Master Thesis

Architecture for the Sustainable Project
Politecnico di Torino

FloatScapes: a floating adaptive pavilion

A proposal for a performant prefabricated modular building in the maritime context. A study in the Venice Lagoon.

Andrés Medardo Calero Trávez

Supervisor: Roberto Giordano
Co-Supervisor: Giuliana Mattiazzo

Politecnico di Torino
1859

Abstract (English)

Floating Architecture could be one of the solutions for Coastal Risk and the Sea Leve Rise challenges that we are facing nowadays due to Climate Change. This thesis, in the architectural realm, studies and explores the floating alternative as an adaptation strategy with the potential to raise awareness and generate candid reflections about adaptation and future scenarios.

In addition to raising awareness, the thesis puts in evidence the following hypothesis: To what extent floating architecture is an alternative when developed with a sustainable vision and solutions? From this point onwards, topics such as building with ease over water, and environmental impact reduction, developed a “know-how” competence in floating architecture. Thanks to SEAform’s project opportunity, the research concerned mainly the design of a temporary floating pavilion for Venice, Italy. A project that delivers a waterborne experience, named FloatScapes.

To address the research products, the thesis was divided into three parts. An initial part in which Floating Architecture and Sea Level Rise research set the guidelines for FloatScapes concept and schematic design. In this initial part, decisions about the construction process, materials, and technology were taken effectively, considering the maritime context conditions, which differ from traditional construction.

The second part instead, focuses on the development and detailed design of one of the three platforms of the floating pavilion that provides a food production experience.

[N 0.1A]

Adopted Language:
The abstract is reported both in English and Spanish (author's native language and main language of the master's degree course), while the rest of the thesis will be completely redacted only in English.

Additionally, this section provides a deeper study of Prefabrication and Design for Disassembly while considering the Lifecycle of the project to explore the use of engineered wood as the main low-impact material proposed to reach a Lifecycle-friendly design.

Lastly, the third part oriented to Climate Design, involves an environmental performance study of the passive strategies of the project’s greenhouse, as a climate adaptation experiment in which the thermal conditions are evaluated and assessed.

The thesis finally tests the SEAform model for floating platforms with the development of the project in addition to the involved implications and the reasoning behind it. By building competence in this architectural scope where prefabrication and floating architecture work together, this work aimed to produce good design practices that could contribute to the decision-making processes of future floating developments like FloatScapes.

Abstract (Español)

La Arquitectura Flotante podría ser una de las soluciones para los desafíos de Riesgo Costero y el aumento del nivel del mar que enfrentamos en la actualidad debido al Cambio Climático. Esta tesis, en el ámbito arquitectónico, estudia y explora la alternativa flotante como estrategia de adaptación con el potencial de generar conciencia y fomentar reflexiones candidas sobre la adaptación y los escenarios futuros.

[N 0.1B]
Lengua Adoptada:
El abstract se presenta tanto en inglés como en español (idioma nativo del autor y lengua principal del curso de maestría), mientras que el resto de la tesis será redactado exclusivamente en inglés.

Además de crear conciencia, la tesis pone de manifiesto la siguiente hipótesis: ¿Hasta qué punto la arquitectura flotante es una alternativa cuando se desarrolla con una visión y soluciones sostenibles? A partir de este punto, temas como la construcción sobre el agua con facilidad y la reducción del impacto ambiental desarrollaron una competencia en la arquitectura flotante. Gracias a la oportunidad del proyecto SEAform, la investigación se centró principalmente en el diseño de un pabellón flotante temporal para Venecia, Italia. Un proyecto que ofrece una experiencia en el agua, llamado FloatScapes.

Para abordar los productos de investigación, la tesis se dividió en tres partes. Una parte inicial en la que la Arquitectura Flotante y la investigación sobre el aumento del nivel del mar establecieron las pautas para el concepto y el diseño esquemático de FloatScapes. En esta parte inicial, se tomaron decisiones sobre el proceso de construcción, los materiales y la tecnología de manera efectiva, teniendo en cuenta las condiciones del contexto marítimo, que difieren de la construcción tradicional.

La segunda parte, en cambio, se centra en el desarrollo y diseño detallado de una de las tres plataformas del pabellón flotante que ofrece una experiencia de producción de alimentos. Además, esta sección proporciona un estudio más profundo de la Prefabricación y el Diseño para el Desmontaje, teniendo en cuenta el Ciclo de Vida del proyecto para explorar el uso de la madera ingenieril como el principal material de bajo impacto propuesto para lograr un diseño favorable al Ciclo de Vida.

Por último, la tercera parte orientada al Diseño Climático involucra un estudio del rendimiento ambiental de las estrategias pasivas del invernadero del proyecto, como un experimento de adaptación climática en el que se evalúan y analizan las condiciones térmicas.

La tesis finalmente pone a prueba el modelo SEAform para plataformas flotantes con el desarrollo del proyecto, además de las implicaciones involucradas y el razonamiento detrás de ello. A partir del desarrollo de la competencia necesaria para este ámbito arquitectónico, en el que la prefabricación y la arquitectura flotante trabajan juntas, este trabajo tuvo como objetivo generar buenas prácticas de diseño que podrían contribuir a los procesos de toma de decisiones de futuros desarrollos flotantes como el de FloatScapes.

Foreword

The following thesis work is presented here as an individual endeavor, attributing sole authorship of the research product. However, a very important part of the development is shared with the master's degree student, Gabriele Porporato. Therefore, it's important to acknowledge that a significant part of this thesis was developed in collaboration. To clarify, this academic collaboration produced as research products, a pair of twin theses in which the author's (Gabriele and Andrés) main concern was the design of a floating pavilion for Venice, Italy, called FloatScapes.

After achieving the design together, later in the process, both theses developed their own research paths of development based on the individual interests that originated from the initial collaboration. In this case, this thesis works as follows: "A proposal for a performant prefabricated modular building in the maritime context. A study in the Venice Lagoon."

To illustrate better the distribution of the collaboration, Chapters 1 to 5 are shared between both theses, including textual and visual information elements, with some exceptions. These chapters are mainly the product of this active collaboration between the two authors. On the other hand, Chapters 6 to 8 are the result of the individual effort and contribution to the project created by the individual authors.

These chapters are the main difference between the twin theses, where both present studies linked to the project FloatScapes, but from different topics, approaches, and perspectives as the project itself presents a particular complexity for its type. This approach was taken in order to reach more knowledge about the subject matter.

It is also important to mention and recognize, that the logistics of the theses development as academic assignments, involved a strong architectural dynamic from a technological point of view between the authors and Prof. Roberto Giordano. Several perspectives, knowledge, and competencies were involved during the creative process of the project, enriching the work.

In addition, its also imperative to mention that the final products of both theses were possible thanks to the collaboration, support, and contribution along the whole process, by the SEAform members from the MORElab , with co-supervisor Prof. Giuliana Mattiazzo as front chair of the MORElab, and the very appreciated SEAform board including Alice Rosiello and Diego Bonilla. The parallel interoperability between all the actors of the party developed a complex yet successful collaboration.

As of Summer 2023, both twin theses have been completed, and beyond providing different developments from a common ground, it's worth noting that they also represent a valuable example of successful teamwork.

Acknowledgements

“Gratitude is not only the greatest of virtues but the parent of all others.”

– Marcus Tullius Cicero

With joy, gratitude, and respect, I would like to honor all the people who were part of this process.

To my supervisor Prof. Roberto Giordano for his guidance, teachings, and expertise that influenced my career from the beginning of this master's degree. To my co-supervisor Prof. Giuliana Mattiazzo, front chair of the MORElab, and to all the MORElab research group members that move forward the marine energy field research in the DIMEAS department of Politecnico. The opportunity to complete my studies with a collaborative project with MORElab turned out to be a remarkable experience.

To the SEAform research group, for their project initiative, experience, and vision. Without their technical and logistical support, this collaboration wouldn't have been possible. My gratitude to Alice Rosiello, whose professional coordination permitted the needed interactions to develop this thesis; to Diego Bonilla, whose experience and consistent support in all the thesis stages ensured the standards of the final work, and to Marco Fontana, whose technical support allowed an upgrade in the methodology of the thesis.

To my colleague and friend Gabriele Porporato, for the shared ideas, knowledge, reflections, and competencies in the FloatScapes project of the twin theses.

To Professors, Lorenzo Savio, Guido Callegari, and Paolo Simeone, who positively influenced my path in architecture with their valuable lessons about dry assemblage techniques, prefabrication, and wood construction during the master’s degree.

To all my friends from the master’s degree, for their generosity and unforgettable shared experiences. Special thanks to my friend Juan Diego who introduced and encouraged me to learn VPL tools; and to my friend Lina María, who always shared her technical knowledge with me.

To my friends from all over the world who supported me all this time, especially the ones in Ecuador.

To my partner Fia, for her unconditional love and faith towards me. Your presence in this process made the experience even more beautiful.

To my family, the force behind the strength. Whose constant support and unconditional love, oriented me to achieve my goals and dreams. Anilu and Medar, your legacy is the driving force behind my actions. Pau, your noble intentions always inspire me to be a better architect, but especially a better human being. Esthercita and Polito, you are my example of true life. May God reward you for your generosity.

TABLE OF CONTENTS

03 State of Art

04 Venice Floating Pavilion: FloatScapes

05 Experience Platform

06 Modular Design

07 Climate Analysis

08 Conclusions

01
INTRODUCTION

"What I want is the world to remember the problems and the people I photograph. What I want is to create a discussion about what is happening around the world and to provoke some debate with these pictures.

Nothing more than this.

I don't want people to look at them and appreciate the light and the palate of tones. I want them to look inside and see what the pictures represent, and the kind of people I photograph."

Sebastião Salgado

Cover: Penguins of Paulet Island on an iceberg.
Sebastião Salgado, Antarctica, 2005

01.1 Motivation and Relevance

In the past decades, our planet has experienced the increasing effects and consequences of climate change in an evident and dramatic way. Polar melting, rising oceans, floods, droughts, temperatures, and precipitation volatility are just some of the extreme weather events, and more of them will be coming in the close future.
Hundreds of millions of people are affected by hunger and experiencing displacement from their homes or countries. Government actions should reduce and mitigate these consequences, but even if effectively executed, the efforts to reduce carbon emissions and strive for greener economies won't be enough, more support is needed.

In the global maritime context, coastal and island communities are becoming increasingly vulnerable and fragile as years pass by. Coastal Risk is nowadays one of the main concerns as it could probably cause, in the next decades, the biggest percentage of material and social losses.

In 2015, with the Paris Agreement, governments around the globe declared their intentions to take effective action against climate change. Precise objectives were settled [N 1.1], and between the main developed strategies , one specific milestone in the "Climate Change Quest" is that cities, and citizens, must follow two paths to tackle Climate Change: Mitigation and Adaptation. From this starting point, cities and communities must also act in this realm for the sake of balance, and therefore, should consider and adopt adaptation as a solid strategy for climate change resilience.

Furthermore, in the European context, the EU's autonomous Green Deal development stated its main objective of becoming the first climate-neutral continent by 2050. Their first milestone is to reach a

[N 1.1]
2015 Paris Agreement Goals:
the international community approved and ratified a common agreement on the moves to be followed as an active response to climate change.

Three main specific goals were defined here:
- To limit the mean temperature increase to 1.5 °C (compared to preindustrial data)
- To increase adaptability and resilience to negative effects of climate change.
- To choose a low carbon emission path for economic development.

55% reduction in greenhouse emissions by 2030, and this could only be achieved through an energy transition towards renewable energy sources.

With this goal in mind, several projects were launched as initiatives from the European Commission, where research and funding actively move forward with the proposed green transition.

Among several EU projects, the "Clean Energy for EU Islands", focuses on promoting the energy transition towards renewable energy sources for inhabited EU islands. This specific project opens the topic and goes deeper with the research scope of the maritime context regarding the big potential of unexplored opportunities that the marine (and aquatic in general) environment could offer to substitute carbon-based systems.

Key Points:

- The challenges posed by climate change highlight the necessity for immediate and thoughtful response measures, with the goal of achieving a Green Energy Transition, and reducing environmental risk, specifically for fragile coastal communities.

- Offshore and floating architecture could represent a viable path to follow for safer housing and more variegated energy, water, and food production.

- The evolution of this scope, from a global Green Deal toward the specific goals for EU Islands, is the preface of the following work and research origin developed in this thesis.

01.2 Research Origins

Inspired by the EU initiatives to tackle climate change, institutional and academic projects have started to emerge from universities to test their competence and explore niches in terms of innovation.
Within "Politecnico di Torino", specifically inside the Department of Mechanical and Aerospace Engineering (DIMEAS), the Marine Offshore Renewable Energy Laboratory (MORE Lab) was created as a research centre, which focuses on the development and analysis of Offshore Energy Technologies and Building Solutions.
In addition, inside the MORE Lab research centre, SEAform was created as a multidisciplinary research group (comprising architects and engineers) that explores waterborne living solutions through innovation and technology. Their mission is to develop functional and eco-friendly floating modular platforms as an alternative for vulnerable coastal communities, relying on the technical support of MORE Lab.

During SEAform's first analysis phase, was opened a collaboration with Politecnico's Department of Architecture and Design (DAD), which evolved into two thesis opportunities. Supervisors and tutors from both parts provided support to the thesis development of the involved students. The purpose of this complex, interdisciplinary collaboration has been to enrich both parts, respectively with fresh architectural perspectives, solid academic support, and engineering experience for this specific research context.

Key Points:

- The key elements that induced the development of this thesis are institutional initiatives and the birth of academic entities with the end goal of responding to climate change.

01.3 Research Topic and Content

As a result, the current thesis came forth as the product of this interdisciplinary collaboration, with the goal of developing an architectural design proposal for a Floating Pavilion, based on SEAform's model of concrete floating platforms, for the realization of offshore structures. The project would be located in Venice, and ideally included in the Venice Biennial of Architecture. From here on the project is labelled as FloatScapes.

The floating pavilion would serve an expositive and communicative function, welcoming visitors on its platforms, providing them with an immersive experience, capable of capturing their interest and conveying the strong message and ideals of the whole project.

The thesis starts with a detailed theoric premise, which provides both the author and the readers with a better understanding of the environmental challenges posed by climate change, and of the opportunities provided by floating architecture, as well as the dangers that come with it.
A comprehensive state-of-art linked to the initial pioneers of this research (meaning the MORE Lab and SEAform), introduces the chosen location and includes the inherited limitations and information about the engineered base of the project (SEAform's concrete floating platforms), the already established functional requirements, and the basic goals of the architectural project, main subject of the thesis.

A design concept opens the second part of the thesis, specifically dedicated to the author's project proposal, introducing a development design. Here, the choices in terms of materials, structure, building techniques, systems, and integrated innovative technologies are explained and motivated.

Attention is given to what sits above the floating platforms (upper-structure), but also to the spaces that generate inside them, and finally to all the elements that are submerged below and around the pavilion, to reach as much of a comprehensive design as possible.

The final thesis component is an assessment of the environmental performance of the project, where the author attempts to define the expected changes produced by the building on the surrounding ecosystems and the potential unsolved critical points.

Beyond being aligned with the institutional and academic initiatives, and complying with the inheritance goals and requirements, what makes a step further into this thesis, therefore, is the author's individual research, knowledge, curiosity, and development process, which become the added value that the thesis brings to the broader project.

Key Points:

- The initial work of SEAform and MORE Lab represented the incipit for the thesis and for the author's work, dedicated to the design of a floating pavilion.

- Starting from basic guidelines, provided as basic inheritance, the author was called to produce an architectural development design for the structure, with particular attention to its environmental performance.

-The author's personal research and considerations, concretized in the production of the thesis, represent his contribution to the development of the broader project.

01.4 Research Aim and Expected Results

To elaborate, the floating pavilion design proposal intends to be a detailed prototype within the rules established by SEAform, where the main goal is to reach a Concept and Development Design.
The key goal, however, is not to concretely produce the project but to use this design exercise as an opportunity to test ideas, preconceptions, and starting axioms.
SEAform's model is in continuous development and evolution and needs opportunities to be put to the test. All the choices of materials, shapes, techniques, and technologies need to be evaluated, questioned, and compared with alternatives. What at first seems functional, might turn out to be inadequate. Good practices, indications, rules, as well as unsolved problems, challenges, and research topics, need to be found and extrapolated, and a detailed architectural project becomes a perfect test bench for this.

Through the thesis work, the author aims to build knowledge and know-how on the topic, which can then be shared with the research group (and the entire architectural and engineering community), helping to progress the development of the project. The expected outcome is an assessment of good practices for architectural works for offshore and floating projects. This can serve as a basic reference for future works and act as a launch platform for further developments, providing a contribution to the climate change battle.

Key Points:

- The main goal of the thesis is not to define a concrete and detailed design, but to put to the test SEAform's model and to build shared knowledge and know-how for future

01.5 Research Statement: Goals & Questions

The thesis Specific Goals are here reported, defining a methodology that starts from general ideas, which looks at the bigger picture, and offers the opportunity to establish more detailed and specific objectives. These are then supported by clear and concrete milestones and outcomes, which build a concrete research path.

Main Goals:

- Build a "Know-how" competence regarding floating architecture in the maritime context, defining good practices and potential challenges.

- Share coastal risk awareness, and concretely tackle the problem with research and experimentation.

- Put to the test SEAform's floating model and all the preconceptions on the topic.

Specific Goals:

- Understand Coastal Risk and the environmental challenges and the potential of Floating Architecture as a viable response to the challenges posed by climate change.

- Clarify the context of the project, meaning climate change pathway, project pre-defined rules, and spatial context.

- Develop a Concept Design for the Floating Pavilion and a Development Design for the Experience Platform.

- Produce an assessment of the environmental impacts.

- Create new perspectives for floating architecture with a "lesson learned" approach.

The main research questions indicate what principles move the thesis work and what themes and principles it strives to explore, through the author's work.
Similarly to what happened for the main goals, more detailed sub-questions explore with closer attention the areas of investigation that define the research areas of the thesis.

Main Questions:

- To what extent, floating architecture with sustainable solutions, is a viable path or alternative for institutions and architecture practitioners as a response to the coming adversities posed by coastal risk?

Specific Questions:

- How can we design a building with a food production-oriented function, that suits today's and tomorrow's maritime environment through sustainable and low-impact solutions?

- How can we develop a floating project that could be replicable and feasible in terms of construction, with a more thoughtful approach that overcomes the challenges posed by the water location?

- How can we positively interact with the water environment, taking advantage of the vast resources and possibilities it provides, without producing any critical damage?

- What measures can be taken to reduce the impacts on the environment and on the ecosystems of this building technique?

- How does our design perform compared to other floating examples and compared to traditional architecture?

01.6 FloatScapes

By accepting the design challenge proposed by SeaForm, the two authors and the tutors formed a new design group that was certainly linked to the preexisting research teams and their principles, but also distinct from them and extremely different, from many points of view. The step of identifying a name for the project, was fundamental, as it helped define the character of the group, becoming the manifest of its identity and objectives.

The name FloatScapes originated as a blend word [N 1.2], through the combination of the terms: "floating" and "landscapes".
First of all, it recalls the water location and the main feature that differentiates the thesis project from traditional architecture: the fact that, unlike most other buildings, the connection with water goes beyond the simple vicinity. Indeed, it floats above the surface and responds to the waves, the tides, and the continuous changes.
Secondly, it highlights the idea that this project would not constitute an isolated reality, satisfying its own niche, but would be dedicated to a much larger design process, with the goal of changing drastically the way we look at the water landscape, providing architecture with the means to surpass its traditional limits and interact positively with the water.
On this same line, FloatScapes, recalls the word "seascapes", sharing its aura and its wondering character. But at the same time takes a distance from it, introducing the strong architectural soul of the work and the design group itself.

In the following chapters, therefore, FloatScapes is used to indicate both the specific project (thesis case study) and the workgroup as a whole, comprising the authors and the tutors and the external members that provided support and knowledge.

[N 1.2]
Blend Word: is a form of neologism, indicatina a word formed, usually intentionally, by combining the sounds and meanings of two or more other words together.
A mixed word carries the general aura of both the mother words, but introducing a new and wider meaning.

01.7 Research Approach

The following pages contain two schematic representations, respectively describing the key steps that led to the birth of the thesis (Storyline) and the approach that defined its development (Methodology).

Figure A.1 (next pages) contains the storyline of the thesis genesis, starting from the challenges posed by climate change and the will of actively face them, through the work of the institutions and of the research groups of Politecnico di Torino, which culminated in the design proposal of the thesis.

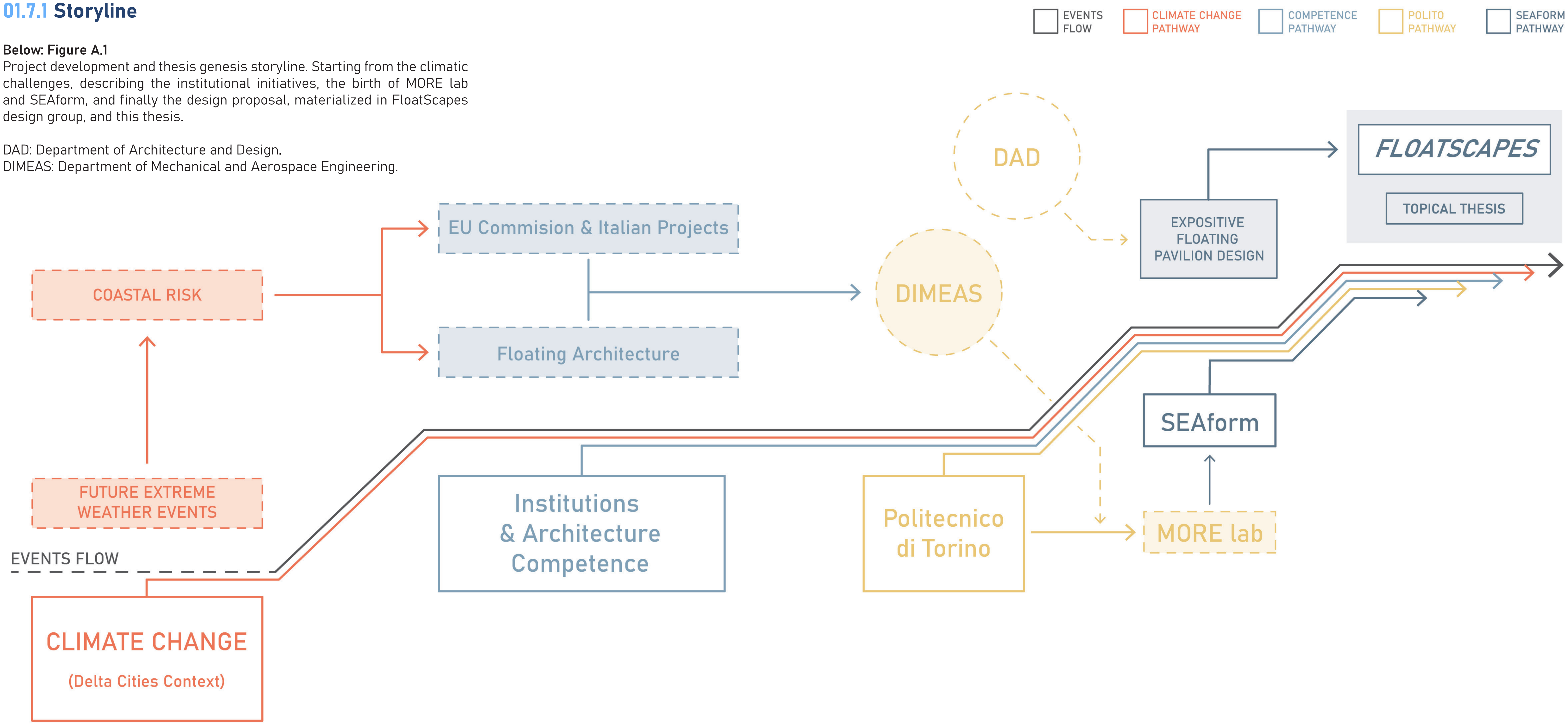
Figure A.2 (next pages) represents the key steps of the thesis, recapitulating in two pages the content of the entire work, through the description of the main topics and procedures, that led to the construction of a solid theoric base and the definition of the design.

