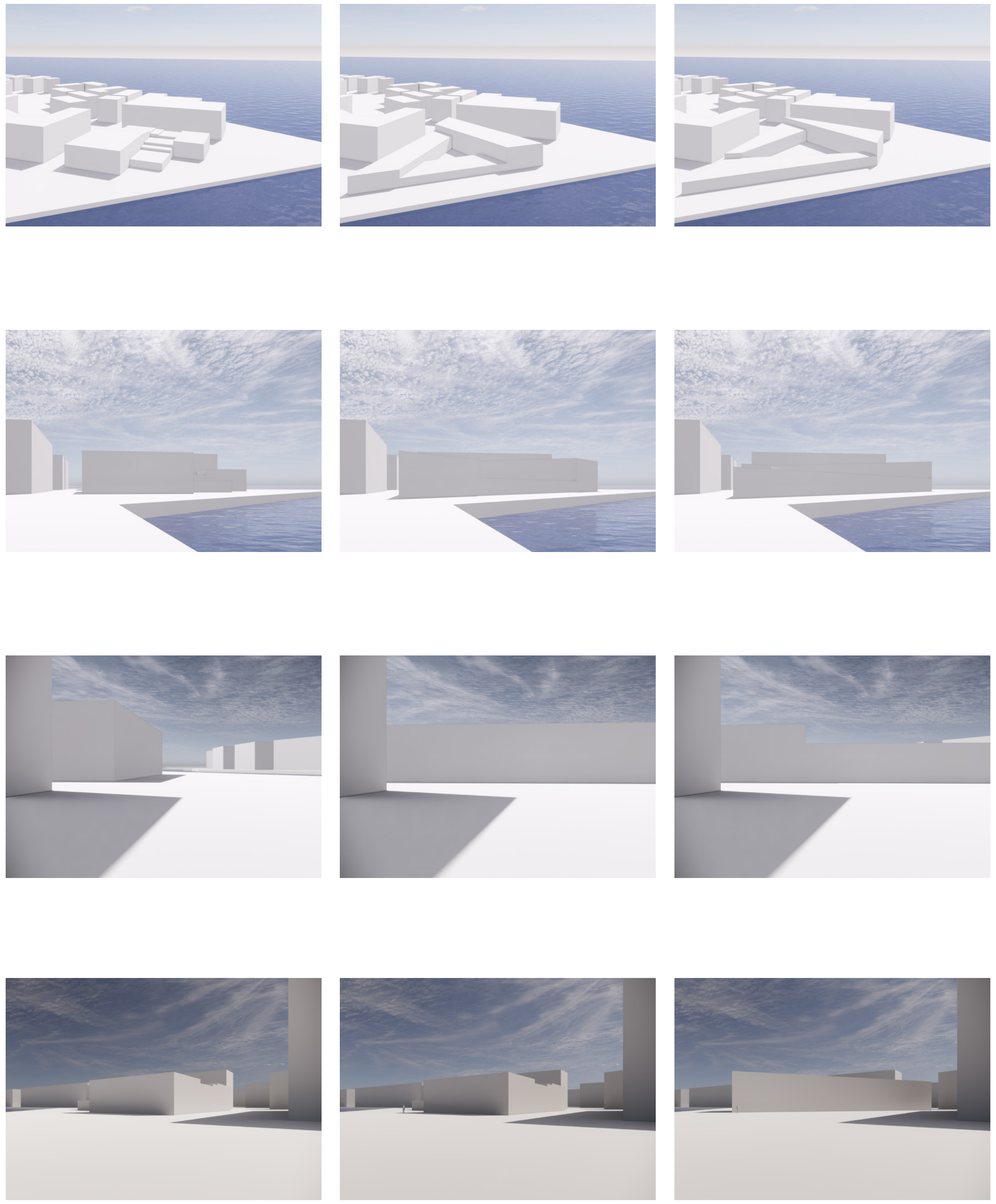
CIRCULAR V1 | CIRCULAR V2 | CIRCULAR V3

PERSPECTIVE / NORTH / EAST / SOUTH



ASCENDING V1 | ASCENDING V2 | ASCENDING V3

PERSPECTIVE / NORTH / EAST / SOUTH



APPENDIX

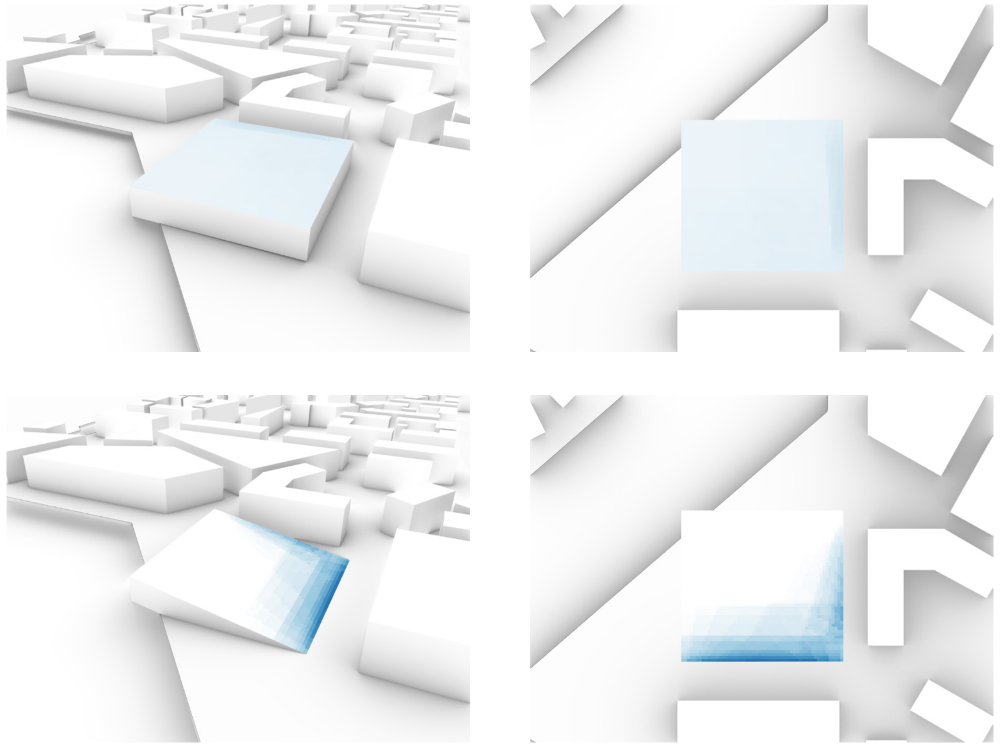
A.3

SOLAR RADIATION

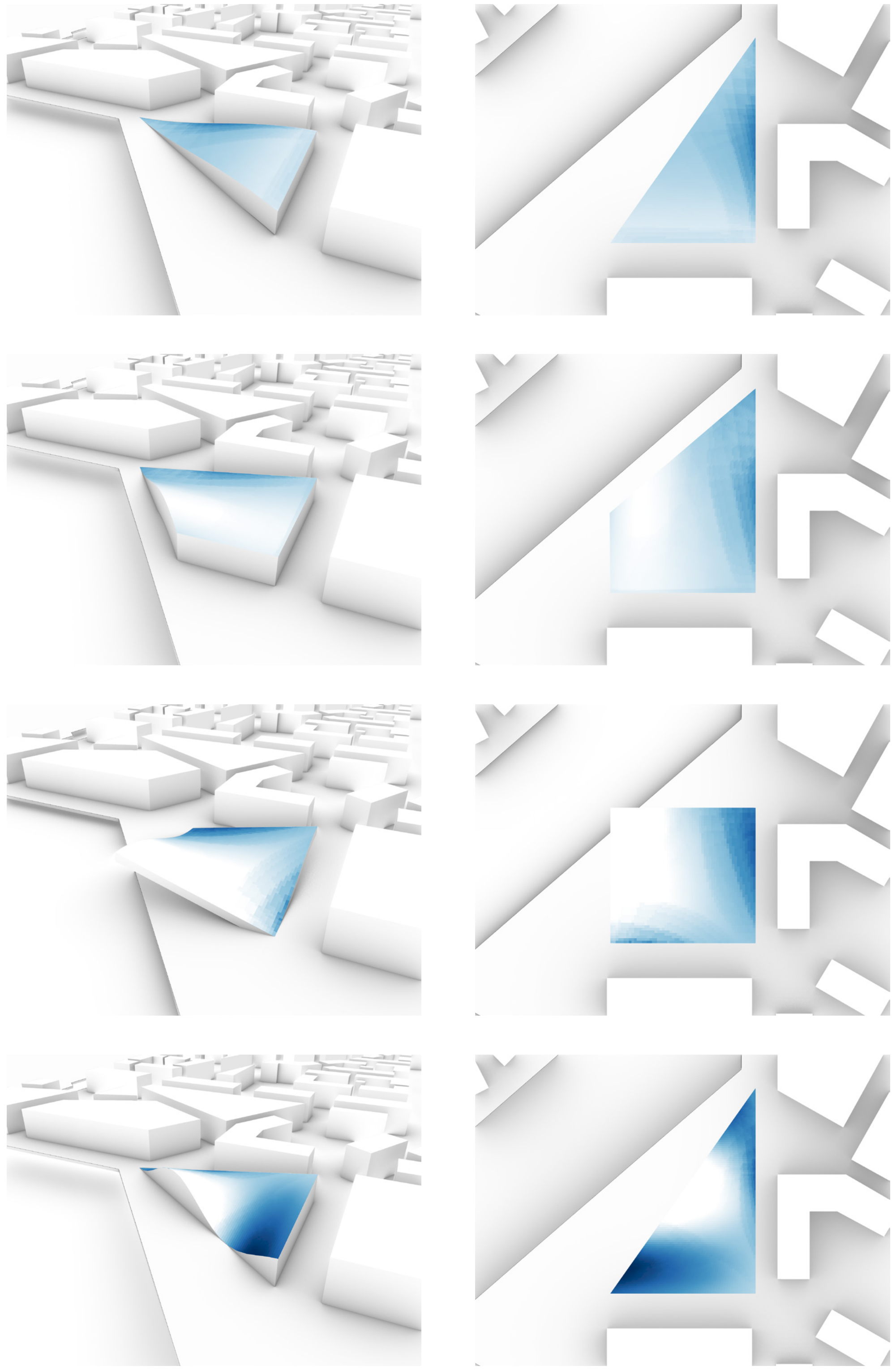
FORM ANALYSES

FLAT ROOF

ANGLED ROOF



RADIANCE ANALYSIS		
CASE	ADIANCE RANGE [kWh/m²]	AVG. RADIANCE [kWh/m²]
FLAT ROOF	914-965	955
ANGLED ROOF	691-1059	970
"THE WAVE"	704-939	866
"THE WAVE 2.0"	737-1001	904
"THE RAY"	655-1089	921
"THE ZAHA"	578-112	829



THE WAVE

THE WAVE 2.0

THE RAY

THE ZAHA

A.4

LOAD CASES

CALCULATION OF LOADS, ULS AND SLS

Calculation of applied load cases

Calculation of snow load

The calculations of snow loads will be based on the assumption that the building is within normal conditions; that expectional snow falls and drifts are unlikely to occur at the site.

As such the persistent and transient design situation from snow loads can be calculated:

$s := \mu_i \cdot C_e \cdot C_t \cdot s_k$

DS/EN1.3 - 5.1

The exposure coefficient, C_e, can be defined as 1,0,, as the topography is determined to be neither windswept nor sheltered:

$C_e := 1.0$

DS/EN 1.3 - 5.2.7

The thermal coefficient, C_t, is used to reduce snow loads on roofs with high thermal transmittance. As this is not determined to be the case, it is defined at 1,0.

$C_t := 1.0$

DS/EN 1.3 - 5.2.8

The characteristic snow load on the ground, s_k, is determined by the region the building is located in (Central East), the zone in the region (Z), and the altitude above Sea Level (A.h)

$Z := 3$

$A_h := 4$

$$s_k := (0.264 \cdot Z - 0.002)\left[1 + \left(\frac{A_h}{256}\right)^2\right] = 0.79 \ \frac{kN}{m^2}$$

DS/EN 1.3 - Tabel C.1

The shape coefficient for snow loads, μ_i is a bit complicated for the roof of the project, because of the geometry.

To simplify things, it is decided to devide the roof into 3 zones, which can each be viewed as monopiched roofs with different angles, see figure 1.

These zones will be referenced again when calculating the wind loads.