The aim is to provide a quick starting outlook for a better comprehension of the thesis, providing the reader with a summary of the material that constitutes the core of the thesis.

01.7.1 Storyline

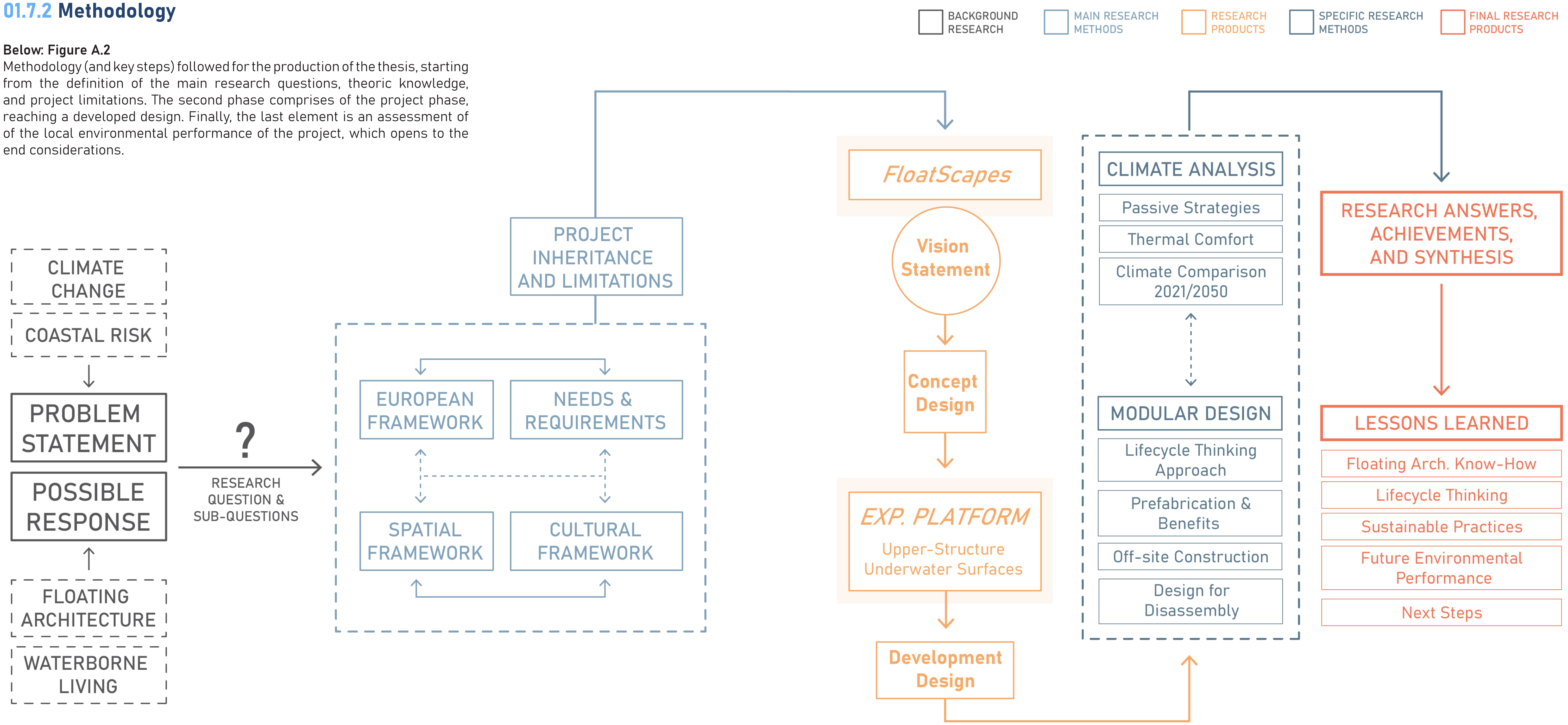
Below: Figure A.1
Project development and thesis genesis storyline. Starting from the climatic challenges, describing the institutional initiatives, the birth of MORE lab and SEAform, and finally the design proposal, materialized in FloatScapes design group, and this thesis.

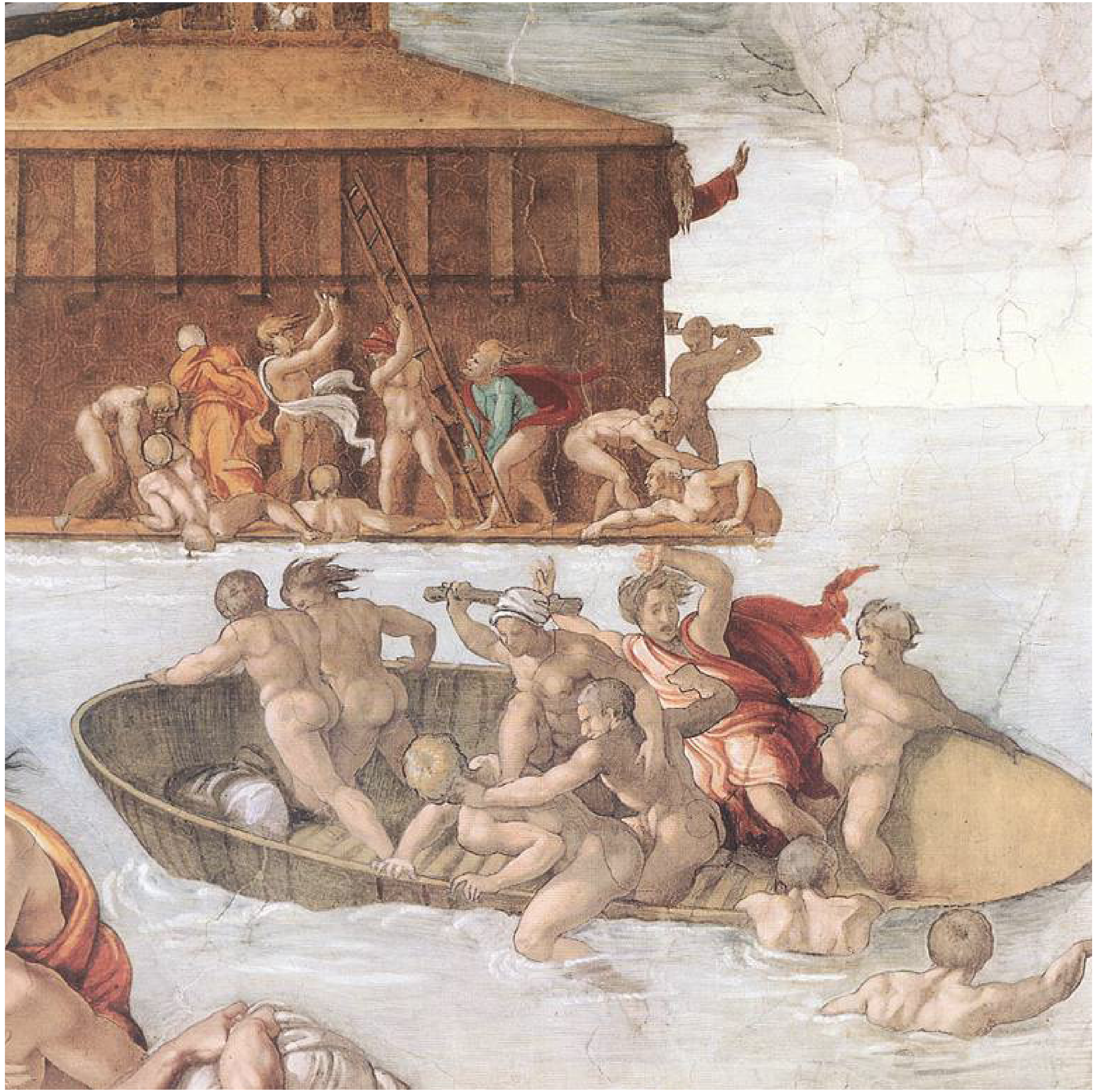
DAD: Department of Architecture and Design.
DIMEAS: Department of Mechanical and Aerospace Engineering.



01.7.2 Methodology

Below: Figure A.2
Methodology (and key steps) followed for the production of the thesis, starting from the definition of the main research questions, theoric knowledge, and project limitations. The second phase comprises of the project phase, reaching a developed design. Finally, the last element is an assessment of of the local environmental performance of the project, which opens to the end considerations.





02
COASTAL FUTURE

“Those who have the privilege to know have the duty to act.”

Albert Einstein

Climate change is set to be one of the main challenges that humanity will have to face in this century. The world is changing, and people and communities are forced to adapt and reinvent themselves and their lifestyles, to survive and thrive in a growingly harsher environment.

Coastal and especially delta regions have to face the most intense changes. Here climate change shows itself in the most direct and evident way, heavily impacting and endangering millions of people’s lives.

This chapter aims to briefly introduce the main adversities posed by climate change on coastal regions and describe what role architects and architecture could have in helping communities to find effective responses and adaptation measures, exploring floating architecture as a potentially viable path to follow.

Cover: The Flood
Michelangelo Buonarroti, Sistine Chapel, Rome, 1508

02.1 COASTAL RISK ANALYSIS

- *Temperature Change and Sea Level Rise*
- *Delta Cities and LECZ*
- *Food, Water, and Land Scarcity*
- *Climate Change: Mitigation and Adaptation*

[N 2.1]
IPCC: Intergovernmental Panel on Climate Change, is the United Nations body, whose task is assessing the science related to climate change, its impacts and future risks, and options for adaptation and mitigation.
Source: www.ipcc.ch

[N 2.2]
RCP: Representative Concentration Pathways, is a greenhouse gas concentration trajectory adopted by the IPCC for climate modeling and research for the IPCC fifth Assessment Report in 2014.
Source: www.ipcc.ch

[N 2.3]
SSP: Shared Socioeconomic Pathways, are scenarios of projected socioeconomic global changes, referring to the next decades, up to 2100. They were defined by IPCC to derive greenhouse gas emissions scenarios with different climate policy premises.
Source: www.ipcc.ch

02.1.1 Temperature Change & Sea Level Rise

In the last century, the mean sea level has been steadily rising, with a continuously accelerating rate, that is today higher than 3,1 mm/year (Cazenave et al., 2018). The leading causes are polar (and glacier) ice melting and increasing air and oceanic water temperatures (with connected increased water volume), both due to excessive greenhouse gas concentration in the atmosphere. There is strong evidence that this tendency will continue until 2100 and beyond, unless drastic mitigation measures, such as emissions reduction, are taken at the world scale and the current global mean temperature trend is reversed (Levermann et al. 2013).

Reliable predictions in this field are very hard to achieve, also considering the extreme variability from place to place. Some regions are experiencing larger changes and some others, such as the southern Pacific Ocean, even have a lower mean sea level compared to the previous decades.

The projections for these future environmental changes can significantly differ, depending on which premises are considered. To standardize climate modeling and research, in 2014 the IPCC (Intergovernmental Panel on Climate Change) [N 2.1] defined the Representative Concentration Pathways (RCP) [N 2.2], four different pathways of greenhouse gas emissions for the following years. The RCPs (labeled RCP2.6, RCP4.5, RCP6, and RCP8.5) represent four different scenarios, characterized by increasing higher emissions and corresponding higher radiative force increase for the year 2100 (2.6, 4.5, 6, and 8.5 W/m2, respectively). In 2021 greenhouse gasses emissions scenarios were then connected to different socioeconomic and climate policy scenarios that would generate them, defining the Shared Socioeconomic Pathways (SSP) [N 2.3], labeled from 1 to 5, with SSP1 corresponding to a green development road (linked with RCP2.6) and SSP5 (linked with RCP8.5) to a scenario where little to no mitigation measure is taken.

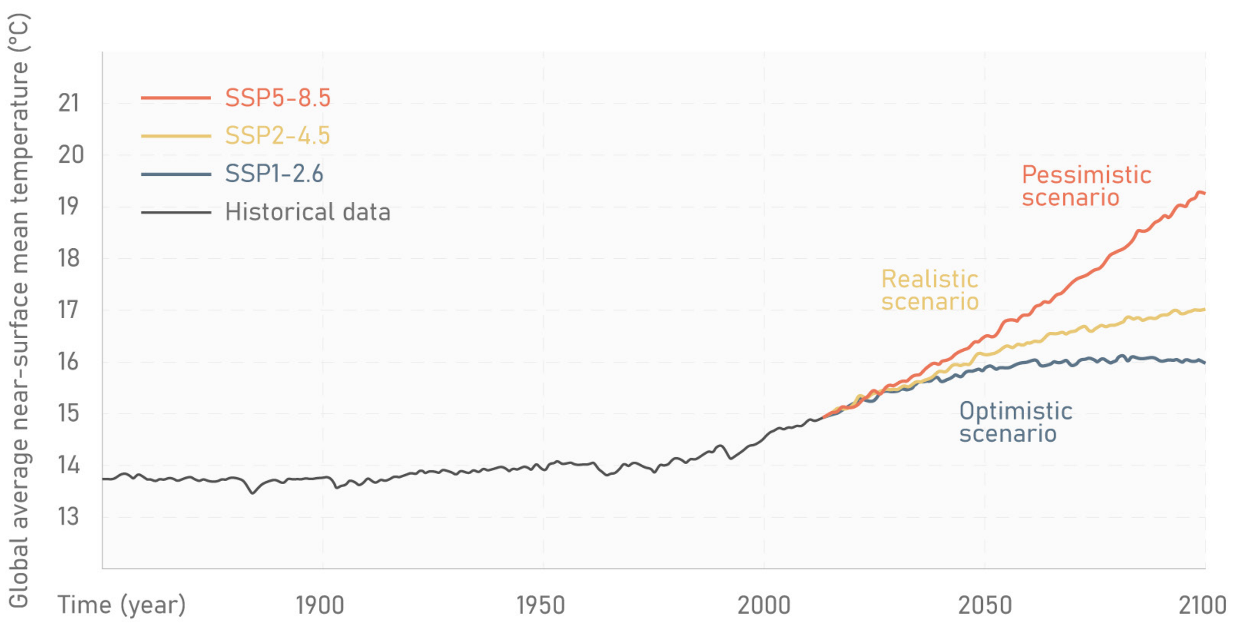
Figure B.1 represents surface temperature change projections for 2100, given a pessimistic (SSP5 8.5), a realistic (SSP2 4.5), and an optimistic scenario (SSP1 2.6), given a baseline of historical data of temperature changes. Similarly,
Figure B.2 reports mean sea level rise projections for corresponding emission scenarios (RCP 2.6, RCP 4.5, and RCP 8.5).

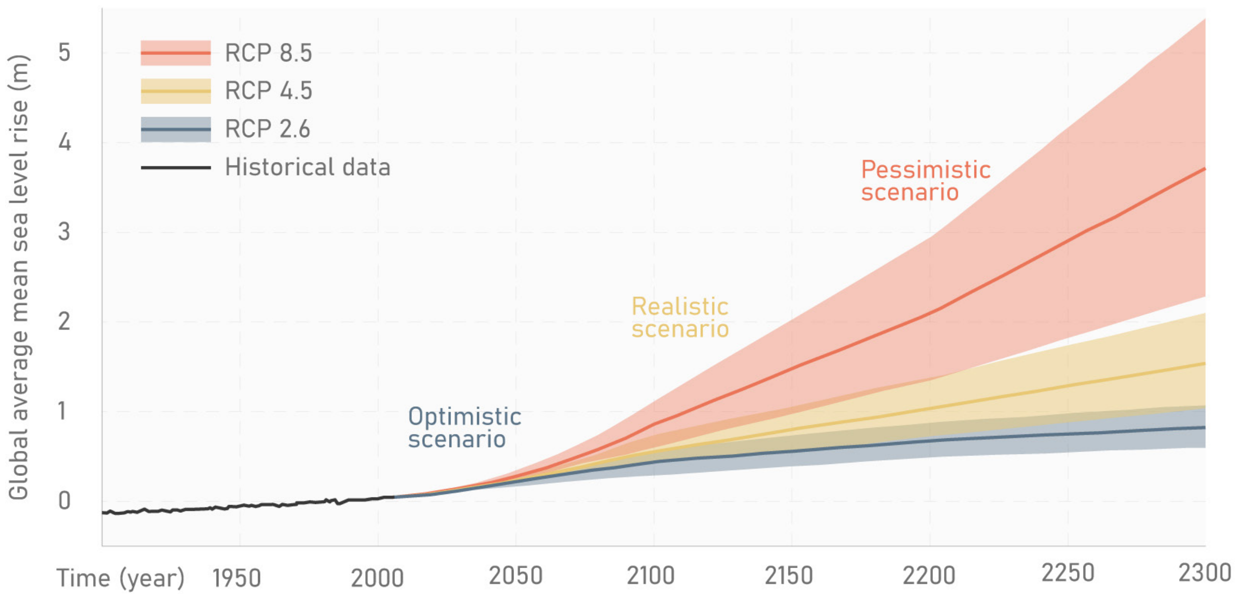
Considering a pessimistic approach (SSP5 8.5), a 4°C temperature increase can be expected for 2100, and a corresponding pragmatic estimate of global sea-level rise laying between 0.5 m and 2 m (Nicholls et al., 2011). More likely scenarios indicate more moderate changes, but the tendency is however concerning.
Sea level rise will submerge large portions of land and will have repercussions on tidal flows and flood patterns as well. It is observed that even small increases in sea level can lead to much higher probabilities of coastal flooding, with an exponential ratio (Kriebel et al., 2015), even causing an increment of the scale of this kind of phenomenon. Just the continuation of the current sea level rise trend would be sufficient to significantly increase flood frequency and depth. Adaptation measures are imperative and might not be sufficient on their own.

The local specific effects of these changes are hard to quantify, and unpredicted consequences are likely to occur. Storms, land erosion, floods, increased salinity levels of marshes and wetlands, and growing tidal patterns will become more and more frequent challenges around the world and something that governments and administrations will have to acknowledge and adapt to.

Top right: Figure B.1
Global mean temperature projections for three socioeconomic and correlated emission scenarios: SSP5, SSP2 and SSP1.
Source: Copernicus Climate Change Service, ECMWF
(Graphic by the authour)

Bottom right: Figure B.2
Global mean sea level rise for three greenhouse gasses concentration scenarios: RCP 8.5, RCP 4.5 and RCP 2.6.
Source: Earth Observatory, NASA
(Graphic by the authour)





02.1.2 Delta Cities & LECZ

Since the birth of sedentary communities, river deltas have been one of the privileged locations for human populations and settlements. Here, the ground is fertile, very open, and flat, making it extremely suitable for agriculture and urbanization. Water is abundant and easily available, and the rivers and seas offer easy transportation methods for both people and goods.
Still today, most of the world's megacities are situated on the coast, and many of them are built in delta regions or along the course of a large river. Tokyo, Shanghai, Cairo, Mumbai, Dhaka, Osaka, and New York are just the first on the list, giving home to tens of millions of people each. These regions tend to host important industrial and production facilities, as well as some of the largest commercial nodes worldwide, given the abundance of resources and the easy transport for goods import and export.

Low-elevation coastal zones (LECZ) are defined as coastal land areas characterized by an elevation of less than 20 meters above (or below) sea level (often largely composed of delta areas). These, despite accounting for less than 2% of the world's land area, were home to 625 million people, 9,8% of the world population in the year 2000, making them some of the most densely populated and urbanized regions in the world. In the next decades, a large portion of the global population growth is expected to happen here, due to both a worldwide increase and the ever-going inurbation of rural inhabitants. By 2060, the LECZ population is likely to approach 1.4 billion people, more than doubling their inhabitants in half a century (Neumann et al., 2015).
These regions will, therefore, experience strong urban pressure, with a growing demand for housing and services, as well as for food, water, and energy.

[N 2.4]
Subsidence: is a slow and progressive downward vertical movement (with little to no horizontal shifting) of the Earth's surface, which can be caused by both natural processes and human activities.

Top Right: Figure B.3
World megacities (more than 8 millions inhabitants) located in LECZ for the year 2050 (some of these cities currently have less than 8 mil. inhabitants).
Source: Neumann et al., 2015
(Graphic by the authour)

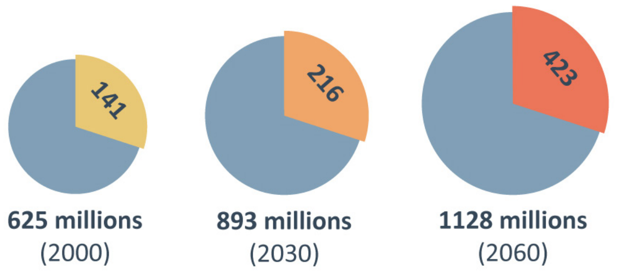
Figure B.3 contains a representation of world megacities situated in LECZ that are projected to have (or already have) more than 8 million inhabitants by the year 2050.

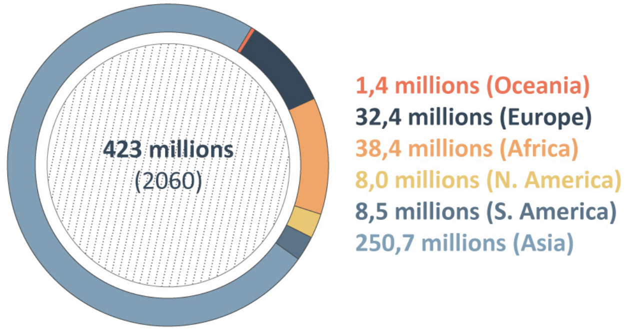
LECZ and deltas are, at the same time, some of the most fragile and vulnerable areas worldwide. Most of the land here sits a few meters, if not centimeters, over sea level, meaning that LECZ present very high risks linked to sea level rise, with intense and quick land loss due to erosion. Furthermore, the deltas' recent ground layers deposition generates intense natural ground subsidence [N 2.4], hugely amplified by human activities, such as inurbation and extraction of groundwater and oil. This, obviously, tends to exacerbate the problem of low relative altitude of these regions (Brown et al., 2015).