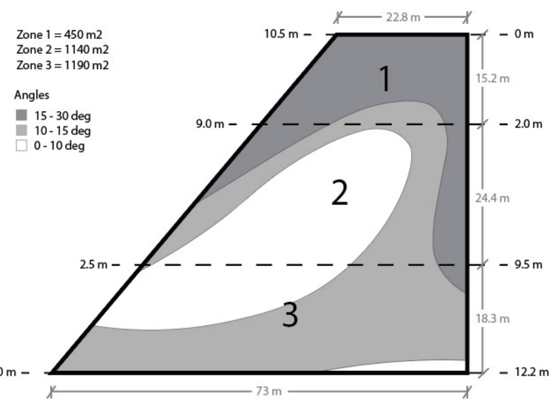


Figure 1 - Zones on roof and their angles

As no angles on the roof are above 30 deg, the values of μ is defined as:

$\mu_1 := 0.8$

DS/EN1.3 - Table 5.2

Zone 1 and 3 can be calculated using μ_1 for both drifted and undrifted load arrangements.
Zone 2 can use μ_1 for undrifted arrangements, while another coefficient, μ_1, is needed for drifted arrangements, since there is a risk that snow from the higher areas on the roof can slide to the middle.
The steeper angles on each of the sides of zone 2 aproximates 17 deg:

$\alpha := 17$

$$\mu_2 := 0.8 + 0.8 \cdot \frac{\alpha}{30} = 1.253$$

DS/EN1.3 - Table 5.2

The snowloads for drifted and undrifted load cases can thus be calculated:

Undrifted load cases for all zones and drifted load cases for zone 1 and 3

$$s_1 := \mu_1 \cdot C_e \cdot C_t \cdot s_k = 0.632 \ \frac{kN}{m^2}$$

Drifted loadcase for zone 2:

$$s_2 := \mu_2 \cdot C_e \cdot C_t \cdot s_k = 0.99 \ \frac{kN}{m^2}$$

To consider the worst case, the load case for zone 2 will be an interpolation between these to cases, with the maximum in the middle of the zone and minimum at the edges.

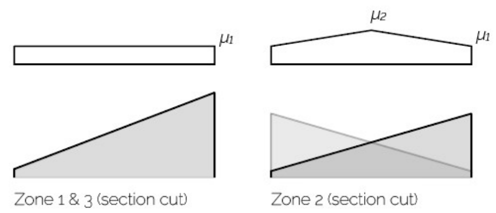


Figure 2 - Load cases determined by μ

Load cases on zones

$cc2 := 2$
$cc4 := 4$

	Uniformly distributed load	Line load (cc 4 m)	Line load (cc 2 m)
Zone 1:	$s_{1.1} := s_1 = 0.632 \ \frac{kN}{m^2}$	$s_{1.1} \cdot cc4 = 2.529 \ \frac{kN}{m}$	$s_{1.1} \cdot cc2 = 1.264 \ \frac{kN}{m}$
Zone 2:	$s_{1.2} := s_2 = 0.99 \ \frac{kN}{m^2}$	$s_{1.2} \cdot cc4 = 3.962 \ \frac{kN}{m}$	$s_{1.2} \cdot cc2 = 1.981 \ \frac{kN}{m}$
Zone 3:	$s_{1.3} := s_1 = 0.632 \ \frac{kN}{m^2}$	$s_{1.1} \cdot cc4 = 2.529 \ \frac{kN}{m}$	$s_{1.1} \cdot cc2 = 1.264 \ \frac{kN}{m}$

Calculation of wind load

Calculation of wind loads based on the method described in EC1:

Determination of the basic wind speed

$v_b := c_{dir} \cdot c_{sesson} \cdot v_{b.0} =$ ▪ DS/EN1.4,- (4.1)

$v_{b.0} := 24 \frac{m}{s}$ danish basic wind speed DS/EN1.4,- 4.2, note 2

$c_{dir} := 1.0$ recogmented value for omnidirectional wind DS/EN1.4,- 4.2, note 2

$c_{sesson} := 1.0$ for the whole year DS/EN1.4,- 4.2, note 3

$$v_b := c_{dir} \cdot c_{sesson} \cdot v_{b.0} = 24 \frac{m}{s}$$

Determination of the mean wind speed

$v_m(z) := c_r \cdot c_0(z) \cdot v_b$ DS/EN1.4,- (4.3)

$c_0(z) := 1.0$ The orography factor. Taken as 1.0, since none of the cases specified in 4.3.3 applies. DS/EN1.4,- 4.3

Since the building is partly exposed to the sea towards west and south, the worst case will be considered and the building is considered to be in terrain category I.
The building is taller than z.min and $c_r(z)$ is calculated using the equation in (4.4):

$c_r := k_r \cdot \ln\left(\frac{z}{z_0}\right)$ DS/EN1.4,- (4.4)

$z_0 := 0.01$ for terrain categori I DS/EN1.4,- Table 4.1

$z := 10$ building height above terrain

$k_r := 0.19 \cdot \left(\frac{z_0}{0.05}\right)^{0.07} = 0.17$ DS/EN1.4,- (4.5)

$$c_r := k_r \cdot \ln\left(\frac{z}{z_0}\right) = 1.173$$

Middel wind speed

$$v_m := c_r \cdot c_0(z) \cdot v_b = 28.143 \frac{m}{s}$$

Determination of the peak velocity of the wind

Turbulence of the wind, by the recommended rules in (4.7):

$I_v = \frac{\sigma_v}{v_m} = \frac{k_I}{c_0(z) \cdot \ln\left(\frac{z}{z_0}\right)}$ for $z_{min} < z < z_{max}$ DS/EN1.4,-(4.7)

$k_I := 1.0$ The turbulence factor. The recommended value is 1,0. DS/EN1.4,- 4.4

$$I_v := \frac{k_I}{c_0(z) \cdot \ln\left(\frac{z}{z_0}\right)} = 0.145$$

Peak velocity pressure

$\rho := 1.225 \frac{kg}{m^3}$ the density of air during a storm. Using the recommended value DS/EN1.4,- 4.5, note 2

$$q_p := \left(1 + 7 \cdot I_v\right) \cdot \frac{1}{2} \cdot \rho \cdot v_m^2 = 0.977 \cdot \frac{kN}{m^2}$$

Wind pressure on the outer parts of the construction:

$w_e = q_p(z_e) \cdot c_{pe}$ DS/EN1.4,- (5.1)

c_{pe} is the pressure coefficient for external pressure and is dependant on the shape of the roof.

To simplify the calculations, the zones from before will be used, which will further be subdivided into zones, given by figure 7.7 for pitched roofs, as seen on figure 3

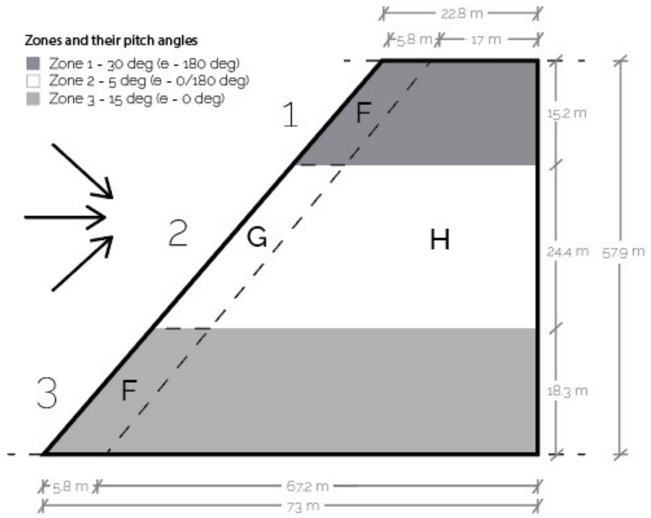


Figure 3 - Wind zones

Wind loads on facades

The zones for the facades are determined by the relationship between the lengths of the facades in the direction of the wind (denoted d) and the height of the building times 2 or the length on the facade perpendicular to the wind direction (denoted b): whichever is smaller (denoted e).

Wind from west:	Wind from south
d = 22.3 m / 73 m	d = 67.9 m
b = 67.9 m	b = 22.3 m / 73 m
h = 0 to 12 m, 2h= 0 to 24	h = same as west

As the worst case is considered, which is the case in which e is largest compared to d) the following is considered:
West: e = 2h, resulting in a relationship in which e approx. equals d. e = d
South: e = b (22.3 m), resulting in a relationship in which e approx. equals 3d. e = 3d

Both cases are calculated using two zones for the wind, A and B, as shown on figure 7.5, page 36 in EN 1999-1-4:2005.

A = e/5 = 4.8 m
B = d-e/5 = 17.5 m / 68.2 m (west) and 63.1 (south)

The facades perpendicular to the wind are denoted D and E for the facade exposed to the wind and facade on the opposite side respectively

As the loaded areas are all larger than 10 m2, $c_{pe.10}$ is used to determine the pressure coefficients

Load cases :

	Uniformly distributed load	Line load (cc 4 m)	Line load (cc 2 m)
Zone A:			
	$w_A := q_p \cdot -1.2 = -1.172 \cdot \frac{kN}{m^2}$	$w_A \cdot cc4\,m = -4.688 \cdot \frac{kN}{m}$	$w_A \cdot cc2\,m = -2.344 \cdot \frac{kN}{m}$
Zone B:			
	$w_B := q_p \cdot -0.8 = -0.781 \cdot \frac{kN}{m^2}$	$w_B \cdot cc4\,m = -3.126 \cdot \frac{kN}{m}$	$w_B \cdot cc2\,m = -1.563 \cdot \frac{kN}{m}$
Zone D:			
	$w_D := q_p \cdot 0.8 = 0.781 \cdot \frac{kN}{m^2}$	$w_D \cdot cc4\,m = 3.126 \cdot \frac{kN}{m}$	$w_D \cdot cc2\,m = 1.563 \cdot \frac{kN}{m}$
Zone E:			
	$w_E := q_p \cdot -0.5 = -0.488 \cdot \frac{kN}{m^2}$	$w_E \cdot cc4\,m = -1.953 \cdot \frac{kN}{m}$	$w_E \cdot cc2\,m = -0.977 \cdot \frac{kN}{m}$

Wind loads on roof, calculated with the external pressure coefficients from table 7.2

	Uniformly distributed load	Line load (cc 4 m)	Line load (cc 2 m)
Zone 1:			
F	$w_{1.F} := q_p \cdot -0.5 = -0.488 \cdot \frac{kN}{m^2}$	$w_{1.F} \cdot cc4\,m = -1.953 \cdot \frac{kN}{m}$	$w_{1.F} \cdot cc2\,m = -0.977 \cdot \frac{kN}{m}$
H	$w_{1.H} := q_p \cdot -0.2 = -0.195 \cdot \frac{kN}{m^2}$	$w_{1.H} \cdot cc4\,m = -0.781 \cdot \frac{kN}{m}$	$w_{1.H} \cdot cc2\,m = -0.391 \cdot \frac{kN}{m}$
Zone 2:			
G	$w_{2.G} := q_p \cdot -1.2 = -1.172 \cdot \frac{kN}{m^2}$	$w_{2.G} \cdot cc4\,m = -4.688 \cdot \frac{kN}{m}$	$w_{2.G} \cdot cc2\,m = -2.344 \cdot \frac{kN}{m}$
H	$w_{2.H} := q_p \cdot -0.6 = -0.586 \cdot \frac{kN}{m^2}$	$w_{2.H} \cdot cc4\,m = -2.344 \cdot \frac{kN}{m}$	$w_{2.H} \cdot cc2\,m = -1.172 \cdot \frac{kN}{m}$
Zone 3:			
F	$w_{3.F} := q_p \cdot -0.9 = -0.879 \cdot \frac{kN}{m^2}$	$w_{3.F} \cdot cc4\,m = -3.516 \cdot \frac{kN}{m}$	$w_{3.F} \cdot cc2\,m = -1.758 \cdot \frac{kN}{m}$
H	$w_{3.H} := q_p \cdot -0.3 = -0.293 \cdot \frac{kN}{m^2}$	$w_{3.H} \cdot cc4\,m = -1.172 \cdot \frac{kN}{m}$	$w_{3.H} \cdot cc2\,m = -0.586 \cdot \frac{kN}{m}$

Self load and imposed loads

The self load of the structure has been applied with the 'gravity load case'-component in grasshopper. This only accounts for the load from the geometry that is inserted into it however, so an extra load case of 0.5 kN/m2 has been applied on the frames as well to accounts for the rest of the roof.

This number for a light roof and defined in 'Statik og kostruktiv forståelse' page 11.

Imposed loads is determined to be in category I, from table 6.9 in EN 1991-1-1:2002, which futher states that the load should account for the use of the area. Loads are expected from the people gathering on the roof, but these are not expected to gather in too large numbers, so a load of uniformly distributed load of 2.5 kN/m2 are deemed to be sufficient. Certain areas of the roof are inaccessable due to PV panels, which adds an imposed load of 0.195 kN/m2 (20 kg / m2).