The 100-year flood plain is any area that has a 1% chance of experiencing an intense base flood (river, lake, or coastal flood) in any given year. It is often referred to as floodplain and generically represents the regions with a significant risk of inundation.
Figures B.4 and B.5 present a visualization of the LECZ population growth for the years 2030 and 2060, highlighting the 100-year floodplain inhabitants, and describing the distribution by continent.
Most Delta cities will be highly vulnerable to climate change and the number of people strongly affected by it will grow year after year. By 2060 more than 400 million people could live in the 100-year floodplain and be at risk of intense coastal floodings, more than doubling today's number (Neumann et al., 2015). Similar trends will likely also be true for buildings and economic assets in general.
Furthermore, sea level rise would affect some regions more than others. Africa, Southeastern Asia, and Pacific Ocean atolls are the most endangered. Here, the main problematic factors are the high LECZ population density, the number of endangered inhabitants (more than 70% of the world's LECZ population lives in Asia), and the lack of adaptation potential. Already troubled countries, where hunger, poverty, and social injustice cripple the communities, are exponentially more vulnerable to climate change.

Bottom left: Figure B.4
World population projections (millions) for LECZ and relative 100 year flood plain, for the years 2000 (baseline) 2030 and 2060.
Source: Neumann et al., 2015
(Graphic by the authour)

Bottom right: Figure B.5
Distribution by continent/ macroarea of 100 year flood plain population for the year 2060.
Source: Neumann et al., 2015
(Graphic by the authour)





02.1.3 Food, Water, and Land Scarcity

The world population is currently close to 8 billion and is expected to widely surpass 9 billion by 2050, with most of the growth concentrated in developing countries, in Africa and Asia in particular.
Developing countries at the same time are experiencing a fast and drastic improvement in the mean living conditions. In more developed countries inhabitants consume more food and water, travel more, require more energy, and in general conduct a more environmentally impactful and wasteful lifestyle. Less developed countries aligning their living conditions to occidental standards directly correlates to a significant increase in per capita resource demand and consumption. All of this will happen in a world that is already extremely overexploited.
With the current state of technological knowledge, sustaining this additional population and this additional intense resource demand is set to be one of the main challenges for governments across the world.

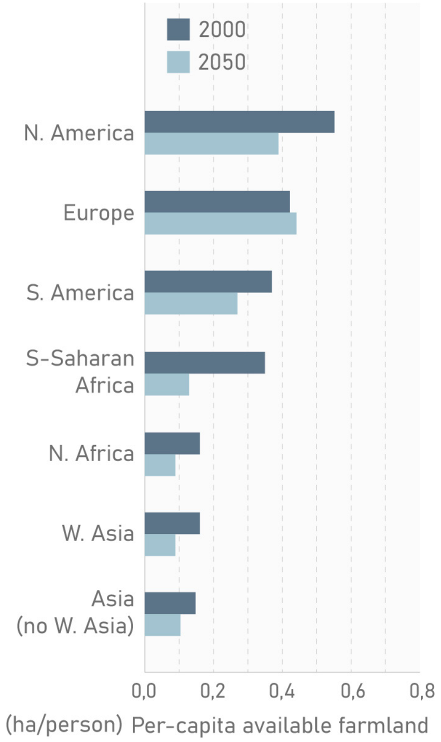
To feed the expected 9 billion people, agricultural production must increase by about 70 percent globally and by 100 percent in developing countries (to align with developed world agricultural performances), requiring a 1,5% annual increase.
This growth seems difficult to achieve, especially in resource-poor regions, where water scarcity, unsuitable land, and economic limits already hugely undermine production. Furthermore, this increased production must happen on already cultivated land (or with different production methods) to not consume important forest and grassland ecosystems and to not impact the carbon sink potential of the land (FAO, Fisher et al., 2011). Significant climate changes also must be accounted for, since important parts of the suitable areas could be quickly rendered less productive by desertification and new

unreliable precipitation regimes.
Available farmland is already a scarce resource for many countries, that rely on food importation to sustain their population. Given the likely future challenges, the problem can only aggravate.
Figure B.6 reports per capita available farmland per continent, for both the current state and for the year 2050. Again, here is shown the complex situation for Asia and Africa, where large parts of the local population will likely struggle to find sustenance.

Larger agricultural demands, higher consumption related to grown population, and better living conditions, are expected to increase water demand at a similar (if not faster) rate. In many areas, surface water is already not sufficient to sustain local communities. Rivers are often diverged or dammed for intensive agricultural use or for energy production, most of the time at the expense of rural communities. Low water quality, due to wastewater dumping, is another big limiting factor, that renders many water sources not suitable for human use. Entire regions are already forced to rely on extremely seasonal precipitations and especially on groundwater extraction, to sustain their basic needs, often withdrawing at a higher rate than natural replenishment **(De Graaf, 2012)**.

In highly urbanized areas, such as many delta cities, these problems could be even more intense. Here the growing cities tend to expand in the surrounding areas, often comprised of fertile lands, directly competing with food production.
High concentration of industrial plants, high transport traffic, intense withdrawal, and waste dumping can create prohibitive conditions, completely depriving residents of clean water access and crippling the food production chains.

While there might be enough resources at a global scale to sustain



Top Left: Figure B.6
Per capita current available farmland and projections for the year 2050, if no new land is converted. Oceania is not included as the extremely low population compared to its land availability provides a value too large to be efficiently compared with other continents.
Source: FAO, Fisher et al., 2011.
(Graphic by the authour)

the future population, locally, food, water, energy, and land are likely to become insufficient, presenting the hardest challenges to the most fragile countries and segments of populations **(FAO, Fisher et al., 2011)**. Quick and major technological innovations and carefully planned adaptation strategies will be required to effectively meet these new demands. This is imperative, to prevent increased social injustice, dramatic migration crisis, international tensions, open conflicts, and a diffused worsening of living conditions.

02.1.4 Climate Change Impacts: Mitigation and Adaptation

Producing reliable models and predictions of climate change implications is an arduous, almost unsolvable, task. Empirical results can differ significantly from the expected ones since the related variables are numerous and hard to consider. Some of the key aspects of the topic, such as global climate policies, technological development, and concrete emissions reduction measures, are also impossible to foresee.

What is certain, is that, in the next decades, countries and communities will have to face growing environmental challenges, many of which are already showing their presence: increased mean temperatures, sea level rise, more intense and frequent weather extreme events, food and water scarcity, to cite some **(IPCC Working Group II, 2022).**

Moreover, already poorer, and underdeveloped communities are the most fragile and exposed to these changes and their ability to effectively withstand additional stress is limited. This would grow the gap between rich and poor and generate conflicts or exacerbate the existing ones **(Laukkonen et al., 2009)**. Tens (if not hundreds) of millions of people will be pushed out of their houses and forced to

move and found home elsewhere, in an unseen migration crisis, as governments struggle to find responses.
Acknowledging and assessing this problem is a first step of primary relevance for governments and administrations, especially in coastal areas, since here the climate change impacts are, and will be, faster, more dramatic, and clearly visible.

In the Paris Agreement of December 2015, signed and ratified by 183 countries, with the main goal of facing climate change, it was accorded that governments and citizens should concentrate their funds and active efforts on two main objectives:

- **Mitigate** climate change, tackling the main problems and causes, to hopefully reduce its negative outcomes. In particular, mitigation measures aim to reduce greenhouse gasses emissions and resource consumption, and to promote a renewable energy transition, effectively limiting the expected mean temperature increase (the concrete goal set in the Paris Agreement is an increase of less than 2° C) and all the correlated negative consequences.

- **Adapt** to the inevitable consequences and challenges posed by the mutated conditions. Adaptation measures consist of effective adjustments to actual or expected climate changes that reduce the vulnerability of natural and human systems. This is a concept with open borders, which can include a wide variety of actions, ranging from protective infrastructure from natural catastrophes (for example flood protections) to innovative production chains that better suit the new local environmental conditions (Boucher et al., 2013).

Considering the dramatic climate scenarios defined by the IPCC, some form of immediate intense effective mitigation is imperative, to successfully respond to climate change, but it will likely not be

sufficient: it would require strong centralized policies and an intense global effort, large investments, and fast technological development to achieve even small positive results. The world will change, and it needs to prepare for the inevitable consequences and to be ready to adapt when those will occur.
Therefore, both approaches are key and better perform if approached together, in order to build and ensure resilience in the communities, as mitigation aims for risk reduction while adaptation focuses on preparing communities and successfully managing the impacts.

Preparing for these adversities, defining intervention plans and strategies, and taking immediate action becomes mandatory for governments worldwide, particularly in those cases with the previously explained characteristics of a possible larger impact (south-eastern Asia and Africa). Realizing preventive infrastructures, building knowledge, and dedicating technological research to these challenges could be the difference between the survival and perish of coastal communities.

02.2 FLOATING ARCHITECTURE

- *Resilient Housing and Infrastructure*
- *Sustainable Energy Transition*
- *Food and Water Access*
- *Urban Strategies*

In this complex scenario, architects and designers could have a significant role, by directly considering and tackling climate change obstacles in their projects. Whether designing a city or a house, projects should take into account the changing environmental conditions, producing buildings that are more resilient and performing, and suitable for the desired sustainable green transition.

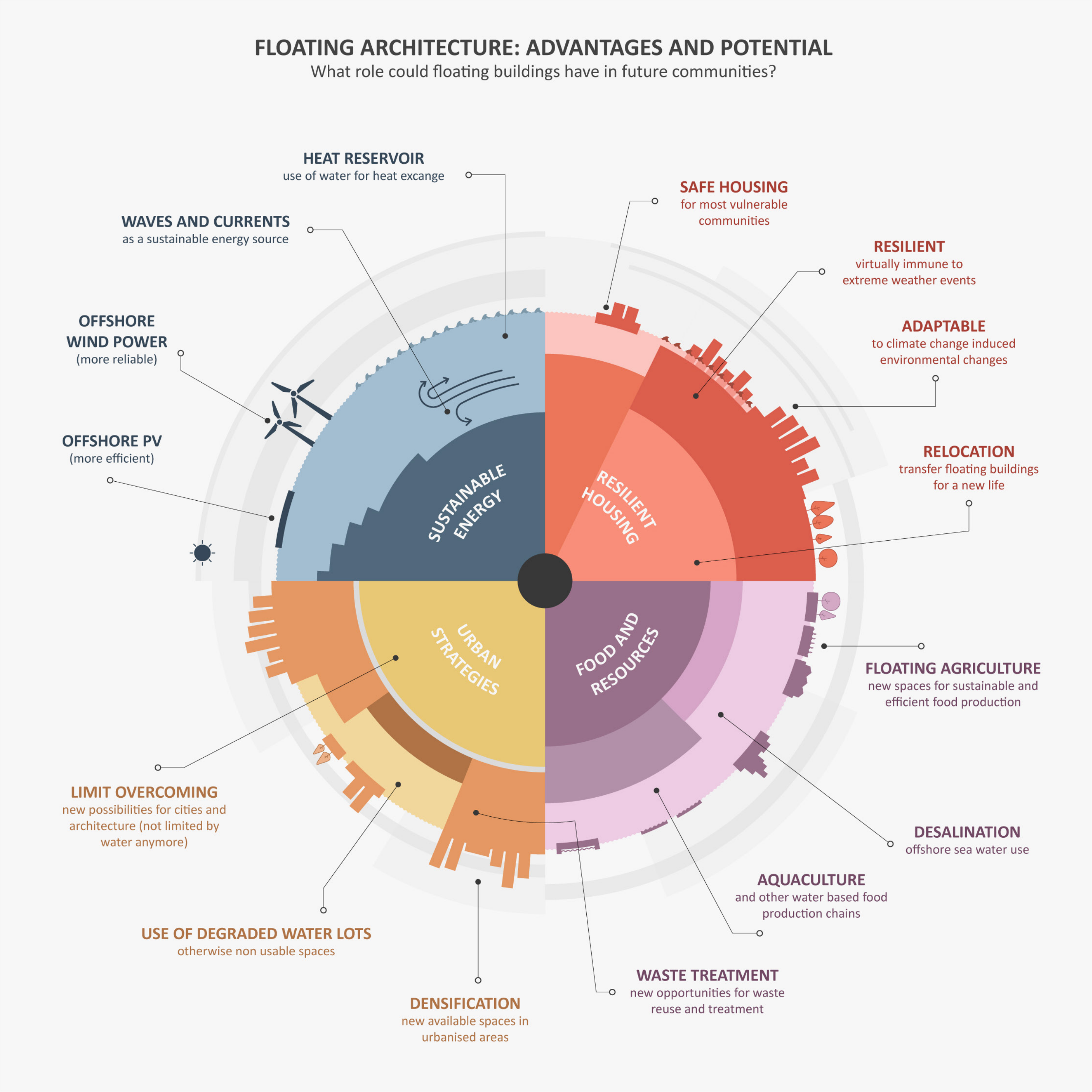
One promising experimentation path in this direction is floating architecture, a practice in use for centuries, which is now at the core of offshore building experimentation. This is seen as a great opportunity to create cities and communities that positively and actively interact with water and are not simply at the mercy of sea level rise. It could provide interesting possibilities for a greener way of living.

This paragraph reports a summary of the main possibilities and advantages potentially provided by the use of floating architecture in both the open sea and already urbanized areas.
The text is divided into four main topics, which are then declined into more specific points: resilient housing and infrastructure, sustainable energy transition, food and water access, and urban strategies.

Figure B.7 (next page) visually represents the information contained in the paragraph, providing a complete overlook of the topic.

Figures B.8, B.9, B.10, and B.11 (following pages) report, instead, the key aspects of the specific sections, with a direct reference to Figure B.7.

The goal of this paragraph is to provide a quick glance at what role could floating architecture concretely play for future communities and cities if properly developed and perfectioned.



Left: Figure B.7
Advantages of floating architecture compared to standard building techniques and standard urban choices.
Source: Created by the author.

02.2.1 Resilient Housing and Infrastructure

Floating architecture could become a fundamental tool for many coastal communities: here the effects of climate change are expected to be shown with the greatest and clearest intensity (Neumann et al., 2015; Szabo et al., 2016).

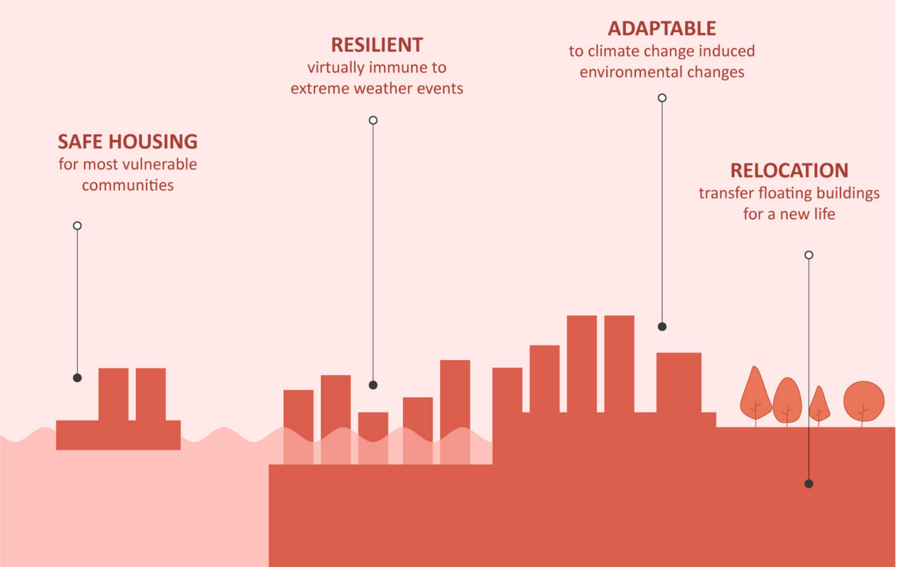
By their nature, floating buildings sit above the surface, regardless of level changes (as opposed to fixed offshore structures and standard land reclamation methods), giving them a much more **adaptable and resilient behaviour** than traditional architecture. This can render them virtually immune to any relative sea level change and to most extreme water-related weather phenomena such as strong storms and river or coastal floods. Once the tides inundate the city, floating buildings can simply sit above the water and endure the challenge.

Building neighbourhoods with this type of technology could help to adapt to climate change, providing **safe housing** for the hundreds of millions of inhabitants of the 100-year flood plain.

If an area would be rendered inhospitable by intense environmental changes and people were forced to leave, floating structures could even be transported elsewhere and **relocated to a new area**. This would also allow families to move to another city or neighbourhood for everyday life reasons, without being forced to sell their homes.

This could make floating buildings a more adaptable solution for areas prone to intense climate and environmental changes and could render it a more reliable and safer economic and social investment as well. In the future, floating platforms could become the best location for structures of strategic importance for communities, as well as for assets with great economic value, greatly reducing the risk of

being damaged by extreme events.
Housing power plants, hospitals and schools on water could become the best choice, ensuring their operation and functionality even in times of emergency and difficulty.



Left: Figure B.8
Advantages of floating architecture: Resilient Housing and Infrastructure
Source: Created by the author.

02.2.2 Sustainable Energy Transition

Floating architecture opens the door to vast new opportunities, regarding the production of energy from renewable sources. Seas and oceans hold an immense untapped energy potential, that, if properly addressed, could play a key role in achieving the green energy transition, necessary to reach the climate change mitigation goals.

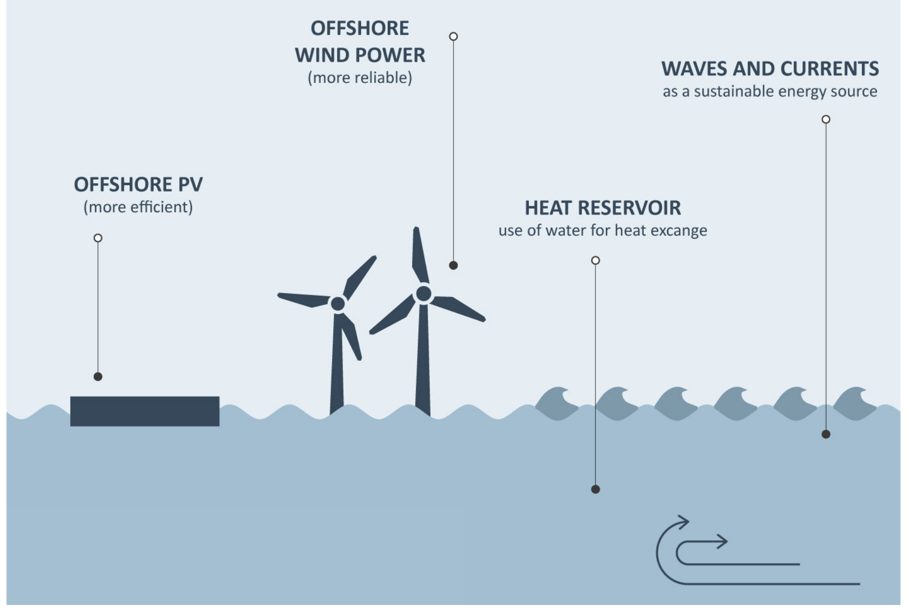
Offshore and floating architecture are now being explored as a way to access this energy pool, with **offshore wind farms and floating photovoltaic plants** being the leading approaches.

In the open sea, the absence of obstacles in every direction ensures easier and prolonged access to solar radiation, which can be exploited during all daylight hours. These systems can be easily optimized, reaching efficiencies 10-15% higher than similar photovoltaic systems on land, thanks to the cooling effect of the water they directly sit in. One of the main limiting factors of standard PV is indeed the lower performance at high temperatures **(Choi, 2014; Vo et al., 2021)**.

At the same time, the almost completely flat landscape of water bodies, together with the sea breeze phenomena, ensures a much more continuous and reliable wind regime than the inland regions, with associated greater production **(Perveen et al., 2014)**. In this case too, higher efficiency is found in off-coast wind farms, which can effectively run for longer periods. This can help bypass production unreliability, the major drawback of wind energy, that forces communities to integrate it with non-renewable carbon-based energy sources (making it more suitable for example for inhabited islands and other off-grid communities).

However, sun and wind are not the only renewable energy sources that can be used at sea. Innovative systems exploit the energy of **waves or currents** to produce electricity, opening completely new renewable energy sources, not accessible on land.
Sea water can be used as a **heat (or cold) reservoir** for heating or refrigeration systems, given its higher winter temperature and lower summer temperature compared to the external air, making it suitable for pre-heating and pre-cooling of vector fluids **(Moon, 2014; Habibi, 2015)**. Innovative heat exchange systems could be implemented in most floating projects, potentially greatly reducing the energy demand of buildings.
The literature proposes **Ocean Thermal Energy Conversion (OTEC)** as another promising opportunity for green energy production. Sea

water is characterized by a temperature gradient between different depths, with the upper layers receiving enormous amounts of solar radiation that increase the temperature, compared to the deeper waters, where the temperature is permanently lower (2-4° C below 1000 meters). This gradient could be used for energy production through a thermodynamic cycle. This technology, however, still needs intense research and large investments to be viable but it is useful to exemplify the variety of possibilities linked to offshore energy production.



Left: Figure B.9
Advantages of floating architecture:
Sustainable Energy Transition
Source: Created by the author.

02.2.3 Food and Water Access

As said, global food production will need to substantially grow in the next decades (70% required increase), to sustain an intense additional demand. Instead of cutting down forests and destroying grasslands and wetlands, to convert them into farmland (as it has been diffusely done all over the world in the last millennia and is today usually linked to the Amazon Forest's fast reduction in South America), the required additional space could be sought elsewhere. A significant component of the future increase in food production could happen on water. **Floating architecture** could provide space and the opportunity to diversify food sources and production chains, without competing with areas with a strong natural character **(Lin et al., 2018)**.