	Uniformly distributed load	Line load (cc 4 m)	Line load (cc 2 m)
Imposed load (people)	2.5 kN/m^2	$2.5 \frac{kN}{m^2} \cdot cc4\,m = 10 \cdot \frac{kN}{m}$	$2.5 \frac{kN}{m^2} \cdot cc2\,m = 5 \cdot \frac{kN}{m}$
Imposed load (PV)	0.195 kN/m^2	$0.195 \frac{kN}{m^2} \cdot cc4\,m = 0.78 \cdot \frac{kN}{m}$	$0.195 \frac{kN}{m^2} \cdot cc2\,m = 0.39 \cdot \frac{kN}{m}$

Determination of limit states

Ultimate Limit State

The formular for load case combinations in ULS is defined in DS/EN 1990:2007

$$\sum_{j \geq 1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$ DS/EN0 - (6.10)

The consequence classification of the building is judged to be CC3 , as it is a larger public building. This results in the following factor of K_{FI}

$K_{FI} := 1.1$ DS/EN0 - Table B3

The factor applied to the permenant loads (self load), as defined in tabel A1.2 in DS/EN0 1991:

$\gamma_{G.j} := 1.0 \cdot K_{FI} = 1.1$

The leading variable action is defined as:

$\gamma_{Q.1} := 1.5 \cdot K_{FI} = 1.65$

The non-leading variable loads are defined similarly, but with the addion of an extra combination factor, ψ. These are defined in table A 1.1 in DS/EN 1990 FU:2010

$\psi_{0\_imposedH} := 0$	In general
$\psi_{0\_snow} := 0.3$	In general
$\psi_{0\_snow.w} := 0.0$	In combination with a dominating wind load
$\psi_{0\_wind} := 0.3$	In general

Essentially these factors reveal that the only combination that really needs to be explored to get the worst case senario, is a combination with the imposed load as the leading virable action:
In case the snow is leading, the imposed load is reduced to 0 and in case the wind is leading, both the snow and imposed load are reduced to 0.

Thus the combination factor is as follows for different load cases in the worst case senarios

Leading action is the imposed load

$$\sum_{(j \geq 1)} \left(1.0 \cdot 1.1 \cdot G_{k.i} + 1.5 \cdot 1.1 \cdot Q_{k.imposed}\right) + \sum_{(i>1)} \left(1.5 \cdot 1.1 \cdot 0.3 \cdot Q_{k.snow} + 1.5 \cdot 1.1 \cdot 0.3 \cdot Q_{k.wind}\right)$$

$$\sum_{(j \geq 1)} \left(1.1 \cdot G_{k.i} + 1.65 \cdot Q_{k.imposed}\right) + \sum_{(i>1)} \left(0.495 \cdot Q_{k.snow} + 0.495 \cdot Q_{k.wind}\right)$$

Service Limit State

The equations for SLS are simpler:

$$\sum_{(j \geq 1)} \left(G_{k.j} + Q_{k.j}\right) + \sum_{(i>1)} \left(\psi_0 \cdot Q_{k.i}\right)$$ For the characteristic load combination

$$\sum_{(j \geq 1)} \left(G_{k.j} + \psi_{2.1} \cdot Q_{k.j}\right) + \sum_{(i>1)} \left(\psi_{2.i} \cdot Q_{k.i}\right)$$ For the quasi permanent load combination

These factors are found in tabel A1.1 as before

$\psi_{2\_imposed} := 0$
$\psi_{2\_snow} := 0$
$\psi_{2\_wind} := 0$

As the factors for quasi permanent loads both result in forces being = 0, the calculations in SLS will be based on the characteristic loads:

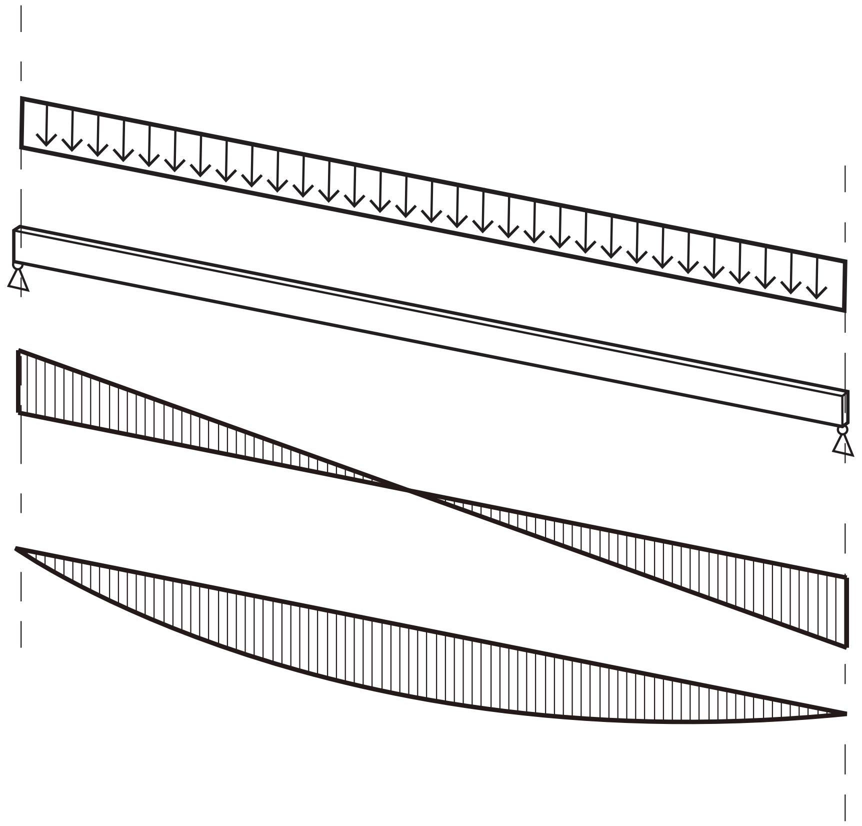
$$\sum_{(j \geq 1)} \left(G_{k.j} + Q_{k.imposed}\right) + \sum_{(i>1)} \left(0.3 \cdot Q_{k.snow} + 0.3 \cdot Q_{k.wind}\right)$$

A . 5

BASE CASE

INITIAL ANALYSIS OF BEAM LENGTHS

CASES	CC 4 M, L: 25 M	CC 4 M, L: 22 M	CC 2 M, L: 25 M	CC 2 M, L: 22 M
CROSS SECTION	300X1100	250X1000	250X900	200X900
MATERIAL	0.33 M3 / M	0.25 M3 / M	0.24 M3 / M	0.18 M3 / M
SHEAR	17.8 KN	204.64 KN	12.14 KN	104.88 KN
MOMENT	111.24 KNM	1125.53 KNM	75.85 KNM	576.86 KNM
DISPLACEMENT	15 MM	192 MM	23 MM	192 MM



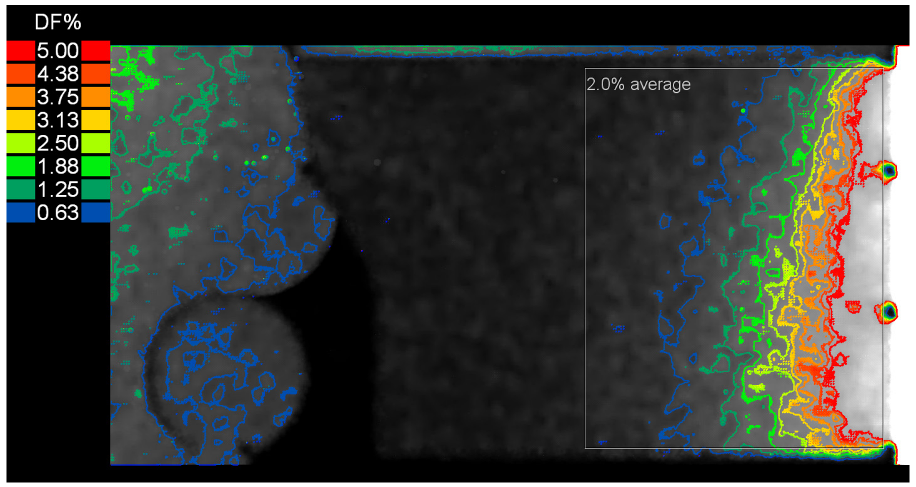
A.6

DAYLIGHT CONDITIONS

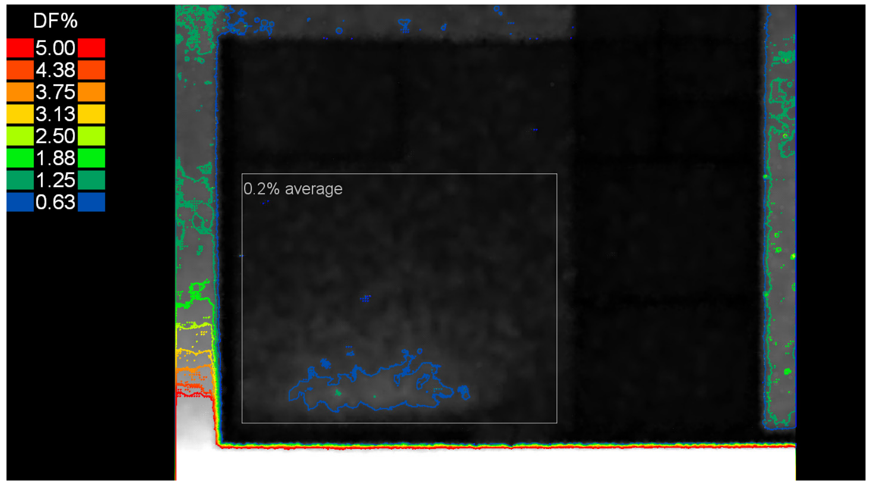
ANALYSES IN VELUX VISULIZER

Due to a possibly tall building close to the kitchen, a good deal of windows are needed here to fulfill BR18 requirements. The kitchen has been analysed in three different scenarios, increasing the amount of glass every time. Since the third iteration with a skylight does not fulfill the requirement of 2,1% daylight factor, the final design includes a larger skylight.

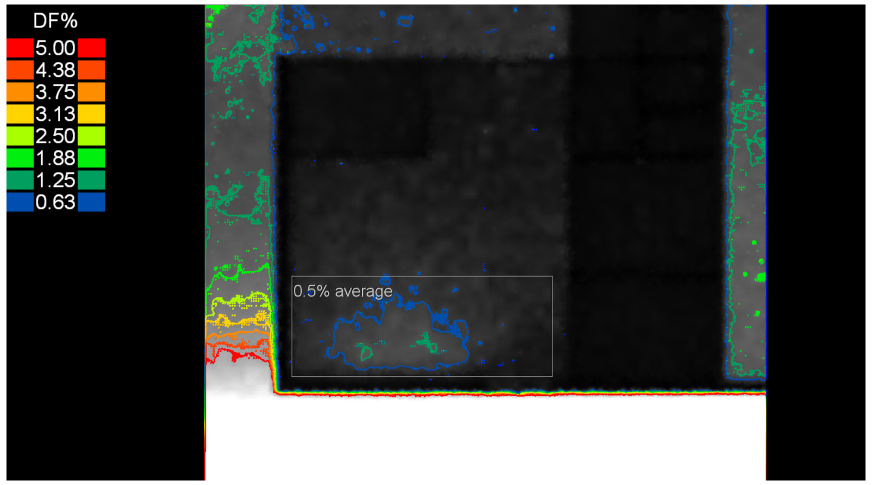
The workshop is placed in the lower floor to the east, a large building close by. Therefore the very first analysis has been of the largest amount of glass area possible for this room. Since the 10%-rule is not recommended for rooms of high depths, a skylight has been added in the final design to meet requirements for sufficient daylight.