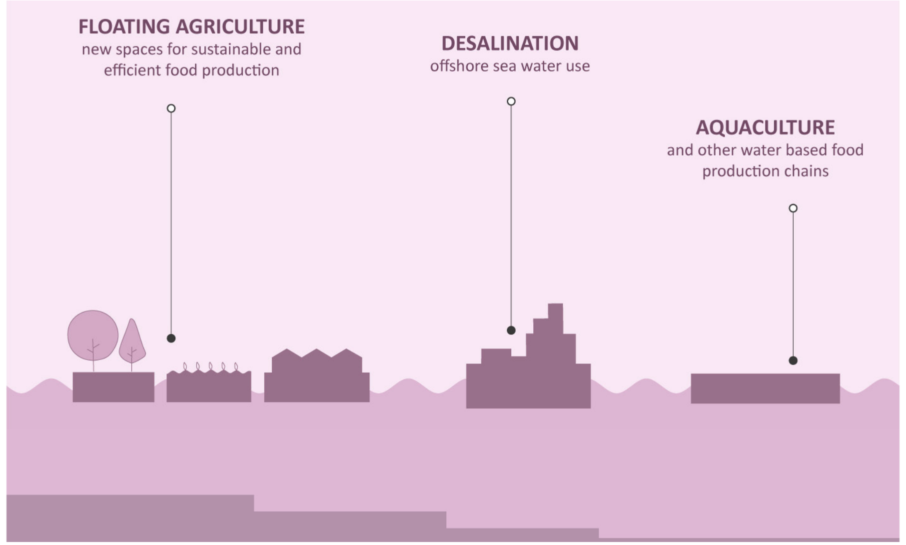
Greenhouses and all the connected innovative agriculture techniques (vertical farming, hydroponic and aquaponic, to cite some) perfectly suit the marine environment. Here there is easy access to basically unlimited sun radiation (both for direct natural lighting of crops and for PV energy production), water (as seawater can be easily desalinized with dedicated systems) and space (De Graaf, 2012). Furthermore, floating solutions are far more adaptable than land farming, being immune to droughts, because of the easy access to water, and resistant to heat and cold waves, thanks to the conditioned indoor growing environment. Periods of low seasonal production or unexpected poor harvests of traditional production could be partially compensated by the more reliable floating supply.

Water is already exploited for **fish and mussel farming**, that, despite being the subject of controversies regarding its actual sustainability and environmental impacts **(Goldburg & Naylor, 2015)**, if accurately assessed, can be effectively integrated into aquaponic agriculture production chains. The organic waste produced by aquaculture can be used to produce fertilizers used in the greenhouses for crop production, while the agricultural by-products can be repurposed as fish feed. This creates cooperation between the two systems, with reduced nutrient demands for both.

The opportunity to **desalinize sea water** is particularly significant in arid or remote areas, with little water availability and infrastructure,

but also for intensely urbanized regions, where access to clean drinkable water could be problematic, given the intense pollution or withdrawal.
Desalination plants could be initially produced to sustain agricultural needs and then cover human consumption as well. Floating desalination plants could represent a viable opportunity for countries with unreliable water access (Northern Africa, the Middle East, and Southern Asia). Those would be more resistant to natural catastrophes and could operate in times of emergency, greatly increasing the communities' resiliency (Amin et al., 2020).
Small floating plants could also travel the oceans, operating during the trips, covering, for example, the demand of a multitude of small islands, with a single shared infrastructure.

Floating agriculture and water production are obviously not to be intended as an alternative to traditional land-based ones, as they cannot compete with them in terms of total production, but as a useful tool to integrate and diversify global production (being particularly



Left: Figure B.10
Advantages of floating architecture: Food and Water Access
Source: Created by the author.

fitting for local specific needs). If a significant part of the food and water supply comes from water, communities are less likely to experience shortages and are more resilient to climate changes and extreme events as well.

02.2.4 Urban Strategies

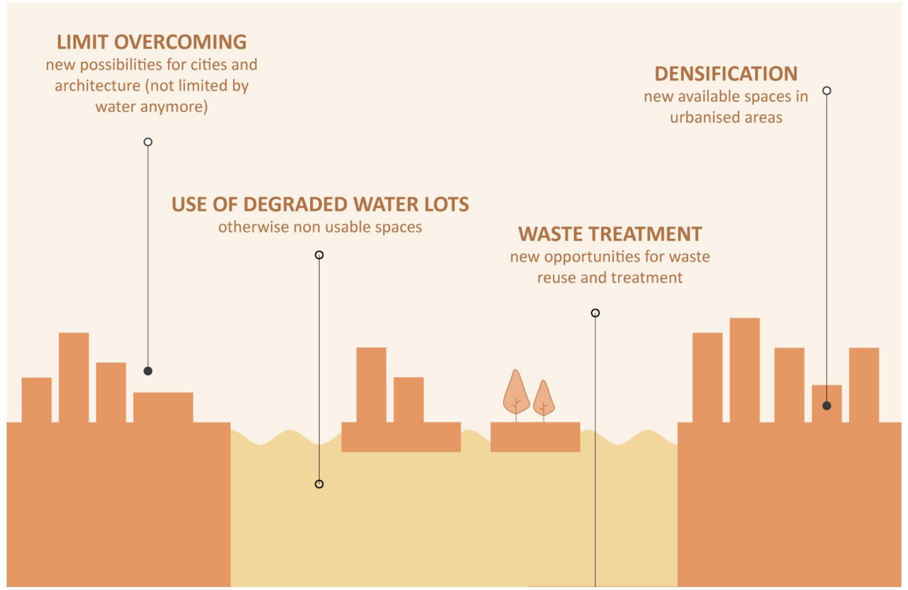
From an urban point of view, building on water opens vast new opportunities.
Coastal cities are traditionally limited by the coastline, which behaves as an almost unsurmountable border. The city ends where the water begins and often faces it with its main public spaces.

In the last decades, the practice of land reclamation tried to solve this limit, but at a great environmental price. Floating architecture is presented as a valid low-impact alternative. Cities could solve their lack of space problem, by **expanding on water** with floating neighbourhoods, without negating the existing ecosystems and with the opportunity to transfer the structures or to completely remove them at the end of their life. This could significantly ease the urbanization pressure on the peripheral areas of cities, which often house important farmland or naturalistic areas, but also allow for the expansion of central districts (De Graaf, 2012).

Floating architecture could also give the opportunity to **densify the existing cities**, by using the gaps left in the urban fabric by rivers, canals, and ponds. Water building lots could be defined inside the city borders, even in high-value neighbourhoods.
Particularly interesting is the application in **degraded water lots**. Intense industrial and commercial activities of the last centuries have deeply transformed delta regions and coastal cities, drawing canals, harbours, docks, and artificial ponds. Many of those are now empty

and unused, retaining very low water quality and biodiversity, due to the past intense waste dumping and pollution. Floating buildings could represent an optimal choice for these, otherwise almost unusable, spaces. Furthermore, here the environmental impacts would be less significant, being concentrated in already deeply altered and damaged ecosystems.

The current technological development already allows for the construction of a large variety of floating structures and, as said, the advantages of this type of design can be substantial. The challenge for architects and designers, therefore, becomes that of developing this path, experimenting with construction techniques, shapes, and materials, and defining basic models and rules of good design, to adapt to this new problematic environment. This is a unique opportunity, to build a future know-how that has sustainability and impact mitigation as fundamental principles, to set up a positive path for future floating projects.



Left: Figure B.11
Advantages of floating architecture: Urban Strategies
Source: Created by the author.

02.3 DESIGN RECOMMENDATIONS

Environmental Impact of Floating Buildings

Recommended Design Practices

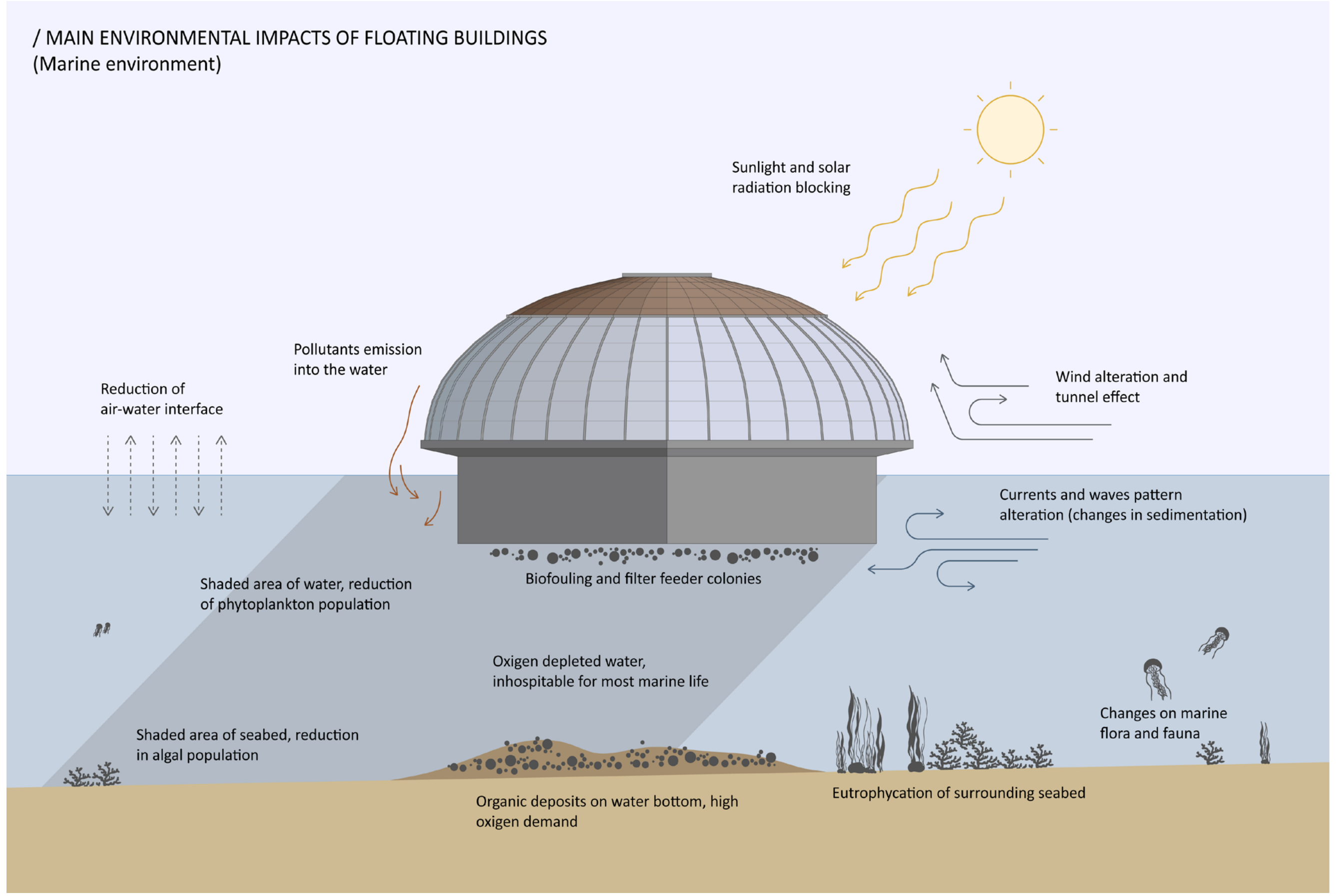
Contextually to the production of the thesis, the author redacted a research essay (Porporato, 2023), assessing the environmental impacts of floating buildings on the surrounding ecosystems. The essay underlines the most problematic consequences of building on water, as well as the possible positive roles that floating architecture could play for the existing cities and ecosystems.
This paragraph will first briefly display the key results of the research, giving, in the end, particular attention to the design indications and good practices, directly defined by the literature, or derived from the author's reworking, which could be followed to try to limit the impact of the building on the aquatic environment.

02.3.1 Expected Environmental Impacts of Floating Buildings

As a floating building is positioned in a water body, it inevitably and immediately changes the starting environmental conditions. What was before an empty water plot hosts now an object, which acts as a feature on an otherwise extremely regular landscape.

Figure B.12, produced by the author, represent the main environmental impacts of floating buildings on their surroundings, highlighting the main changes produced both on the aquatic environment and on the local flora and fauna.

With its volume, the floating structure intercepts and alters winds, currents, and wave patterns, with repercussions on sedimentation processes and on water mixing. Sitting on the water's surface limits the contact between air and water (important for substance exchange between the two) and blocks a significant portion of sunlight from reaching the water. If the lighting level goes below a minimal



Top Right: Figure B.12
Main Environmental Impacts of Floating Buildings, Graphic Summary for the Marine/Lagoon Environment
Source: Created by the author.

threshold, it can hamper the aquatic photosynthetic reactions, both in the upper layers of water (phytoplankton) and on the sea floor (benthic algae). The presence of the floating object can alter water temperature, by intercepting solar radiation or exchanging heat from the building's conditioned spaces.
Building materials can leach dangerous substances into the water, biocides, and protective finishes in particular. Any human activity implies some level of local pollutants emission and some degree of unintentional waste runoff.

Submerged surfaces host colonies of filter feeder organisms, which, together with the reduction of photosynthetic reactions can significantly reduce the diffused oxygen content of the water, by depositing large quantities of organic material on the water bottom (decomposition processes extract oxygen from the water). Floating objects create anchor points and hiding spots for both local and alien invasive species and can significantly alter the organisms' composition of the area **(de Lima et al., 2022)**.
Further and more detailed descriptions of these topics can be found in the author's research essay **(Porporato, 2023)**.

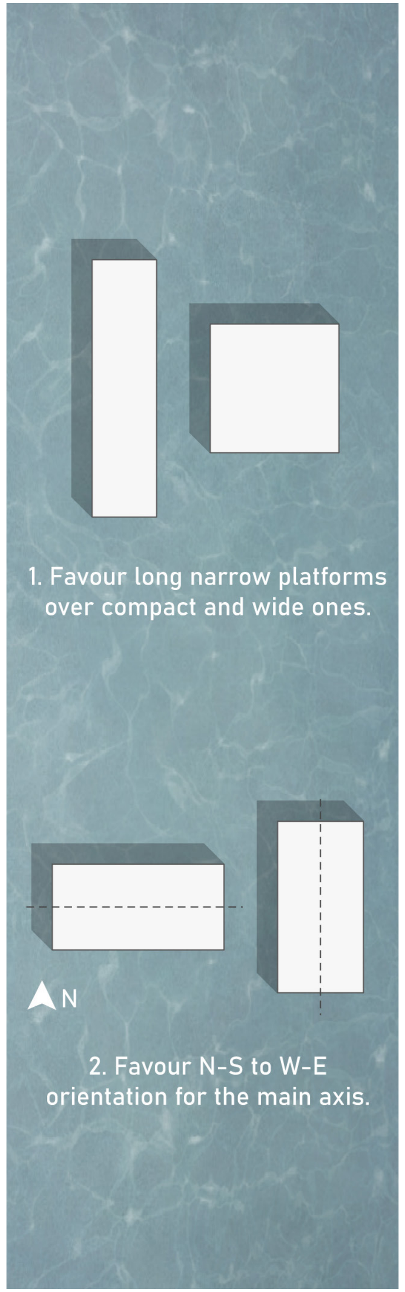
The environmental impacts of floating architecture hugely depend on a multitude of variables: water depth, building dimensions and shape, bathymetry, materials, design choices, water transparency and compositions, the intensity of tidal currents, and density of surface coverage (to cite some of them). The subject is too complex and not investigated enough to accurately predict what consequences a certain building would have on a certain water body, and on its ecosystems. Effects and phenomena encountered in specific projects might not be transferable to other situations, or to our case study.

Nevertheless, the literature provides some indications that can be considered almost universally valid, being referred to and based on tendencies and recurrent observations.

02.3.2 Recommended Design Practices

Here follows a list of good design practices for floating projects, either directly proposed by the literature, or elaborated and deduced by the author, during the redaction of the research essay. Every guideline is referenced and briefly explained and motivated, as well as accompanied, if necessary, by a small visualization scheme, to help better comprehend.

Right: figure B.13
Good design recommendations visualization, guidelines 1 and 2.
1. (Top): Favor long narrow platforms to compact and wide ones (top view).
2. (Bottom): Favor N-S orientation to W-E orientation for the main axis (top view).
Source: Created by the author.



1. Favour long narrow platforms over compact and wide ones.
Direct light rays can travel through water for a limited distance, even shorter in the case of diffuse light. Given a determined area of the floating object, narrow shapes (elongated rectangles) have a shorter distance from the centre of the bottom surface to the sides, meaning they tend to ensure better lighting in the water below. Compact shapes, such as circles, squares, and hexagons, on the contrary, tend to maximize this distance, reducing lighting more significantly and increasing the likelihood of generating dark spots **(Burdick et al., 1999, Härtwich, 2016)**. This is true for both the single platforms' shape and for the connection of multiple buildings, meaning that compact platforms (such as the case study ones) can anyway be efficient from this point of view if they are arranged in narrow layouts (given their dimensions are small enough for the light to reach the central areas of the bottom surface).

2. Favour N-S to W-E orientation for the main axis.
Platforms with the main axis oriented in the N-S direction produce a smaller continuously shaded area in the water below or on the water bottom, compared to identical platforms that are oriented W-E **(Burdick et al., 1999)**. In the Boreal Hemisphere, dark areas generate on the northern side of the platforms (the opposite happens in the Southern Hemisphere), because of the sun's path. Smaller northern sides ensure smaller dark areas below the platforms, therefore, given a rectangular shape, orienting the main axis along the N-S direction ensures better lighting of the water.

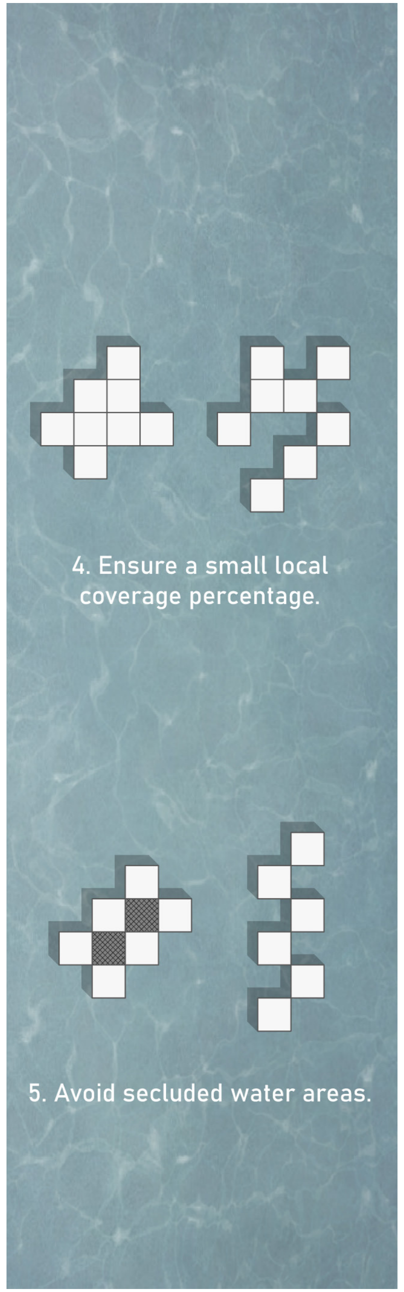
3. Privilege deeper and wider water bodies.
The deeper the water, the more diffuse the casted shadow is on the bottom of the water body during daylight hours **(Burdick et al., 1999)**. In very shallow ponds, floating objects can even produce perpetually shaded areas on the bottom, completely blocking sunlight. Deep

enough water bodies set this problem aside since the casted shadow sits in the same spot of the water bottom for a very short time.
Water currents seem to be influenced just in the very upper layers of water, while below 4-5 meters even extremely large floating structures have little to no influence on water movements (Kyozuka et al., 2001).

As a general rule, deeper and larger water bodies are also less susceptible to water composition alterations and to water quality worsening. The same quantity of pollutants can be extremely harmful to a small pond while being completely insignificant if diluted in the ocean. Furthermore, large water bodies tend to have much better water column mixing and better sediment dispersion, meaning the effects of oxygen deprivation, temperature alteration, and organic enrichment of the bottom would be significantly limited. Exchange and movement of water tend, indeed, to conform local water quality with that of the surrounding areas (de Lima et al., 2022).

4. Ensure a small local coverage percentage.

A high local coverage percentage of the water body amplifies any adverse effect of floating buildings. Densely connected platforms have universally a larger effect on the ecosystems, compared to the same platforms positioned over a larger area.
Effects of all the individual buildings add up with those of the surrounding ones, implying a higher chance of reaching critical values for the impact indicators. If three independent platforms have a low chance of excessively lower oxygen content, the same three platforms, tightly connected to each other pose a much more significant danger, because the water is already oxygen deprived by the surrounding structures. The same reasoning is valid for most of the water quality indicators, with low-coverage systems outperforming high-coverage ones.



Left: figure B.14
Good design recommendations visualization, guidelines 4 and 7.
4. (Top): Ensure a small local coverage percentage (side cross-section view).
5. (Bottom): Avoid secluded water areas (top view).
Source: Created by the author.

5. Avoid secluded water areas.

Secluded water areas tend to have scarce water column mixing since waves and currents are intercepted from every direction. Here nutrients and pollutants can easily accumulate, potentially causing eutrophication and excessive growth of phytoplankton or floating algae.
This could render the area completely unsuitable for other organisms (de Lima et al., 2022). It's important to ensure a connection between the water close to the buildings and the open water, for substances and temperature exchange.

6. Privilege materials without polluting components and finishes.

Rainwater (acidic rain in particular) and seawater can interact with the outer components, damaging and degrading them. Water runoff then washes into the sea any withdrawn substance. Biocides and finishes, if applied to the building materials to protect them, can easily end up in the water, retaining their antibiotic effects, with the potential for significant damage to aquatic organisms and ecosystems (Burkhardt et al., 2007 & 2011).

Concrete mixes, particularly those that contain furnace slag and ashes, can leach large amounts of heavy metals into the water they are floating in, during the component lifetime (Lu et al., 2015). Similar phenomena can happen for other building materials as well. Designers have to carefully select those that are as inert and non-reactive as possible.

7. Avoid rainwater runoff into the sea.

Some dose of leaching and substance emission is inevitable. The pollutants released by the building components can, however, be intercepted, by collecting rainwater to properly treat it afterwards, before unloading it in the water body.

8. Favour smaller bathymetry designs.

Floating buildings influence waves and current patterns in the water. Although this effect seems to be of small scale and limited to the upper layers of water (Kyozuka et al., 2001), the intensity of the changes is directly related to the bathymetry of the project.
Smaller bathymetries tend to have more neglectable impacts. Acceptable bathymetry values again mostly depend on water depth. A 2 metres high platform could produce drastic changes in shallow ponds, where the alterations of the currents could impact the deposition patterns of the water bottom and change its compositions, by washing away the lighter organic component of the soil. The same platform would instead have little to no effect on the currents of a 10 metres deep bay.

9. Choose orientations that have a limited influence on natural water currents, wave patterns and tides

Orienting the platforms according to the main direction of the currents can significantly reduce the impact on water velocity and mixing, limiting the alterations in sedimentation processes as well. This approach should be adopted only after evaluating the opportunity to orient the platform according to the water lighting guidelines (guideline n. 2).

10. Prevent the formation of filter feeder colonies or provide the possibility to remove them.

The formation of filter feeder colonies on the submerged surfaces (biofouling) is one of the main challenges for the surroundings of floating buildings.
Reducing the proliferation of these organisms on the platforms could have significant positive effects on the oxygen content of the water, by limiting the deposition of organic matter (dead mussels and organic deposits) on the seabed under the structures (de Lima et al., 2022).

Right: figure B.15
Good design recommendations visualization, guidelines 8 and 9.
8. (Bottom): Favour smaller bathymetry designs (top view).
Source: Created by the author.
9. (Top): Choose orientations that have a limited influence on natural water currents, wave patterns and tides (top view).
Source: Created by the author.

The use of particular materials (for example wood) as a finish for the submerged and semi-submerged surfaces of the platforms can help prevent the formation of these colonies. Another possible response could be to provide a system for fast and manageable removal of the organic formations, for example with the replacement of finish components, or the use of easy-to-clean surfaces.

11. Favour the growth of photosynthetic organisms.

The presence of floating objects can significantly limit the photosynthetic reaction in the water and on the sea floor, because of the light interception. This can lead to important reductions in oxygen production, up to the point of dissolved oxygen deprivation in the water. It is important to choose a design that intercepts a limited amount of solar radiation, but this is just possible to a certain degree. Providing support substrates and anchor points in non-shaded areas of the water and of the seafloor can be important to encourage the growth of algae and phytoplankton around the floating structure, partially making up for the lost oxygen content.

12. Favour the growth of local flora and fauna.

Most offshore structures tend to be linked with higher concentrations of flora and fauna, if compared to the surrounding areas. This is because they represent a nutrient-rich landmark in a somewhat flat and uniform landscape, where organisms can find sustenance and shelter. Presenting different conditions from the local open water (for example offering vertical or floating anchor structures in a flat water bottom) these structures tend to attract a different species composition, often promoting the growth of alien invasive species. To limit the influence on ecosystems it could be important to provide new habitats that favour the growth of local organisms and limit the diffusion of alien invasive species, which could significantly alter the local balance (Wilson, 2011).

03
STATE OF ART

"Streets Flooded. Please Advise."

Robert Benchley (humorist, actor and journalist)
Telegram to a friend, upon arriving in Venice

This chapter goes deeper into the complex background of the thesis as it explains the frameworks that sculped the range and constraints of this thesis's practical research product. It is divided into 5 different sections that are initially explained in general terms, and later with further detailed information about the aspects that directly affected or influenced this thesis.

Starting from the different entities and institutions linked by climate change, it is described how they were directly (or indirectly) involved, cause or effect, in the genesis of the thesis, and of their role with the Institutional and Academic Framework. Followed then by the Spatial Framework, where different perspectives are found regarding the spatial context in which the whole research takes place. A brief Climate Analysis describes the characteristics of the location. In addition, the Needs & Requirements of the research product itself are illustrated, as the experimental nature of the research product has a credible set of defined parameters and "rules" from their respective entities, that need to be respected and accomplished for the sake of realistic practice. Finally, with the References Framework, several case studies are explained with different features, solutions, and processes, that as lessons learned, are synthesized to add some experience from these specific similar projects and share how the AEC industry, is moving forward in the floating architecture pathway.

Cover: Canal Grande from San Marco Square
Luca Bravo, Venice, 2017

03.1 INSTITUTIONAL AND ACADEMIC FRAMEWORK

- *European Initiative & EU Sustainable Islands*
- *MORE Lab*
- *SEAform*
- *Commission for the Venice Floating Pavilion: FloatScapes*

03.1.1 European Initiatives & EU Sustainable Islands

CLEAN ENERGY FOR EU ISLANDS

Top: Figure C.1
Clean Energy for EU Islands's Logo
Source: https://clean-energy-islands.ec.europa.eu/

In the last decades, the energetic opportunities that have appeared in the maritime context opened a new path in the energy industry. Although many islands still depend on expensive fossil fuel imports for their energy supply, strategic planning is taking place. For this reason, the Clean Energy for EU Islands Secretariat was created as an initiative for the European Commission.

Their job is to be the central platform for the actual clean energy transition of more than 2200 inhabited European islands. Acting as an entity that showcases best islands practices, is their main objective; and between the information that they share, policies and regulations are the main elements that the secretariat focuses on, by analysing and producing diagnoses of the different countries involved in this topic. [N 3.1]

The European context is big enough in terms of legal and regulatory frameworks. As a matter of fact, the Study on regulatory barriers and recommendations for clean energy transition on EU Islands, created by the Clean Energy for EU Islands Secretariat, presents this framework for different member states in the realm of the island's territory. The diagnosis exposes the barriers to the renewable energy transition, followed by the respective recommendations to overcome them.

In the case of Italy, the main barriers regard: [N 3.2]

- Constraints in spatial, strategic, and systemic planning.
- Coordination and monitoring of the energy transition.
- Complex and lengthy authorization.

[N 3.1]
Source: Clean Energy for EU Islands.
https://clean-energy-islands.ec.europa.eu/

[N 3.2]
Source: Study on regulatory barriers and recommendation for celan energy transition on EU Islands.
https://clean-energy-islands.ec.europa.eu/

Nevertheless, the secretariat has come up with the following recommendations:

- Develop a regional energy plan and climate targets.
- Implement a monitoring schedule and calendar of all funding programs.
- Develop a National Taskforce for the island energy transition.
- Guidelines to the regional level framework law for spatial planning.
- Develop energy master plans in suitable areas for the islands.
- Involve regional and local stakeholders in the landscape planning process.

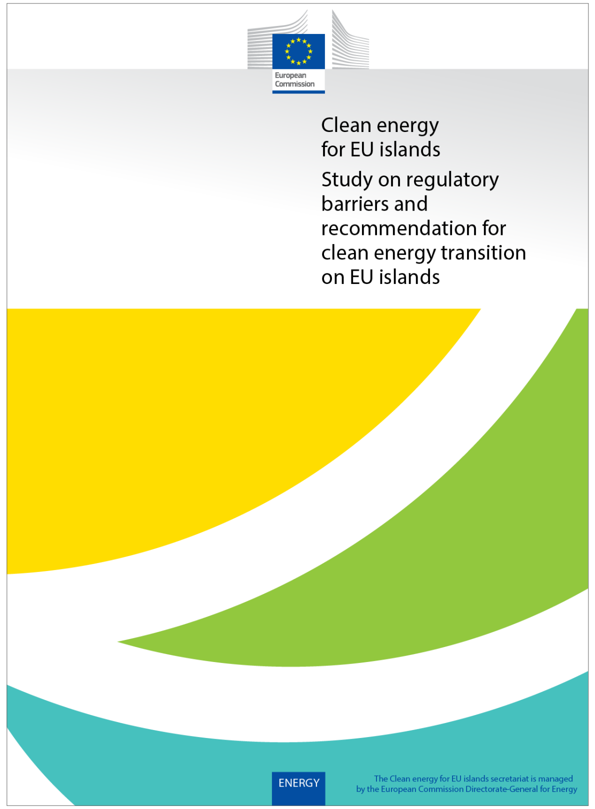
As Italy has 450 islands, where almost 11% of the Italian population lives, this recommendations overview is one the most important European projects regarding the energetic transition. The importance relies again on the relationship with the maritime context, as every effort that could be developed in terms of energetic transition, must be aware of the constraints and opportunities that the national laws and regulation scope allows to develop or not.

Due to the limited spatial planning existing in Italy for this transition, one of the main recommendations is to "put forward islands as innovative laboratories". In this sense, we can infer that experimentation is promoted, and governmental benefits as incentives could be included when launching this kind of development.

Nevertheless, the Italian clean energy national targets include reaching 30% of total energy production with renewable sources by 2030. In the electricity sector, this represents 55%, in the cooling and heating 33.9%, and in the transport sector 22% [N 3.3].

[N 3.3]
Source: Study on regulatory barriers and recommendation for celan energy transition on EU Islands.
https://clean-energy-islands.ec.europa.eu/

Given the above, it is important to understand that the European Commission launched a program of this nature, where countries of the EU are guided into the energy transition over the sea. This helps to understand where we are located in terms of this transition in the Italian context, as inside the scope of experimentation for the sustainability of the European islands, and therefore the maritime context. In addition, this premise explains the preface of the MORE lab, which of course belongs to an academic institution but at the same time has the experimental character to explore further renewable energy and other potential solutions or alternatives to the climate change quest in the Italian sea.



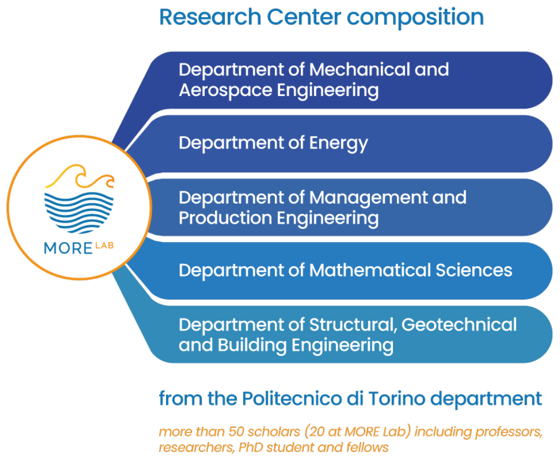
Bottom right: Figure C.2
Cover of the Study on regulatory barriers and recommendation for celan energy transition on EU Islands.
Source: https://clean-energy-islands.ec.europa.eu/

03.1.2 MORE Lab

The Marine Offshore Renewable Energy Laboratory (MORE Lab) is a research center, founded in 2006 by the Department of Mechanical and Aerospace Engineering at Politecnico di Torino. It was initially created to look for marine energy opportunities, and, nowadays, the group still follows its initial quest but with a strong multidisciplinary approach, involving experiences from the departments of Energy, Management, Structural, Geotechnical, and Building Engineering as well.

It is currently composed of more than 50 members, between permanent and temporary researchers, PhD students, and research fellows, with different backgrounds and expertise. Active and positive interactions are also carried out with external experts and other universities and research groups.

The main focus of MORE Lab is the analysis and development of offshore renewable energy production technologies for the marine environment. The activities range from design and numerical

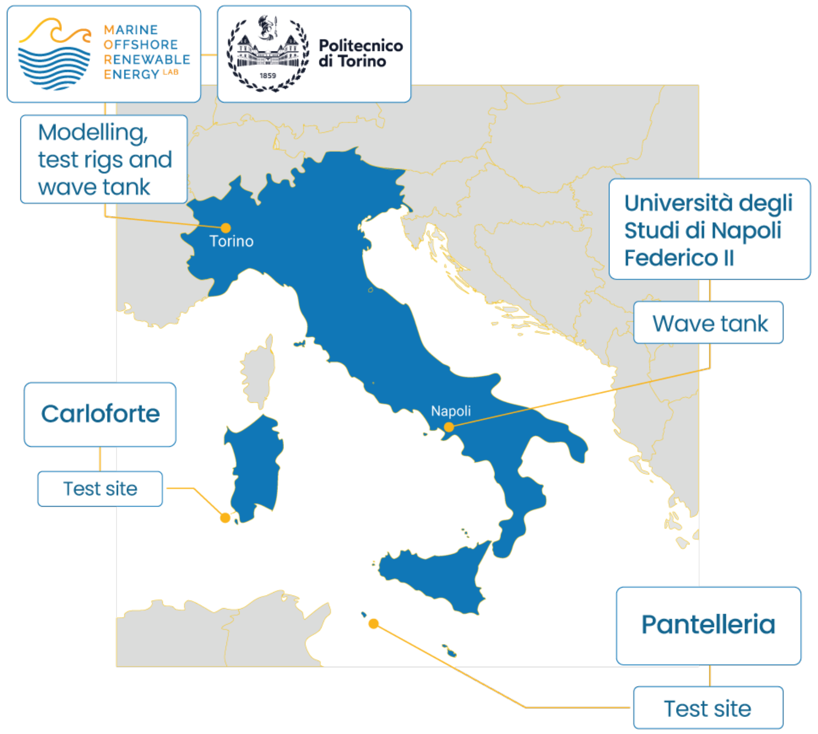


Top: Figure C.3
MORE Lab logo.
Source:
www.morenergylab.polito.it

Bottom Left: Figure C.4
Composition of the MORE Lab research group.
Source:
www.morenergylab.polito.it

modelling of energy powerplants, to Control Systems development, and prototype testing, both in tanks and in the open sea. Given the above, it is clear that the laboratory works on the energetic transition research and execution realm. This is important to understand, as it better clarifies the following steps, that conduce from the work of the research group, to the definition of this thesis proposal, and helps to understand the key goals of the author's work.

In their work trajectory, the laboratory has already produced and successfully tested three prototypes in the Mediterranean Sea and deposited six patents for offshore technologies. The main research field concerns the development of energy scenarios, offshore wind, and wave energy, as well as floating technologies, mooring, and



Bottom Right: Figure C.5
Locations of the main activities of research & testing, MORE Lab.
Source:
www.morenergylab.polito.it

connection systems among others.
Today the laboratory actively partners with the Clean Energy for EU Islands Secretariat, in the effort to de-carbonize European and Italian inhabited islands, proposing a diversified renewable energy mix. MORE Lab's research could help small and isolated communities to achieve energy autonomy, relying on easy-to-access marine sources, instead of imported carbon-based sources.

The philosophy of the research group is strongly aligned with the values and objectives of the European Green Deal, as it moves towards the goal of designing effective green technologies as a tool for a sustainable energy transition to present an effective response to climate change. Seas and oceans are seen as an immense source of energy and offshore technologies as the perfect mean to access it.

In their execution map, Energy Platforms came up as the opportunity to develop floating bodies that could be adapted for energy production. In this sense, experimentation went forward opening the argument to floating structures. In this scope of the research, the laboratory created a research group dedicated to the floating infrastructure, in terms of habitability and communities. As a preface, this could be understood as the starting point of the research group of SEAform.

03.1.3 SEAform

The SEAform research group created within the MORE Lab is a group that follows Sustainable Development Goals. In particular, the goal is to produce more inclusive, safe, resilient, and sustainable communities and cities, with low-impact solutions for life on water.
Its main objective is to tackle sea level rise and climate change consequences, by rethinking urban life and transferring a part of human activities on the sea, to improve the adaptability of cities and

Left: Figure C.6
SEAform's Logo
Source: www.seaform.it

communities, and to reduce their environmental footprint.
The group aims to explore different aspects of human life, such as food production, water and energy supply, or housing, to understand which activities could be successfully carried out on the water and how floating architecture could properly host them. The technologies developed by MORE Lab constitute the backbone of this project, rendering it effectively feasible and, in return, being put to the test in realistic and concrete case studies.
SEAform's program is defined by three major milestones:

- Design and realization of a **floating building** (floating pavilion), as a first, small-scale experience, useful as a starting testing opportunity for both the initial designs and the developed marine technologies (floating platforms, connection system, mooring and ballast system to cite some).

- Full-scale project and realization of a **floating complex**, as the natural following step. This would represent a first scale-up attempt. Ideally, it would consist of an urban extension intervention, taking advantage of the existing urban infrastructure.

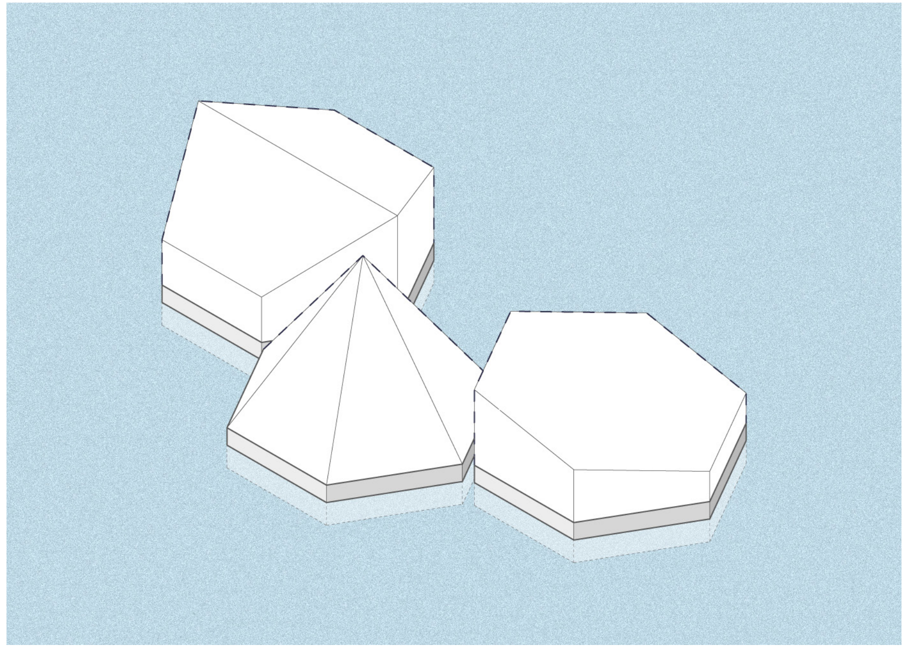
- Definition of a repeatable, expandable, and scalable base model for an autonomous and sustainable **floating city**. This end goal would transform the SEAform model into a standard approach for the design and realisation of floating neighbourhoods and cities.

Each of these steps is preparatory for the following ones and is an opportunity to test and evaluate the viability of technologies and design ideas, with progressively higher precision and definition. The path is however non univocal and around the key activities, SEAform has launched a multitude of propaedeutic studies, design challenges and research, to further enrich the project expertise with multidisciplinary and variegated contributions, gathering proposals, ideas, and different views.

03.1.4 Commission for the Venice Floating Pavilion: FloatScapes

Here the proposal for the present thesis is born, accepted, and developed by the authors, together with Prof. Roberto Giordano, in continuous collaboration and confrontation with the SEAform architects and engineers, as well as external experts and professionals.

The design commission is for the design of a Floating Pavilion, ideally linked to the Venice Biennial, corresponding to the small-scale first-step project of SEAform. As the engineering component of the project is being developed by the research group, the author is commissioned to define an architectural and functional design for the building and the activities that would be hosted on the floating platform.



Bottom Left: Figure C.7
Design challenge proposed by SeaForm for the design of the Upper-Structures of the floating pavilion.
Source: Created by the author.

03.2 SPATIAL FRAMEWORK

- *Venice as a Delta City*
- *Land Subsidence and Relative Sea Level Rise*
- *"Acqua Alta" and Flooding Projections*
- *Climate Context*

The choice of Venice as the location for this first project was already defined by SEAform and one of the project baselines.
The principle behind this choice was, first of all, the will to experiment in a region where such a project would be motivated, where the environmental and social challenges, that move the research, were already present and meaningful. Venice, with the critical problems posed by relative sea level rise and frequent coastal floods, perfectly suited these criteria. Other main driving factors were the strong symbolic character of the city, as well as the opportunity provided by the Venice Biennial, which represents a perfect stage to convey the message of the project and to share awareness, through the realization of a temporary pavilion.

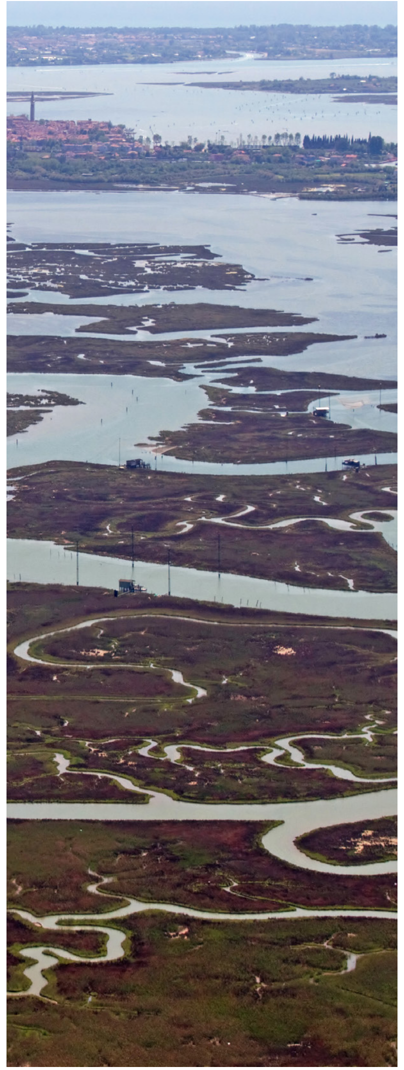
The aim of this paragraph is to briefly describe Venice and its lagoon, focusing on the reasons that make them a suitable location for floating architecture experimenting and for future floating architectures. First, a description of the chosen location and its characteristics is provided, followed by an assessment of the challenging environmental conditions of the city, outlining its complex scenario.

03.2.1 Venice as a Delta City

In most of the Italian territory, sea level rise and the correlated alterations would have a limited impact, mostly regarding the coastline. However, some regions, such as the Po Delta, the Arno Delta, or the South Sardinia marshes are much more vulnerable to these changes.

Out of these fragile areas, the most well-known is the Venetian Lagoon, on the Northern Adriatic coast of the Italian Peninsula. It is part of a larger marsh system that extends along most of the Padan Plain coastline, from the Grado lagoon in the north to the Comacchio Valley, in the Southern Po delta. With a surface of more than 550

Above: Figure C.8
Venice as seen from above, 2012. Saints Geremia and Lucia Church, Canal Grande and Canareggio Canal.
Photo by: Tony Hisgett



Above: Figure C.9
Venice Lagoon as seen from above, 2012. Canals, marshes, and Burano and Torcello islands.
Photo by: Tony Hisgett

square kilometres is the largest lagoon of the Mediterranean Sea, and one of the largest in Europe.
It is mainly composed (80%) of very shallow waters and mud flats, periodically inundated and dried up by the tidal flows of the area. While the average depth is close to 1 m, deeper canals, originating from river water flowing toward the sea, traverse the area and allow for navigation. The remaining part of the region includes land and small islands, where most of the urban centres are located.
The lagoon is separated from the sea by a narrow strip of land, that leaves only three entrances (Lido, Malamocco, and Chioggia), where seawater mixes with the freshwater of the rivers that feed the area (the rivers Brenta and Adige are the main sources of freshwater).

These marshes host unique ecosystems in their brackish waters. These are transition areas between the sea and the land, creating unusual conditions, that reverberate in unique fauna and flora. The area is home to particular fish and benthic organisms populations, as well as unique algae colonies and aquatic birds.

The area, permanently inhabited at least since the first millennium B.C., hosts today more than 100'000 residents (a number that grows considerably if the immediate surrounding areas are considered as well). Here are located some of the most renowned tourist destinations of Italy and of the world: Venice, Chioggia, Murano, and the Adriatic seaside. Tens of thousands of tourists are hosted here every day and millions throughout the year, making it one of the most visited areas of the world.

The Venetian lagoon is, therefore, an area of great naturalistic, cultural, and economic value, but is at the same time highly fragile and susceptible to environmental changes: the mean elevation of the land areas is particularly low and large portions of it could disappear even with small sea level rises. Land subsidence is particularly intense here and tidal patterns have an unusually large scale, meaning that erosion risk is among the highest in Europe. Moreover, the whole lagoon is substantially at sea level, and an excessive intrusion of salt water during floods could drastically change the ecosystems.