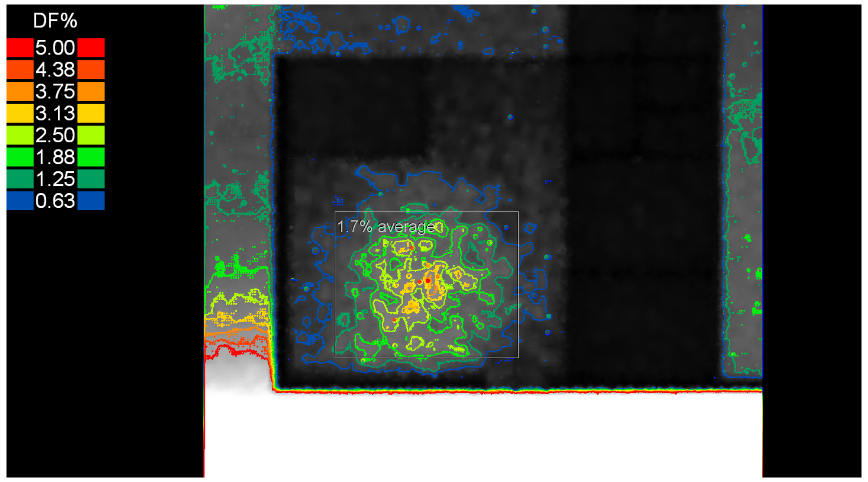
WORKSHOP V1: A LARGE FLOOR TO ROOF WINDOW



KITCHEN V1: ONE SQUARE WINDOW



KITCHEN V2: ONE LARGE WINDOW ALL THE WAY TO THE ROOF



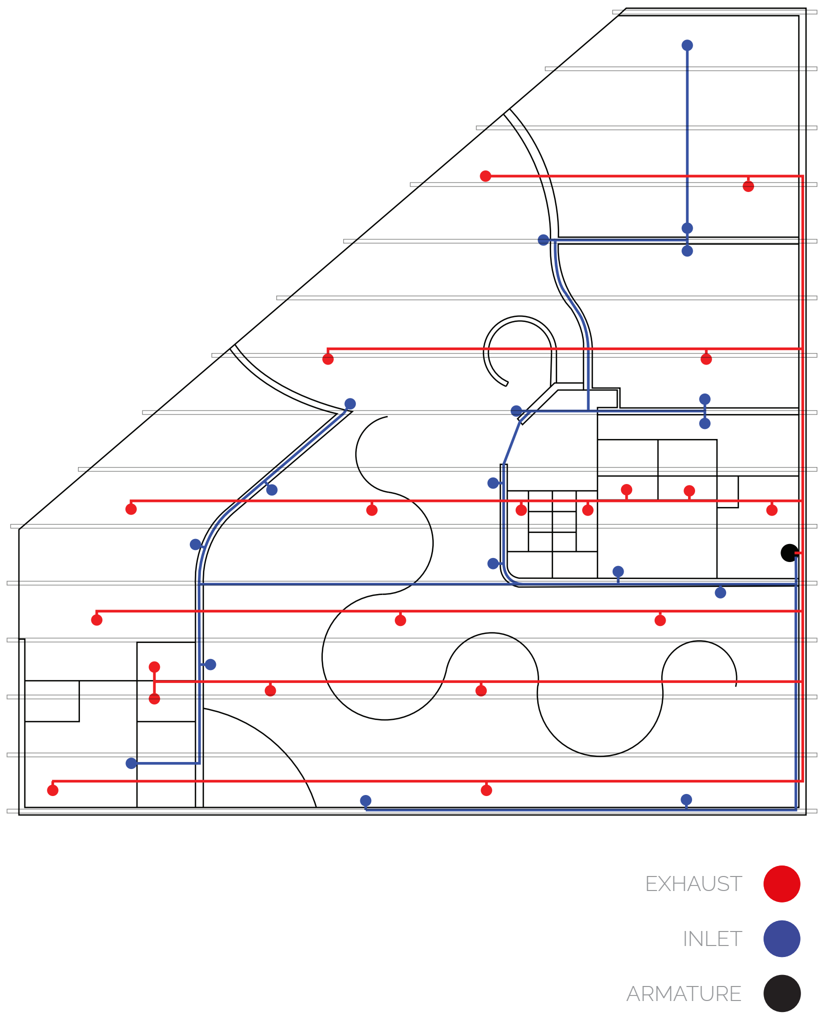
KITCHEN V3: ADDING A SKYLIGHT

A.7

VENTILATION PLAN

PRINCIPLE SCHEME FOR VENTILATION

The ventilation scheme is, like stated in the initial programme, designed on a very conceptual level. The exhaustion pipes are located above the lamellae in a hollow part of the roof construction and follow the 'tracks' in between the beams. Initially the ducts are able to reach their respective 'tracks' while running inside an extension wall on the eastern facade. The ducts for the air supply runs along the floors where possible, with a few exceptions like open spaces or doors, as the inlets are located at the bottom of the wall, in accordance with the proposed displacement ventilation scheme.

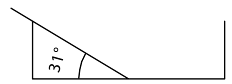


A.8

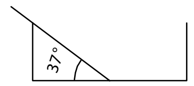
SOLAR SHADING

EXAMINING THE EFFECTS OF SOLAR SHADING

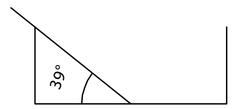
As the explorations show, the difference in depths and distances of vertical lamella shading does not have a huge impact on the total consumption. It is worth noting that horisontal lamellas would likely have had a much bigger influence on the excessive heat. Due to the wish for vertical separation of the long facades and the energy consumption results being so similar, the deciding factor for the facade lamella has been the architectural experience and the need for showcasing and/or revealing.



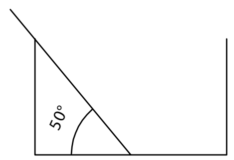
50 cm distance, 15 cm depth:
72 "windows" of 5,4 m2
Total consumption: 50,1 kWh/m2
Excessive heat: 7,1



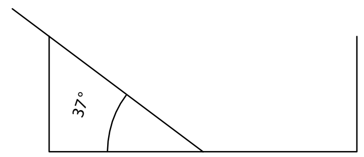
40 mm distance, 15 cm depth:
90 "windows" of 4,3 m2
Total consumption: 50,0 kWh/m2
Excessive heat: 7



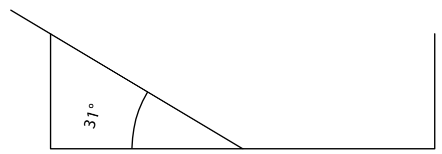
50 cm distance, 20 cm depth:
72 "windows" of 5,4 m2
Total consumption: 50,0 kWh/m2
Excessive heat: 7



50 cm distance, 30 cm depth:
72 "windows" of 5,4 m2
Total consumption: 49,8 kWh/m2
Excessive heat: 6,8



100 cm distance, 30 cm depth:
36 "windows" of 10,9 m2
Total consumption: 50,1 kWh/m2
Excessive heat: 7,1