03.2.2 Land Subsidence & Relative Sea Level Rise

The Venetian lagoon and its surroundings are one of the most sensitive areas to the Relative Sea Level (RSL) [N 3.4] rise of the world. Substantial amounts of land here sit a few tens of centimetres above sea level, if not below it. Even an increase of RSL of a few centimetres represents a dangerous threat to urban areas, farmland, and natural marshes.
From 1872 to 2019 RSL the Venetian lagoon was characterized by a mean annual rise of 2.5 mm/year. This is driven by two main factors: sea level rise, linked to climate change, and land subsidence, both accounting for roughly half of the total (Zanchettin et al., 2021).

Land subsidence (LS) is the gentle settling or rapid sinking of the ground surface and of anything that sits on it, due to the consolidation of sediment layers, caused by increased stress in the ground (Bagheri-Gavkosh et al., 2021). LS is usually produced by a combination of natural and anthropogenic causes, both of which can have important impacts.

Given the presence of unconsolidated Holocene deposits, the lagoon, similarly to most delta regions of the world, is characterized by a significant mean LS, which varies from 1 to 4 mm/year (depending on the considered area). Locally, phenomena such as recent intense urbanization, land reclamation, and groundwater extraction can magnify subsidence, reaching rates of more than 20 mm/year, meaning that specific areas of the lagoon are much more affected than others (Tosi et al., 2018). These LS values are small compared to some of the extreme cases of megacities around to globe (Jakarta in Indonesia, Houston in Texas or New Orleans in Louisiana at a rate of 17 cm/yr, 5 cm/yr and 5 cm/yr respectively) but become dangerously significant if projected for the next decades and put in relation with the extremely low mean altitude of the region and the expected sea level rise.

[N 3.4]
Relative Sea Level: is the sea level value observed with reference to a land-based object or reference system.
Source: Zanchettin et al., 2021.

[N 3.5]
Relative Sea Level Rise: is the observed chance in sea level, measured with reference to a land based object or reference system. It can be caused by absolute sea level increase or by lowering of the coastline (or both).
Source: Zanchettin et al., 2021.

In recent years (1993-2019) was observed a growing rate of sea level rise (RSLR) [N 3.5], reaching an average of 2.76 mm/year, even without the land subsidence component. The projected climatically induced sea-level rise for the lagoon is in the range of 21 to 52 cm (from 48 to 100 cm) by 2100 for the optimistic RCP2.6 (pessimistic RCP8.5) scenario. The additional expected RSLR due to land subsidence is approximately 10 cm by 2100 (Zanchettin et al., 2021). This provides a minimum RSLR for the city of Venice of at least 30 to 60 cm in the next century, an increase that would directly affect large portions of the city, leaving, for example, Piazza San Marco slightly below sea level.

This is a difficult problem to address. While the anthropogenic component of subsidence can be limited with strict regulations on human activities (limiting urbanization and new constructions, prohibiting ground oil extraction and regulating groundwater use), there is no true response to the natural vertical land movement due to sediment consolidation. Sea level rise, being directly linked to climate change, is something that has to be addressed at a global scale and that cannot be solved by single communities, which are forced to look for adaptation measures and infrastructures.
Venice and the other lagoon cities will have to face an inevitable intense RSLR in the next century, which will cause land loss, salination of the marshes and greatly increased coastal flood risk.

03.2.3 "Acqua Alta" & Flooding Projections

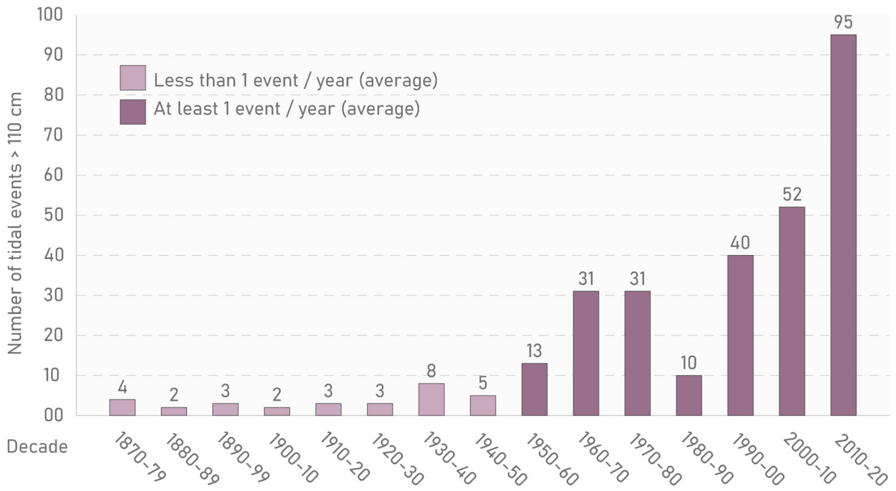
Figure C.10 contains a map of the Northern Atlantic Italian regions (Veneto and Friuli-Venezia Giulia) highlighting the areas at risk of coastal flooding, considering a mean RSLR of 1 meter for the area. The totality of the Adriatic coastal marshes system, together with the Po Delta and vast inland regions would have an extremely high risk of flooding.

The sea has always strongly characterized Venice and its appearance since its birth. Still today, the relationship with water represents a fundamental aspect of the city. Canals cross and characterize the urban fabric, most of the urban traffic and community services (emergency services, garbage collection, taxis, public transport) move on water. But, at the same time, water represents one of the greatest challenges for Venice.

"Acqua Alta" is a very pronounced peak tidal phenomenon in the Venice lagoon, which causes the flooding of a large part of the city. The phenomena of astronomical tides alone (due to the motions of the Moon and the Sun), very common in most of the water bodies of the globe, is not sufficient to generate Acqua Alta. Usually during spring or autumn seasons, the combination of intense winds, atmospheric pressure conditions and abundant rainfall magnifies the tidal phenomenon. A normal astronomical tide reaches about 50 cm in height in this area, while the most intense Acqua Alta ever recorded (November 2022) exceeded 2 m.
Climate Change is directly related to an increase in the intensity and frequency of these events. What was once an exceptional event has turned into a habit. RSLR, caused by land subsidence in the lagoon territories and sea level rise, produces a continuous increase in the hydrogeological risk of the region.

Right: Figure C.10
Area at risk of coastal floodings in the north-Adriatic italian regions, given a 1 meter relative sea level rise.
Source: floodmap.net
(Data visualized by the authors)

Figure C.11 contains the record of exceptional tidal events (above 110 cm) per decade, from 1870 to 2020, clearly showing the exponential growth in the frequency since, at least, 1950. The 2020-2030 decade is not included, since its data could be misleading, regarding only a two-year record.



Since the first half of the 20th century, the number of tides above 110 cm has increased from 4.2 per decade to 95, more than twenty times as frequent (Lionello 2021).

To protect the lagoon from exceptional flooding was constructed the MOSE, a system of mobile dams, capable of closing the three entrances to the lagoon, partially isolating it from the open sea and reducing the peak tide. The MOSE, tested for the first time in 2020, can be closed for any tide higher than 100 cm, but its activation has strong economic repercussions since it isolates the lagoon from the open sea. This is an adaptation measure to extreme events but is limited in its potential, since it can close only the three entrances to the lagoon but leaves the rest of the coastline unprotected.

Top Left: Figure C.11
Number of coastal floods / tides greater than + 110 cm for every decade from 1870 to 2020.
Source: City of Venice, Centro Previsioni e Segnalazioni Maree.

In the future, these phenomena seem destined to become more pronounced. Despite a likely reduction in intense rainfall in the area, the expected sea level rise will increase pressure on these coastal areas (Lionello 2021), challenging MOSE and the adaptive capacity of the lagoon.

This already is one of the areas with the highest exposure of coastal flooding in Europe and the problem can only exacerbate in the future. Strong centralized adaptation measures will be necessary, but at the same time, innovative ways to build on water and with the water are desirable.

Venice, and the whole lagoon, therefore become a perfect case study. Here climate change is having immediate and evident consequences and the city is in desperate need of concrete responses to the ever-growing adversities. Here any architecture project is faced with a highly problematic environment and is forced to change and adapt to it, with new paradigms and innovative design paths.

Bottom Right: Figure C.12
Venice: Acqua Alta flooding in San Marco Square.
Source: www.scienzaverde.it

03.3 CLIMATE CONTEXT

- *Climate Data*
- *Climate Design Guidelines*

Legend: DD=degree days

Zone A: dd<600
Zone B: 601<dd<900
Zone C: 901<dd<1400
Zone D: 1401<dd<2100
Zone E: 2101<dd<3000
Zone F: dd>3001

Top: Figure C.13
Climate Zones of Italy

Source: www.certifico.com.

Reporting the climate data for the project location of Venezia-VE, delivers the needed information that will influence in the following decision making process of the design that will be found in Chapter 04 Venice Floating Pavilion.

For this reason, this section aims to inform and provide a general outlook on the local environmental conditions that could bring concrete thoughts about the behavior of the environment and how to include it in the design. The section develops a presentation of the main climatic characteristics of the location, to later finish with some guidelines as a product of the following information.

The climate data here presented corresponds to the Energy Plus Weather file (.epw) from the Venice Tessera station in the whole year of 2021, the latest and most complete one.

- ITA_Venezia-Tessera.161050_IGDG_EPW

Furthermore in Chapter 07 Climate Design it will be found a further analysis and development regarding a specific portion of the project with the same climate data and a future projection.

In this section though, information like Dry Bulb Temperature, Relative Humidity, Psychrometric Chart, Wind Rose, Radiation Rose, Cooling Period, and Heating Period will be shown.

03.3.1 Climate Data

Dry Bulb Temperature

The Venice-VE location presents a temperate weather during the year with a maximum temperature of 33.6°C and a minimum of -5.8°C. It could be observed from the graph the hottest month as July, and the coldest of as February, where both peaks and bottoms regarding temperature are evident.

Afternoons in summer season might present a moderate higher low temperature of 30°C, that in addition with humidity could increase the "feel like" temperature. The same could be applied for winter season where the lower high temperature of 5°C might feel colder due to humidity.

Cooling Degree Time

CDD, is a measurement to quantify the demand of energy needed to cool a building starting from the base temperature of 18°C. In the case of Venice, the cooling months are June, July, August, and partially September. An average demand of 7°C will be needed in the month of July to maintain a comfort range.

Heating Degree Time

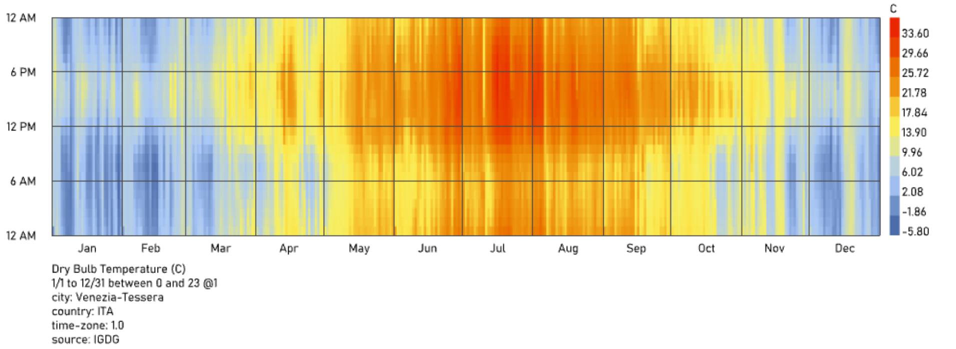
HDD, is similarly a measurement to quantify the demand of energy needed to heat a building starting from the base temperature of 18°C. In the case of Venice, the heating months are December, January, February, and partially November and March. An average demand of 13°C will be needed in the month of February to maintain a comfort range.

Right Top to Bottom: Figure C.14
Dry Bulb Temperature Graph.
Cooling Degree Time Graph.
Heating Degree Time Graph.

Source: Produced by the author with Ladybug Tools.

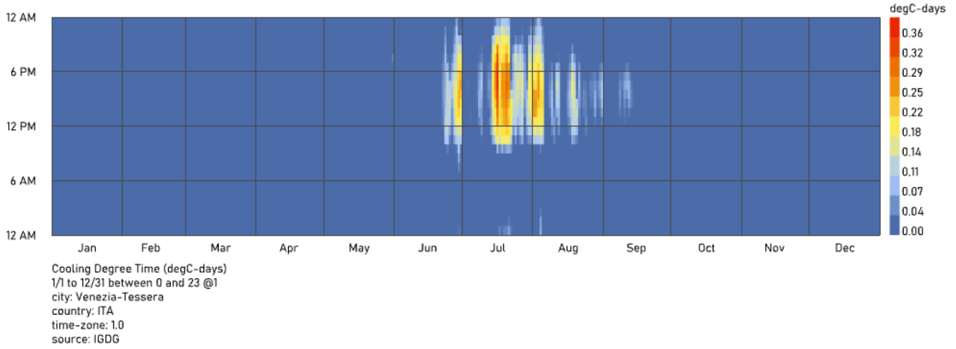
Dry Bulb Temperature:

Max Temperature
33.6°C
Min Temperature
-5.8°C



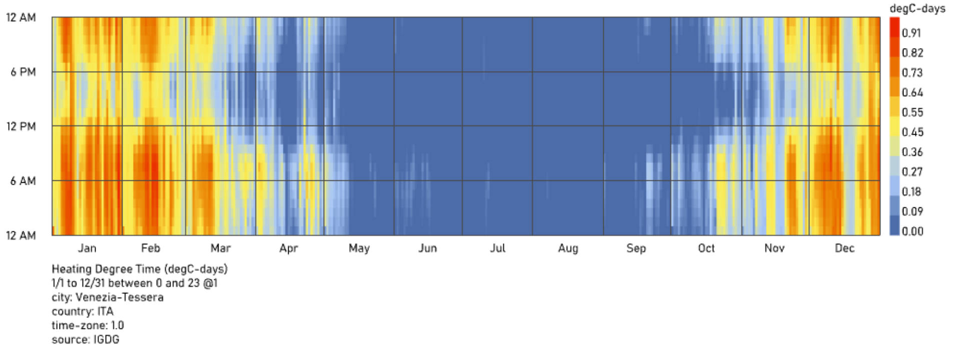
Cooling Degree Time:

Higher Cooling Demand
July
Average Cooling Demand
7°C



Heating Degree Time:

Higher Heating Demand
February
Average Heating Demand
13°C



Psychrometric Chart

The thermodynamic properties of the Venice data could be observed in the following Psychrometric Chart. It could be understand the properties of the air in the year of 2021 simultaneously with the Comfort Polygon which shows the percentage of the year in which there is comfort according to **ANSI/ASHRAE Standard 55-2017.**

With this graph is evident the bigger portion of lower temperatures of whole year accompanied mostly with humidity, in contrast with the lower portion of high temperatures, also accompanied by humidity. Therefore, it could be inferred that due to the location next to the sea produces these effects. The relationship with the previous presented Cooling and Heating Degrees could understood better in this way, how the demands for heating are greater than the cooling ones. Nevertheless, summer seasons presents a higher risk of overheating due to humidity.

Relative Humidity

It is imperative to understand the humidity variations over time in Venice-VE, as it is a key factor in which the perceived temperature gets affected thanks to the water body of the Venice Lagoon. According to the data, it could be observed that nights and mornings have the higher percentages of humidity during the year, while afternoons present lower humidity values thanks to the higher temperatures.

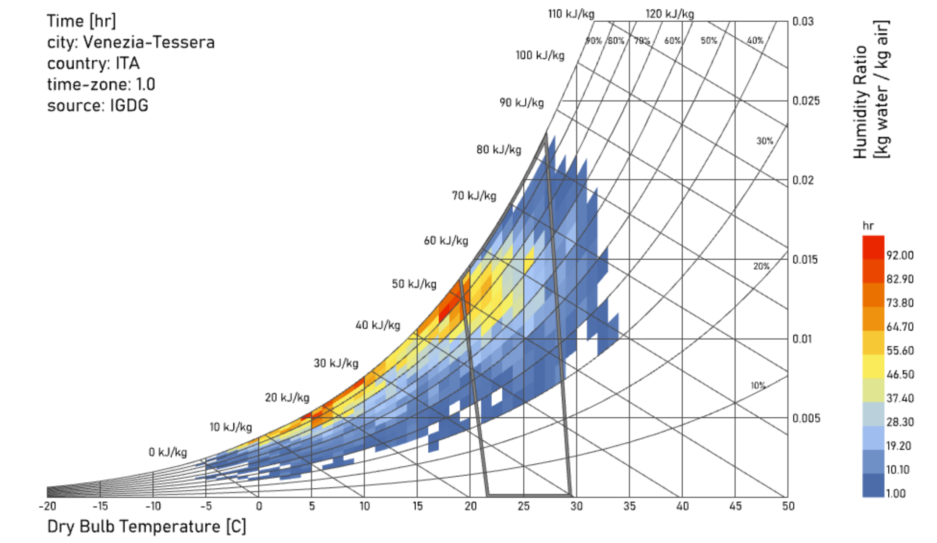
It could be also identified that during summer season, afternoons besides their high temperatures, present the most pleasant humidity values. On the other hand, winter season presents higher humidity that affects the lower temperatures, delivering lower perceived temperatures.

Right Top to Bottom: Figure C.15
Psychrometric Chart with Comfort Polygon.
Relative Humidity Graph.

Source: Created by the author with Ladybug Tools.

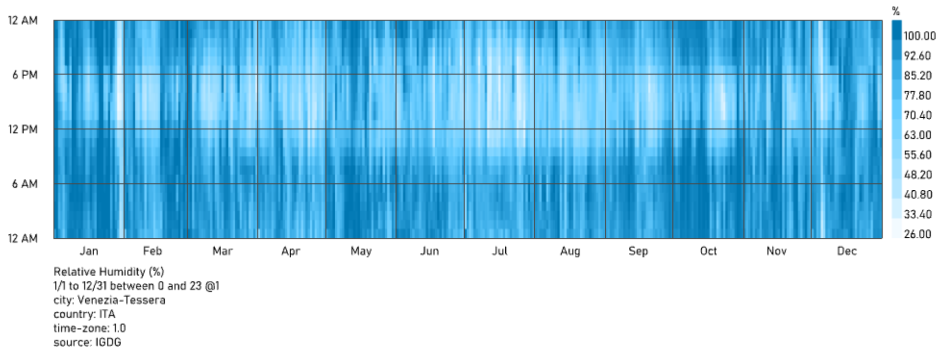
Psychrometric Chart
2021 Total Comfort:

24.6%



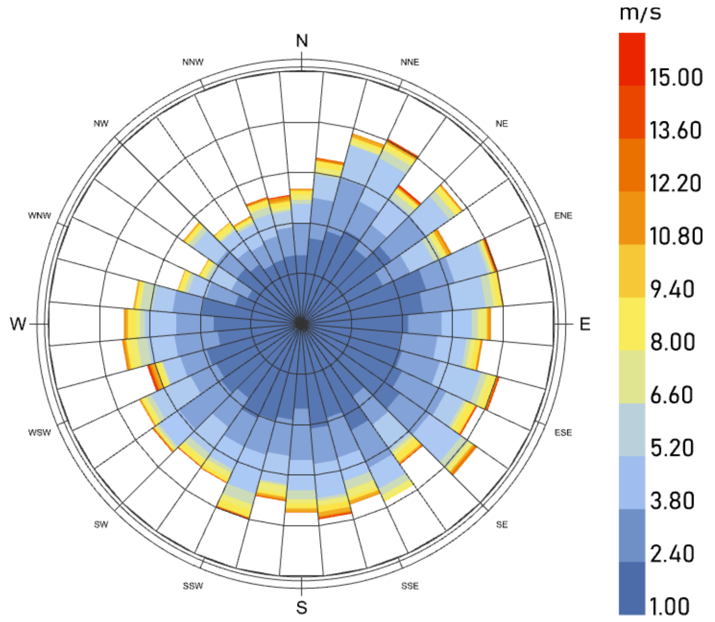
Relative Humidity:

Max Rel. Hum.
100%
Min Rel. Hum.
26%



Wind Rose

The wind direction and speed is another important factor in the Venice Lagoon context. Due to proximity to the Adriatic Sea air currents, speed might fluctuate more than in-land winds, also affecting perceived temperatures. It could be observed that prevalent winds during the year comes from South, South-East, East and North-East directions, reaching wind speed of 15.00 m/s. Venice as a port presents moderate high wind speed.



Wind Speed (m/s)
city: Venezia-Tessera
country: ITA
time-zone: 1.0
source: IGDG
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 29.57% of the time = 2590 hours.
Each closed polyline shows frequency of 0.8% = 50 hours.

Left: Figure C.16
Wind Rose Graph.

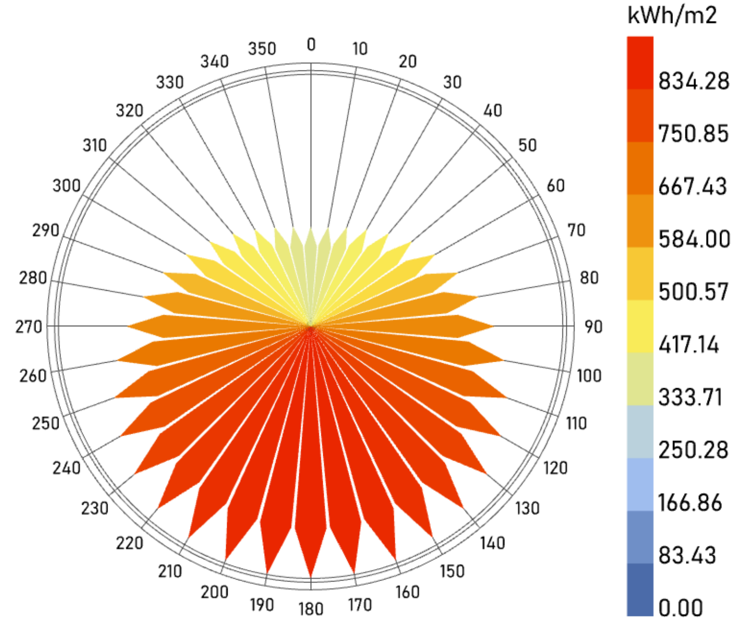
Source: Created by the author with Ladybug Tools.

Right: Figure C.17
Radiation Rose Graph.

Source: Created by the author with Ladybug Tools.

Radiation Rose

In terms of Solar Radiation, thanks to Venice latitude of 45° over the equator in the northern hemisphere, most of the radiation received come from South-East and South-West directions receiving a maximum of 830 kWh/m². This helps to understand where a possible project will need solar protection in the summer season, and at the same time from where it could take advantage of the radiation in winter season. Passive strategies like solar gains and solar shading depends on this valuable information, as well as a guide for photovoltaic ideal location systems.



Total Radiation
01 Jan 00:00 - 31 Dec 23:00
city : Venezia-Tessera
country : ITA
time-zone : 1.0
source : IGDG

03.3.2 Climate Design Guidelines

Depending on the climatic conditions, different design practices could prove to be more effective, from an economic and functional point of view. The use of the software Climate Consultant provided a list of good design strategies, that, if adopted in the project could significantly help to reduce energy consumption and improve its bioclimatic performance, potentially providing environmental comfort without the need for active bioclimatic control (heating and cooling).

This list reports the guidelines provided by the software in order of relevance, specifically for the Venice Location. It has to be noted that the list reports only the guidelines that suit the specific thesis case study, omitting the ones that would not be applicable.

- Face most of the glass area south, to maximize winter sun exposure for passive solar heating, effectively lowering heating energy demand.

- Design overhangs to fully shade the south façade in summer, to protect the structure from intense solar radiation.

- Provide double pane high-performance glazing (Low-E) glass on W, E, and N but clear glass on S.

- Lower indoor comfort temperature at night, to limit intense bioclimatic control to active hours of the structure.

- Keep building shapes tight and well-insulated.

- Sunny wind-protected outdoor spaces can be comfortable in cool weather, expanding available space.

- Extra insulation might prove cost-effective, particularly on the surfaces with the least preferable orientations.

- Tiles or slates as finishes could provide mass help to store daytime heat and nighttime cool.

- Climate-responsive buildings might prove cost-effective.

- Pitched roofs with well-insulated ceilings work well in the wintertime, as a response to the likely snow precipitations.

- Locate storage areas or service rooms on the sides that face the coldest and strongest winds, to act as a protective screen.

- Well-insulated skylights could help reduce energy consumption, providing natural light in the internal rooms.

- Insulating automated blinds can reduce nighttime dispersions.

Most of these guidelines will be indirectly recalled in the following chapters and will provide some first good practices and initial cues for the design.

As the guidelines are merely theoric, not necessarily applicable to the specific case study, and, oftentimes, have to come to terms with different principles and requirements of the project in the Chapter 07 a further development with an analysis could be found.

03.4 FLOATING PAVILION: DATA, NEEDS AND REQUIREMENTS

- *Location Brief: Arsenale, Venice*
- *Functional Framework*
- *Technical Framework*

The design commission for the Pavillion for the Venice Biennial originated from the already active research work of SEAform, which had already established several aspects concerning the project. First evaluations concerning the shape, dimensions, and materials of the floating platform, as well as many structural and technical aspects of the realization, had already been carried out.
While defining the design proposal, SEAform provided, first of all, an early functional concept, establishing the main activities that should be hosted on the Pavilion and the character and the general message that it should convey. The technical specifics of the platform, also defined in collaboration with external experts and with the authors themselves (to ensure that also the architectural needs were taken into account), were then provided as part of the basic guidelines, together with the indication of the chosen location.
This information contributed to building the state of the art of the thesis, establishing the limitations that had to be considered during the thesis and arranging the central structure of the projects.

This paragraph contains a report of the key points of the SEAform's inheritance, each of them briefly described and motivated, which are, from here on, acknowledged as the axioms and foundations of the thesis.

03.4.1 Location Brief: Venice Arsenale

Once Venice and the lagoon were chosen as the location of the project, there was still the need for a specific suitable area. Not every canal of the city could host this kind of realization. The pavilion needed to be separated from the coast, in at least 5 or 6 meters deep waters, to be able to properly install the anchor system. The total dimensions of the pavilion (45 x 23,5 m) forced it to be located outside of the city, in open water, as it wouldn't fit in almost any of the urban canals or would get in the way of water public and private transport.

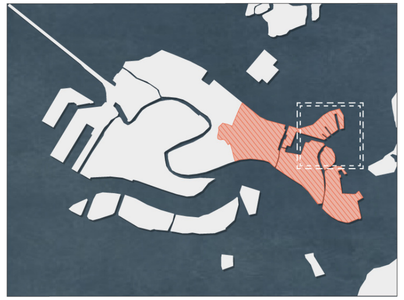
Furthermore, being designed to be a pavilion for the Venice Biennial of Architecture, it needed to be strongly connected to this event.

To identify an appropriate spot, SEAform contacted Venice Port Authority, which indicated a water plot off the coast of Venice Arsenale in the Castello neighbourhood, in the southeastern part of the city. The Arsenale is the former military and commercial shipyard of the city, active from the XII century, during the golden age of the Serenissima (nickname used to indicate the Maritime Republic of Venice), to the Second World War. Today hosts one of the main headquarters of the Biennale, being the location for a large part of the exposition areas and of the events.

The chosen area is a large triangular plot, which sits in a deep canal of the lagoon, with an average depth of more than 10 meters. At the same time is located outside of the main public water transport routes and in an area of low water traffic, meaning that here the pavilion would not disrupt the movement of boats.

Figure C.15 indicates the chosen plot relative to the city of Venice and the Castello neighbourhood.
Figure C.16 represents the available space for the location of the Pavilion, starting from 50 meters off the coast of the Arsenale, and extending for approximately 100 additional meters.

The area is also conveniently detached from the main culturally symbolic elements of the city, where the Pavillion could present itself as a disturbance for the proverbial venetia romanticism. It is instead connected to the centre of the Biennale, the symbol of innovation, art and experimentation, where this kind of realization is much more suited, and the intrinsic message that the authors want to deliver is much more aligned with the local atmosphere.



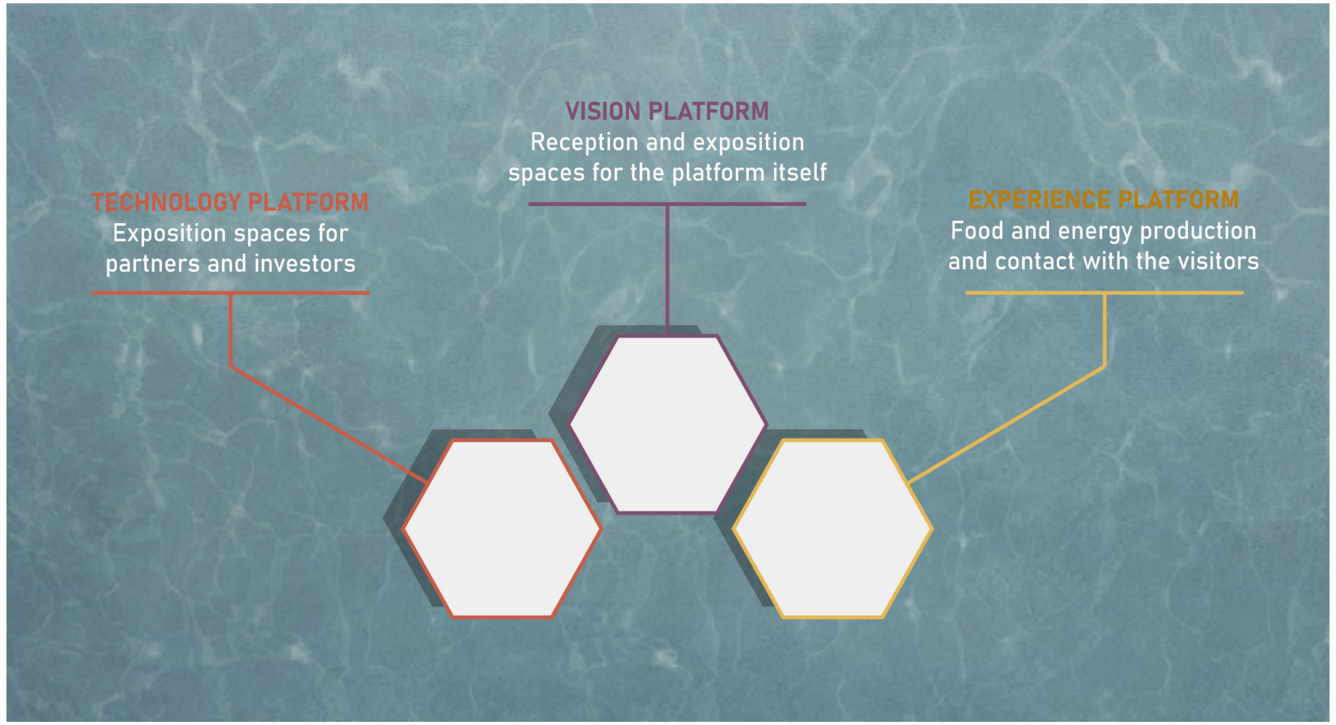
Top: Figure C.18
Localization of the chosen location relative to the city of Venice
Source: Created by the author.

Right: Figure C.19
Project location planimetry, Venice Arsenale. Scale 1:5000
Source: Created by the author.

03.4.2 Functional Framework

SEAform's end goal is to create a floating architectural model, capable of rendering life on water both possible and convenient (efficient, sustainable and affordable). During these first steps, in particular, to ensure progress in the work, becomes extremely important to raise awareness in the community about the opportunities that floating architecture and SEAform's model can provide.
The idea of presenting the structure as a pavilion for the Architecture Biennale moves precisely in this direction, giving the opportunity to show thousands of visitors and passers-by the platform in action. The pavilion could, in particular, convey the message to experts and professionals in the field, increasing the opportunities for profitable interactions and partnerships, that could further advance and strengthen the project.

The functional concept conceived by SEAform, defines a Pavillion for the Venice Biennial of Architecture (or for an analogue exposition event), to be constructed on three floating platforms, located, as explained before, 50 meters off the coast of Arsenale.
The platforms are identical in their floating under-structure which presents predefined unchangeable characteristics, that act as the project basis. The upper-structures, instead, offer more freedom from a design point of view, with no particular imperatives.
An indicative functional program is however provided by SEAform, as a guideline on which to formulate the thesis proposal.
The building should be designed to host a visit tour included in the biennial event, being connected to land by a small boat (potentially inserting it in one of the public transport water lines), acting first of all as a museum of itself, showing and explaining SEAform's idea.
The tour should bring the visitor in direct contact with this particular building technique, providing an example of what life on water



Top Right: Figure C.20
Synthetic representation of the initial concept provided by SEA-form
Source: Created by the author.

could look like, bringing them directly inside a floating building, where innovative technologies and solutions are at the center of the attention.
The pavilion should positively show the opportunities that floating architecture can provide, starting from efficient food and energy production and water management, and presenting the possible future applications of this model.

Figure C.17 is a synthetic representation of the initial concept provided by SEAform for the Pavillion for the Venice Biennial of Architecture, highlighting need to envision a project for three different platforms, with different characters, different objectives and principles.
Sustainability and low environmental impact should be kept as the

backbone of the project, guiding every design solution, as well as the choice of materials, components and building techniques, on which the authors have few restraints.

These same values should also transpire from the building and be clearly conveyed to the visitors. This means that the platforms shouldn't just be efficient and sustainable, but should also have a strong evocative character, to transmit a positive message. Its appearance should be representative of its values, making use of innovative shapes and elements and reserving an important spot for green technologies and approaches.

Some spaces were explicitly required by the design commission.
One of the platforms should be dedicated to food, water and energy production, the main function that floating architecture could serve in the near future. Visitors should also have the opportunity to see and learn in first person about the opportunities offered by the current technologies and by those that are being developed. Another platform should instead be reserved for a showroom for both academic, technical, and financial partners, to give them space and a spotlight to both test on the field and promote their work.

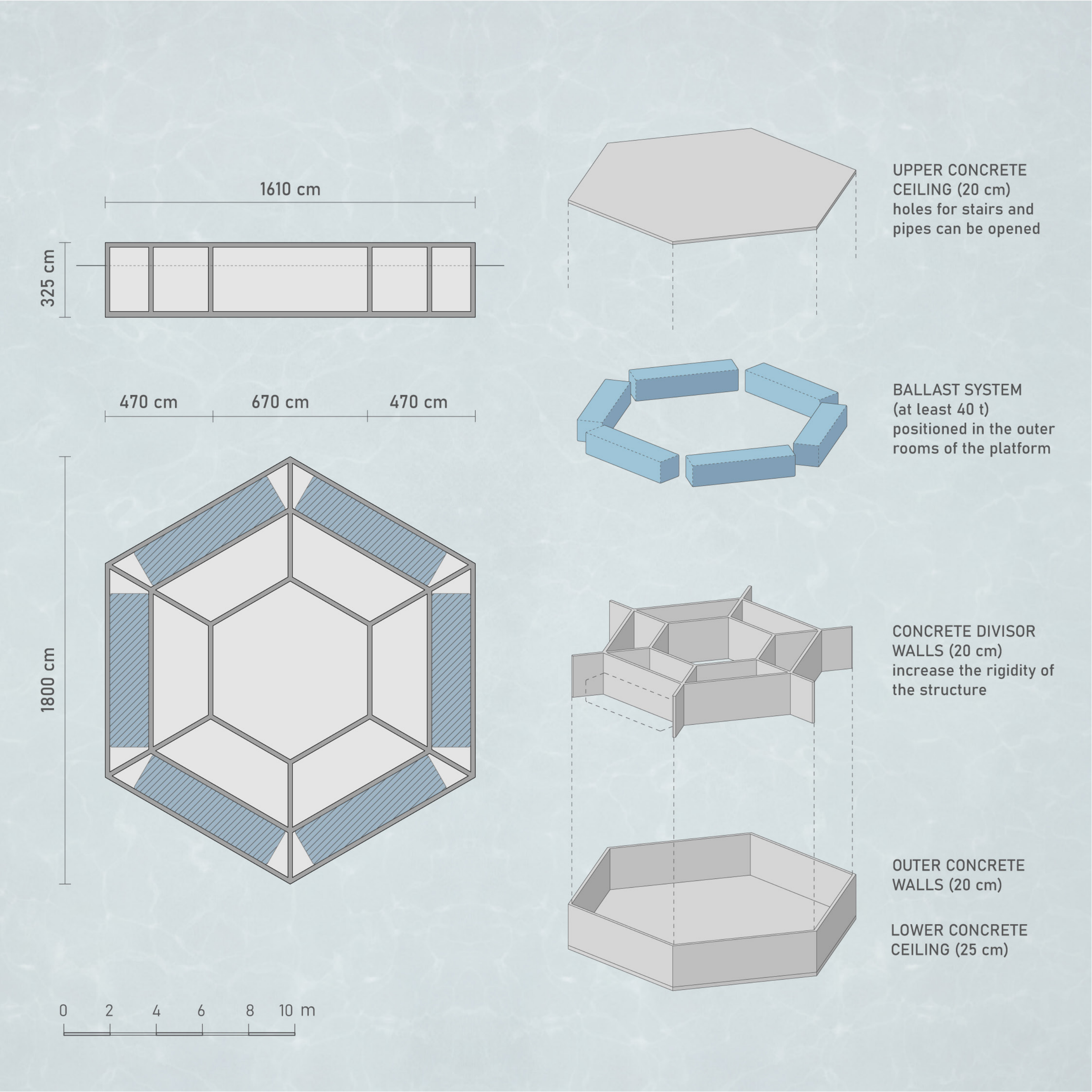
03.4.3 Technical Framework

In addition to the functional concept of the pavilion, SEAform provided a basic definition of the floating platform model, defining materials, shapes, dimensions, and other technical information. This was produced by the research group and was defined to be structurally, technically, and potentially economically feasible (thanks to intense multidisciplinary interactions and confrontations).
Here follows a list of the main limitations and requirements regarding the basic under-structures which are taken as a baseline

for the definition of the thesis project. Every guideline and its main motivations are briefly described and accompanied by an explanatory drawing, to better clarify the concepts.

1. The pavilion composes of three identical, structurally independent, floating platforms, connected to each other to allow for passage.
The platforms (under-structures) are identical to standardize the production phases and reduce costs. The three upper-structures, the object of the thesis project, can, instead, be differently characterized. Every module needs to be independent for structural reasons. Connected platforms would have to respond together to waves and currents, requiring more performing components. Independent elements can on the contrary move freely, only requiring a flexible connection to ensure the passage.

2. The platforms have a regular hexagonal shape and are made out of concrete external and partition walls and floors.
The hexagonal shape was again chosen for structural reasons. Concentric and symmetric shapes better perform with rigidity and response to deformations, as opposed to rectangular ones. The choice of the hexagon combined a satisfying structural behaviour (that allowed to significantly reduce the structural components section, with the same buoyancy potential) to an interesting urban and functional mechanism. Indeed, hexagons can completely tile the plane, giving the opportunity to use these modular platforms to create a complex urban structure (which can not be done with other similar shapes, such as circles or octagons, as they do not tile the plane). The choice of concrete as the building material comes from the good behaviour in marine environments of appropriate cement mixtures, with much lower costs, compared to other inert materials. Another deciding factor was the existence of a know-how for the production of a floating concrete platform.



Left: Figure C.21
Technical data of the floating module, to be used for the Pavilion.
Source: Data from SEAform, visualized by the author.

3. The hexagonal platforms and their main dimensions are defined in Figure C.18.

The dimensions were defined to produce a pavilion that could host the required activities, maintaining at the same time, the realization costs within realistic limits.

The specifics were then elaborated through structural calculations and simulations (by the structural engineers of the research group), which ensured that the platforms would float and could bear a sufficient structural load.

Here follows a list of the main dimensions:

- Main diagonal: 18,60 m
- Side length: 9,30 m
- Total height: 3,25 m
- Submerged portion: 2,25 m
- Above the surface portion: 1,00 m
- Walls thickness: 0,20 m
- Upper floor thickness: 0,20 m
- Bottom floor thickness: 0,25 m

4. The connection to the water floor is ensured by concrete anchors, laid on the bottom surface and fixed to the platform.

The anchors are not tucked into the bottom to ensure a reduced impact. The connection with the platform is realized with steel links and elastomer belts, which allow responding to the variations of water level and to the wave-produced stresses.

5. Part of the floating platforms' internal volume has to be reserved for a ballast system (based on lagoon water use), to ensure the platform partially sinks into the water for at least 2 meters.
The ballast system should be located on the outer area of the platform and placed symmetrically. It should be designed to contain at least 50 tonnes of water. By filling up or emptying the water tanks of the ballast, the platform can respond to the variable loads of the pavilion, ensuring sufficient stability during the life of the building.
The optimal position for the ballast system, which is adjacent to the external hexagonal wall, is represented in Figure C.18.

6. Every platform has a maximum additional bearable load of 132 tons. 92 tons are indicated as an ideal mass for the upper-structure.
Out of the 132 available tons, only 92 can be used for the structure itself. The remaining 40 tons are instead initially contained in the ballast and are progressively freed up to respond to the variable loads of the building, such as the occupants, the snow, the wind, or additional unexpected furniture.

03.5 REFERENCES FRAMEWORK

Case Studies Analysis

03.5.1 Case Studies Analysis

Here is presented a selection of the case studies that were taken into consideration when studying the approaches that architecture firms and institutions are adopting for building on water.
Learning about these specific case studies explains the intention of checking and understanding which solutions, from the point of view of the construction process, functionality, materials choice, and technology, could act as virtuous (or negative) examples for the FloatScapes project and its design process.

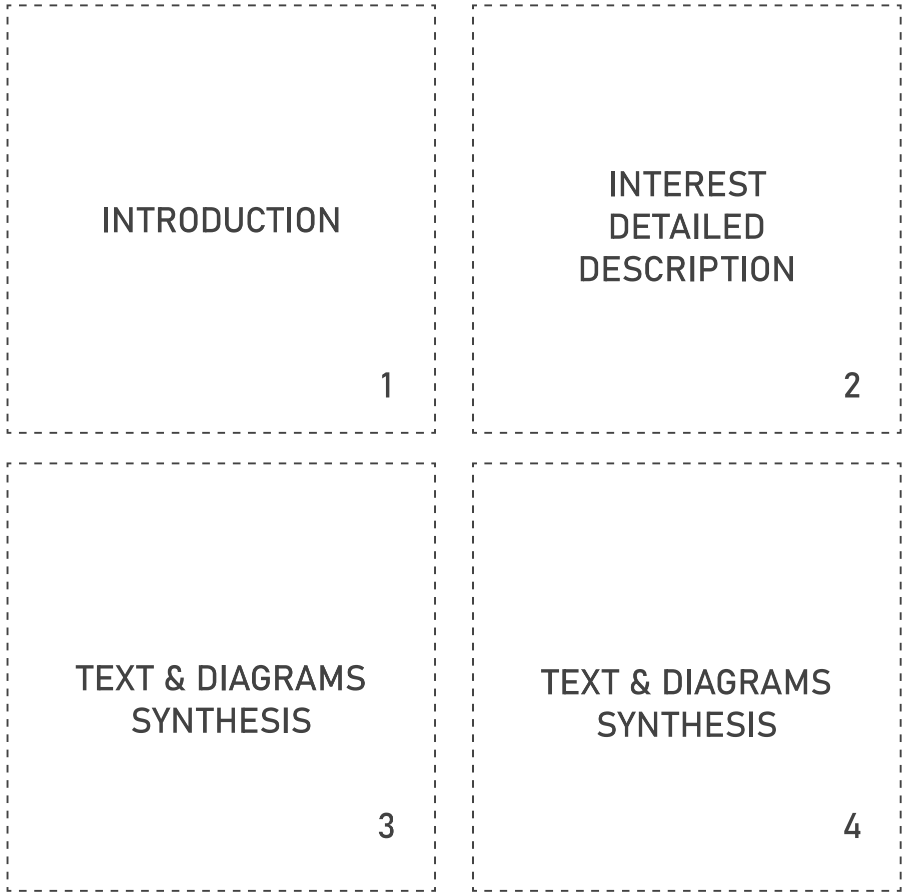
The following 7 case studies belong to both the European and Latin American contexts. This choice is derived, first of all, from the concrete availability of interesting examples and from the possibility to find specific data, drawings, and information about them [N 3.8].
Most of the analyzed case studies are, therefore, located in the Netherlands (and Denmark), where centuries of land reclamation and fighting against the sea, generated an urban fabric which is strongly interconnected with the water, and where the climate change challenges are more pressing than ever.

Each of the projects was analyzed with a critical and technical eye, rather than for its aesthetic value, looking for promising practices and interesting design choices, to be able to extract significant lessons from what was done by others.
The projects have been described following a standardized method. The first description of the project contains an introduction with the general information and vision of the project. Secondly, the elements of interest of that case study are declared, described, and analyzed in detail, trying to understand how the designers approached the chosen theme. Texts, images, diagrams, and photos of the project help with communication. Finally, the analysis is closed with a synthesis of the

learned concepts, either as a text or an illustration.
The idea behind this section is to look for feasible solutions that could go accordingly with our Needs & Requirements, that could inspire our design process or directly be included in the project, providing a deeper starting knowledge on the topic of floating architecture.

Figure C.19 contains a visualization of the standard analysis scheme for the case studies, which is then, obviously, adapted to the specific needs of the single project.

[N 3.8]
Numerous useful examples could for example have been found in Asia, where the high coastal risk attracts the work of architects and engineers. However, these projects would have been harder to comprehend for the authors of the twin thesis, for both language and cultural barriers.



Right: Figure C.22
Diagram to explain the procedure and methodology followed to present the case studies.
Source: Created by the author.

Floating Office Rotterdam (FOR), POWERHOUSE COMPANY

The FOR is a floating sustainable building example. All the strategies involved in the design, point out the importance of sustainable solutions with a Circular Economy vision. This vision could be stated with the modular wooden structure choice and the energy solutions. These specific choices foresee several advantages in the life cycle of the building. Prefabrication, future recycling, lower cost and time of construction, and lower CO2 emission are some of the pros presented in this project.