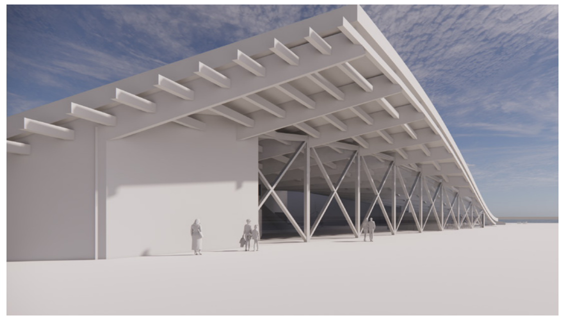
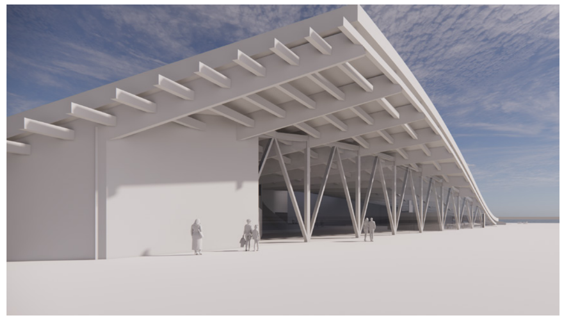
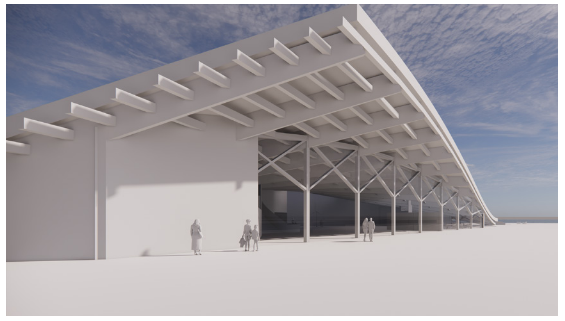
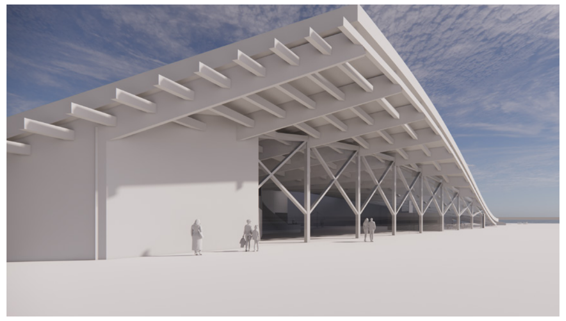
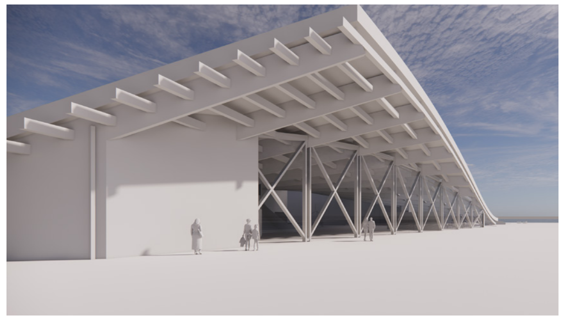
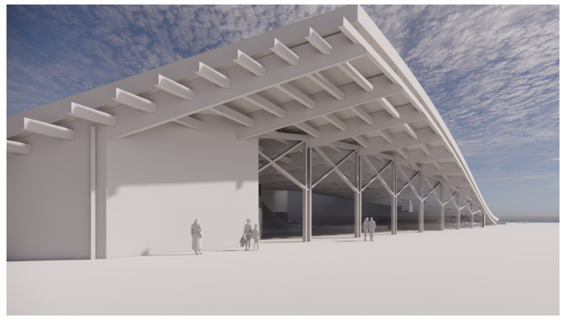
80 cm distance, 20 cm depth:
72 "windows" of 5,4 m2
Total consumption: 50,0 kWh/m2
Excessive heat: 7

A.9

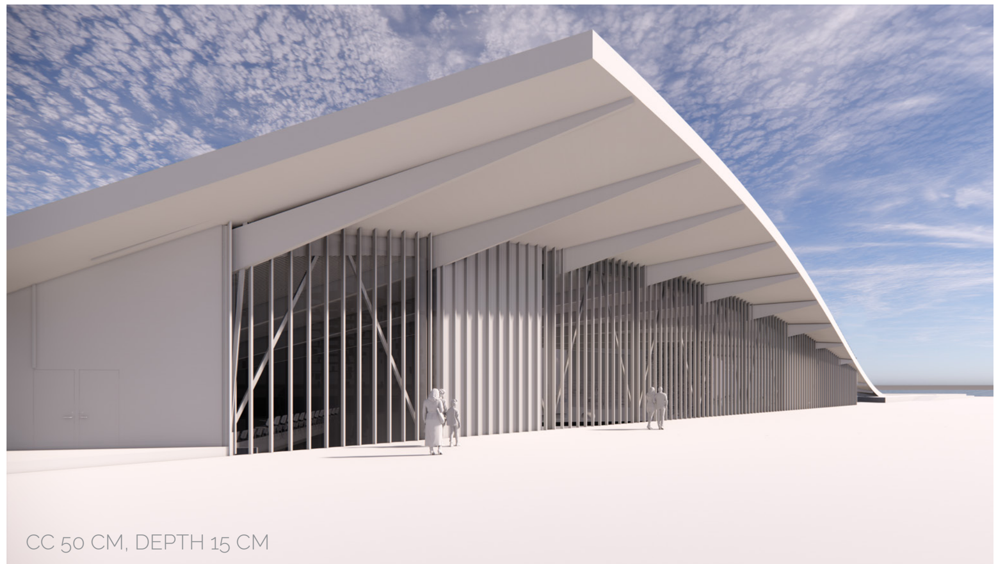
FACADE ITERATIONS

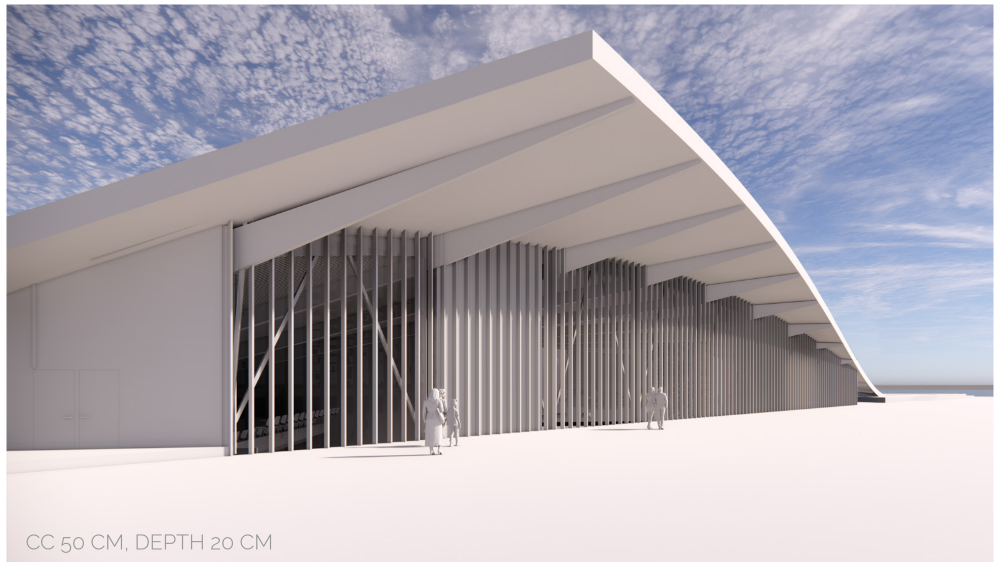
EXAMINING THE AETHETICS OF FACADE EXPRESSIONS

The facade bracing has been assessed according to both structural performance, spatial experience and aesthetics. Deformations can be found in the report.

Facade expressions using different lamellae depths. These are modelled on the chosen case of bracing


CC 50 CM, DEPTH 15 CM


CC 50 CM, DEPTH 20 CM