Going deeper into the energy solutions, the project considers high-tech solutions such as Solar Panels and a very innovative Water-Cooling System with the harbour water. By balancing temperatures with a pipe system where the water level is located, cooling for the warmest seasons could be achieved. On the other hand, the low-tech solutions are the ones that balance the energy input and output with Passive Shading provided by the pitched roof and the overhang terraces [N 3.9].

Rotterdam, Netherlands

Headquarters of the Global Center on Adaptation (GCA)

Year 2021

4 500 m²

Modular Wooden Structure

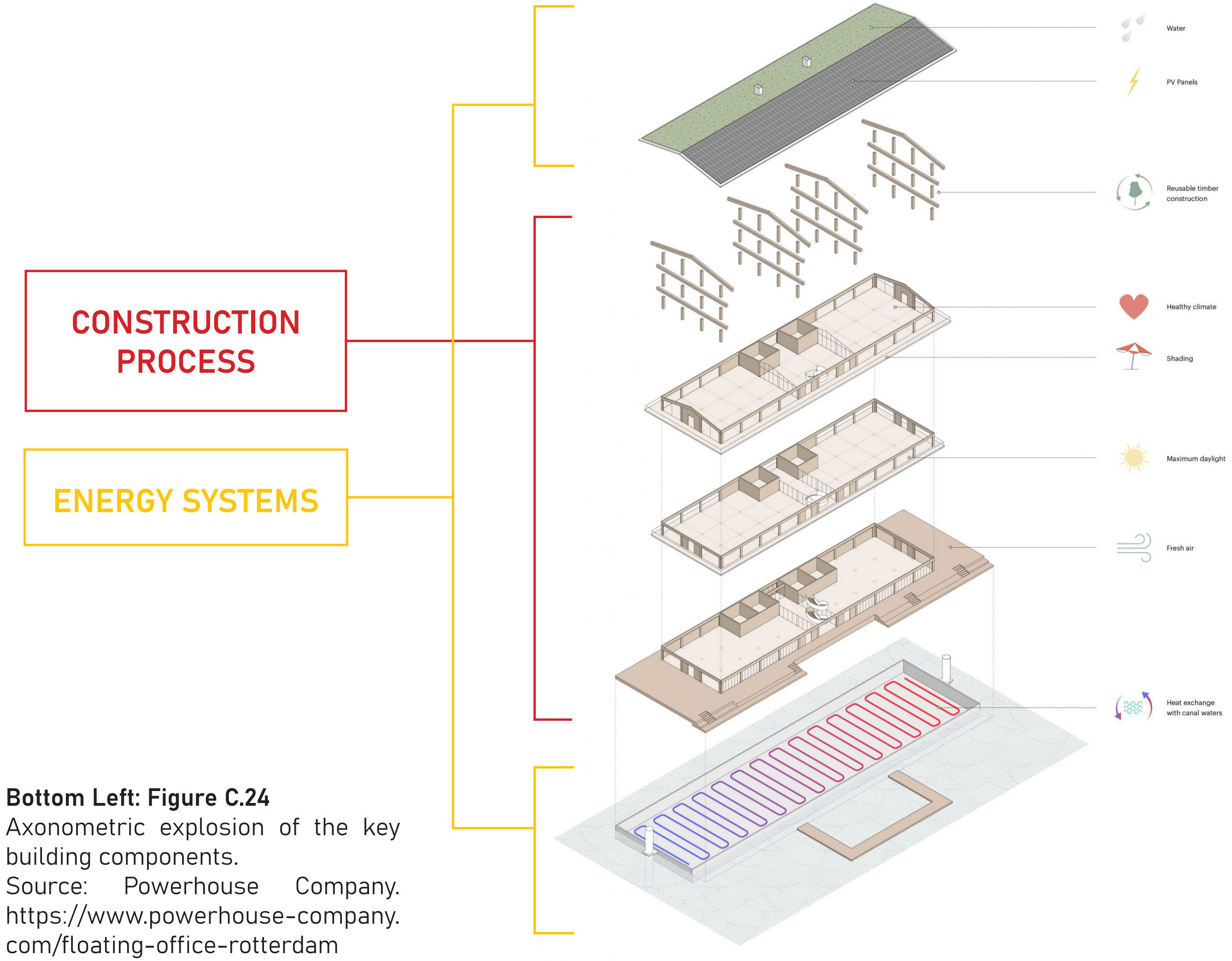
Land & Maritime Transportation

Renewable Energy: Water Cooling System & Solar Panels

[N 3.9]
Text Source: Powerhouse Company. https://www.powerhouse-company.com/floating-office-rotterdam

Bottom Left: Figure C.23
FOR viewed from harbor.
Source: Powerhouse Company. https://www.powerhouse-company.com/floating-office-rotterdam

Nevertheless, the main interest in this project relies mostly on the construction logistics and processes for the construction phase, where several parties were involved in sub-phases according to the applied constructive technology to reach the site and assembly of the building.



Bottom Left: Figure C.24
Axonometric explosion of the key building components.
Source: Powerhouse Company. https://www.powerhouse-company.com/floating-office-rotterdam

Constructive Process Flow Chart

Both Pages: Figure C.25 Construction Process.

Floating Platform: Transport & Assembly → Timber Structure Setting → Modular Panels Assembly → Components Fastening → Completion

1.

Transportation

Both land and maritime transportation were needed for the prefabricated elements. This the initial base for this Off-Site Project.

2.

3.

Prefabricated Elements

Floating Pontoon:
- Prefabricated concrete platform provided and towed by HERCULES FC in Hardenberg, Netherlands.

Timber structural elements:
- Glulam and CLT elements provided and sent in containers by DERIX, in Niederkrüchten, Germany.

4.

5.

Initial Assembly

The towing limitations defined the max dimensions of the building. This was an important variable in the long horizontal design of the project. The main structure, in order to be circular, had to be simple and demountable. All timber elements were also constructed Off-Site and sent to the port.

6.

7.

Modularity/Production

CLT mainly compose the envelope of the building. The long horizontal design made possible to have typical structural modules to make the production more efficient.

8.

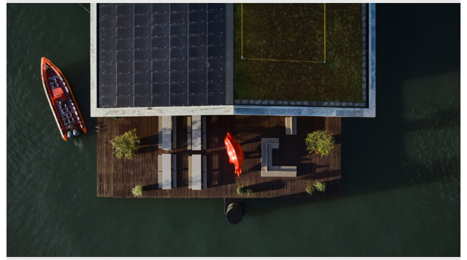
9.

Additional Components

Between the glazing, prefabricated stairs, solar panels, and other finishings, the late assembly phase of the project shapes the final result.

10.

11.



Floating Office

New offices with an amazing atmosphere in the harbor are placed to state how Adaptation looks, like with sustainable strategies.

Collaborators:
Developer: RED Company
Wood Structure: Derix
Solid Foundation: Hercules
Engineering: Solid Timber
Glass: iFS Building Sytems

Oceanix, BIG

As a blue tech company, with several collaborators where the main ones are Bjarke Ingels Group and SAMOO (Samsung), Oceanix (2018) is an alliance that operates in the scope of designing and building sustainable floating cities. The example of Busan is their first prototype for a sustainable floating community [N 3.10].
For our interest in this case study, the pertinence of studying it relies on the interconnected systems in the project program, setting a baseline of kits that responds to sustainability; and, in terms of composition, the geometrical reasoning for floating purposes that uses the same geometrical figure as our project case. The main elements that we found useful for this research are the followings:

- Sustainable Energy Production and Management
- Food Production
- Reliable Water Access and Management

These main topics could be considered as the base of the system for living on the sea, of course, more precise accountability of all the needs should be executed for our thesis, but this example can be extremely useful as a concept.

Busan, South Korea

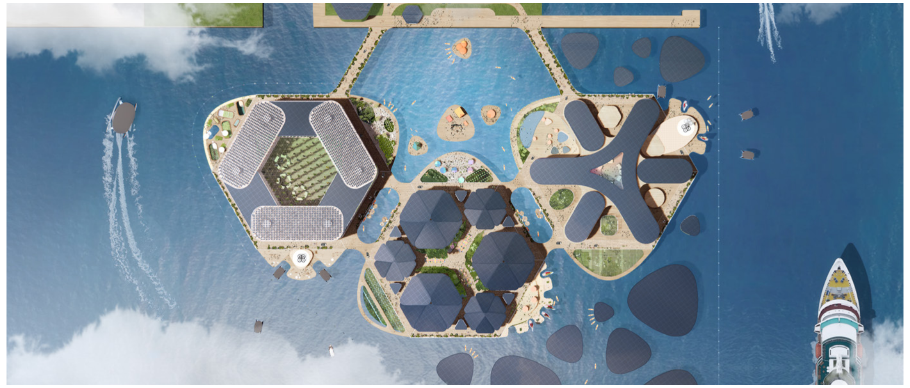
06 Ha
12K People
06 Integrated Systems

Year 2022

Hexagonal Form & Symmetrical Composition

Scalability & Replicability

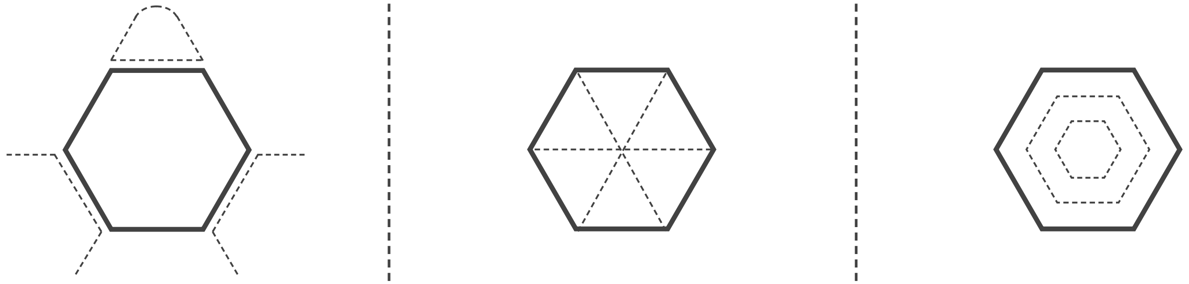
Sustainable Systems



[N 3.10]
Text Source: OCEANIX/BIG-Bjarke Ingels Group.
https://oceanix.com/media/

Bottom Left: Figure C.26
Oceanix city from above.
Source: https://oceanix.com/media/

Top Right: Figure C.27
Reflexions about the Hexagon cells of OCEANIX and their functioning.
Source: Created by the author.



The Hexagon as a origin cell provides **symmetry and balance**. Ideal features for Floating. Exterior volumes could be added as attachments.

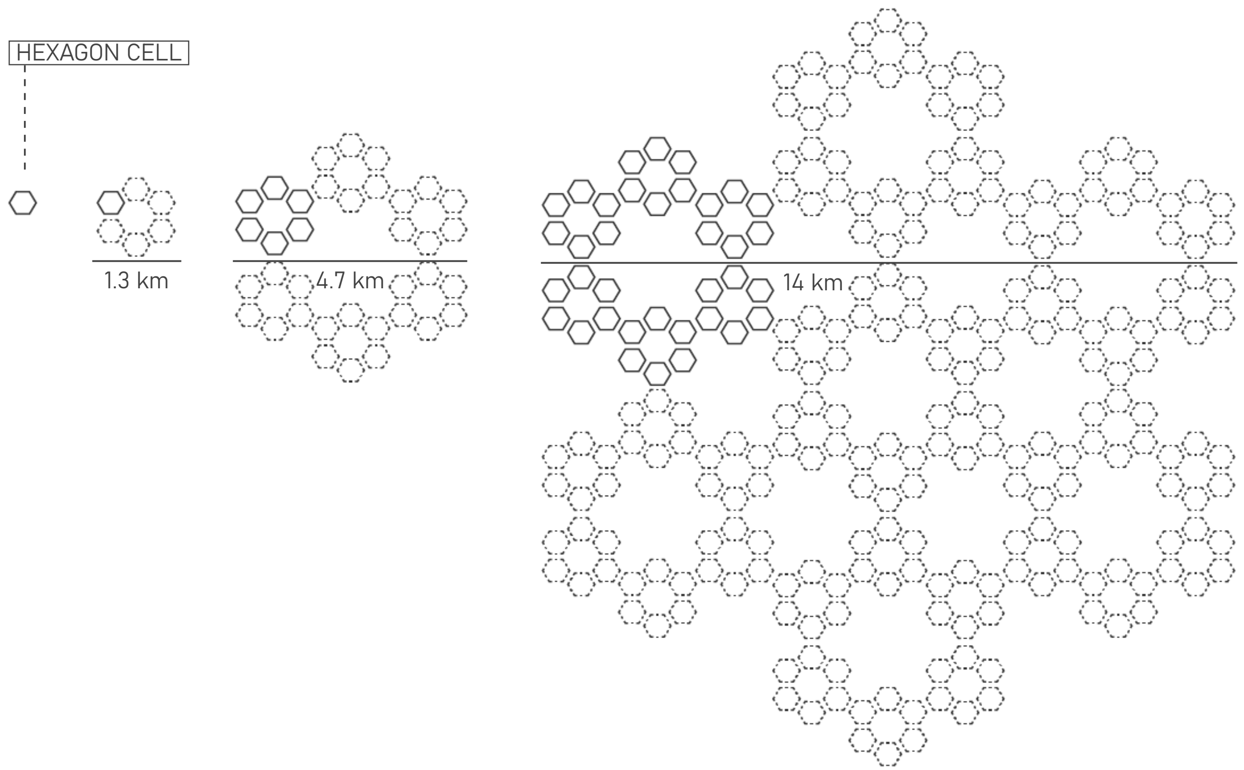
Geometrical **subdivisions** of the hexagon, decompose the form into **modules**. Ideal for execution planning.

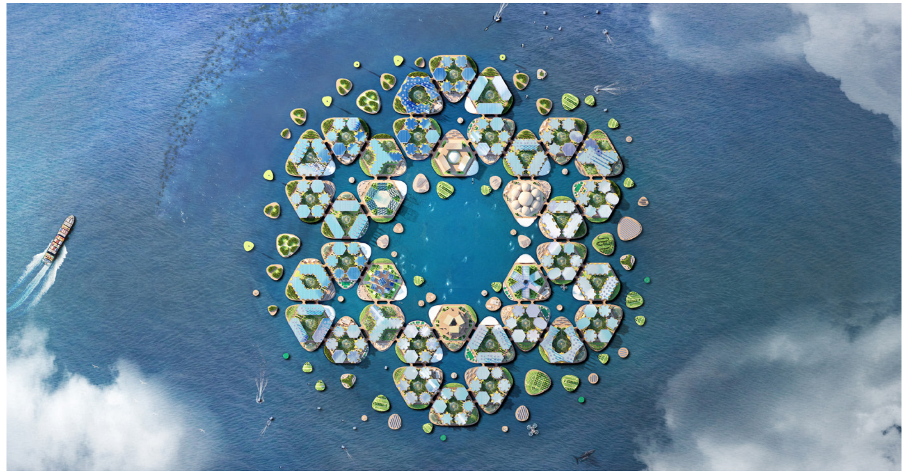
Inner **proportional hexagons** reveals trapezoidal segments. Ideal for **space distribution.**

As seen in the Hexagon's Reflections above, the geometry favours flexibility towards the interior and the exterior. Also, it complies with the needed balance for floating.

On the other hand, talking about the systems, the project suggests a multidisciplinary complexity which is demanded by the maritime context. The autonomy quest is translated as the inclusion of creative alternatives for a sustainable ecosystem of functionality. Either way, the maritime environment impact is something to look for in this sense.
Nevertheless, the project is still in the concept design phase which limits a deeper understanding of the logistics, products and technology; not to mention the investment of the whole development, and the impact on the maritime life underneath.

This case study tries to respond to the shifting needs of Busan, and at the same time to the expected Sea Level Rise. Its design contemplates a form and composition that could be scaled and replicated in different





Top Left: Figure C.28
Oceanix's compositions from a replicable and scalable cell.
Source: Created by the author.

Bottom Left: Figure C.29
Oceanix top aerial in Busan.
Source: OCEANIX/BIG-Bjarke Ingels Group. https://oceanix.com/media/

Top Right: Figure C.30
Energy, Food, and Water Systems
Source: OCEANIX/BIG-Bjarke Ingels Group. https://oceanix.com/media/

scenarios, which is why it is worth to understand and to attempt to relaborate as a reference for our specific case study.

The approach of offering concepts about Renewable Energy systems such as Solar Panels, Heat Exchange, and Wind Turbines puts in evidence the huge potential of offshore energetic sources that could support the needs of a floating building. In the same way, the suggestion of Food Production is equally valid, as both Aquaponics and Aeroponics could be interesting alternatives for Floating Indoor Farming. Last but not least, is Water Management, where concepts such as Clean Water Supply, Storage, Collection, and Gray-waters Treatment are fundamental for future and large-scale urban developments.

Urban Rigger, BIG

As an urban developing initiative, Urban Rigger aims for the construction of floating communities in largely undeveloped areas in the heart of cities that have a diffuse waterscape, with unused harbours, ponds, and ports.

The idea behind this initiative is that urban areas can be transformed into micro-districts by adding affordable housing, especially student housing, but with the special characteristic of living on the water. The increasing number of student applicants in Copenhagen and all of Denmark acted as the trigger to the waterscape transformation in this project. The solution envisions keeping students in the heart of the city by proposing a floating building [N 3.11].

By designing a project that could be replicated, the projection of a community could be achieved. Although getting into the execution of the prototype, there are some very positive aspects like the offsite approach in the construction process, even though the use of "containers" is quite banal.

Copenhagen, Denmark

Affordable Floating Housing

Year 2015

680 m²

Prefabricated Modules made with Containers

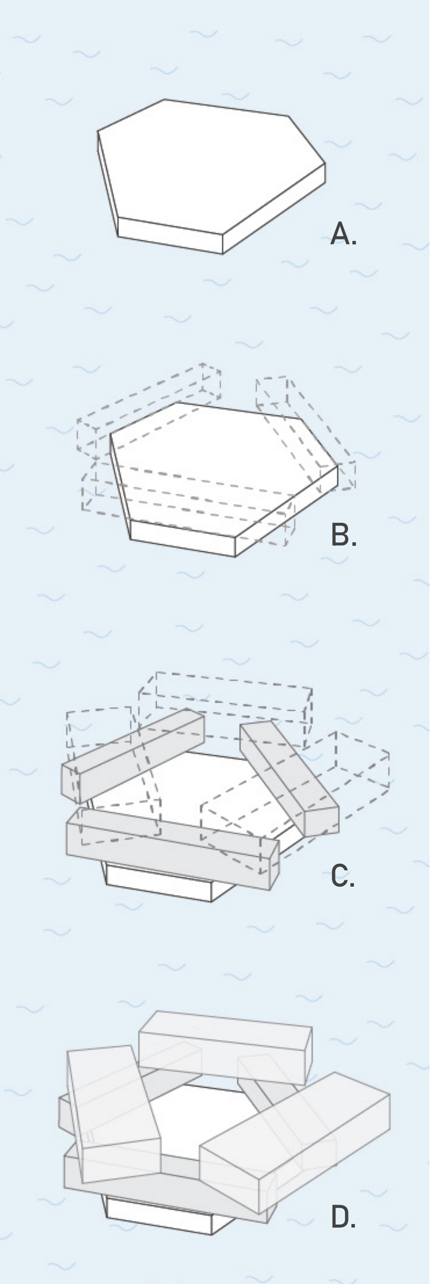
Replicable Design

Renewable Energy:
Solar Panels & Heat Exchange

[N 3.11]
Text Source: Archdaily. https://www.archdaily.com/796551/urban-rigger-big

Bottom Left: Figure C.31
Urban Rigger prototype from harbor. Source: https://urbanrigger.com/architecture/

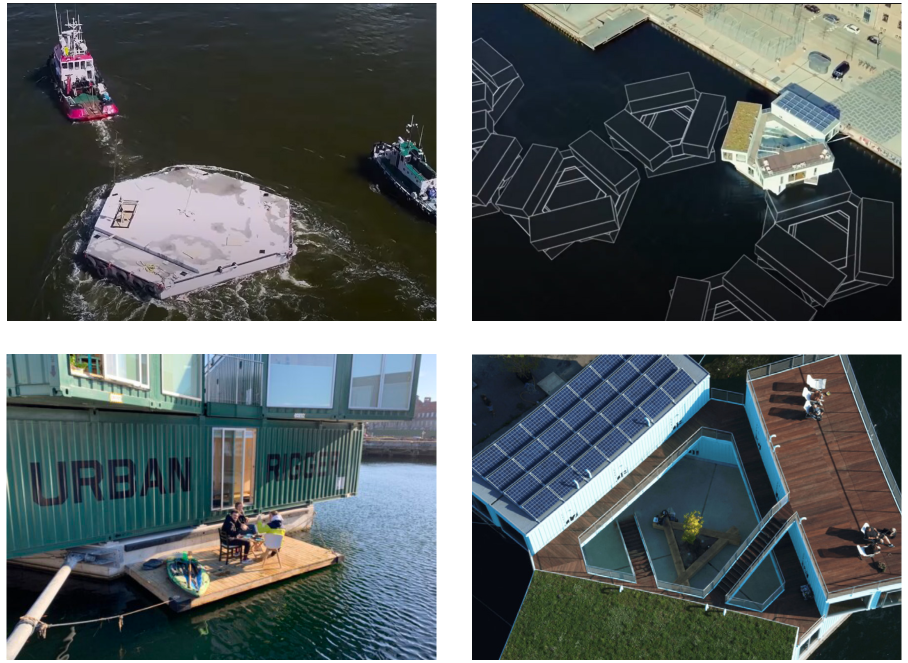
Bottom Left: Figure C.32
Urban Rigger construction sequence. Source: Created by the author



Nevertheless, beyond the several variables that this project includes, this section will be limited to its specific interest area, which is the Assembly process of the project. Besides the use of containers to really make this housing project affordable, what we focused on, is the Prefabricated Modules concept. The prefabrication level of this project is extremely high. The retrofit of old containers is completely made off-site, and, with the right building physics adjustments, produces an envelope that could perform within the comfort standards for living.
Stacking is the main assembly principle. Firstly, 3 units are located on the edges of the platform (A and B), setting up the main floor. Consequently, 3 additional units are located over the extremes of the main floor units (C and D), interlacing the box modules, and creating vanes for views and connections.
What is really valuable in this procedure, is the fact that prefabricated modules are extremely efficient in terms of assembling. Understanding that Dry Assemblage is the technique used for all the bodies over the water level is fundamental, as the concrete prefabricated Pontoon, is also prefabricated for waterproof performance.

Additional reflections:
1. The initial Pontoon is an engineered product that foresees waterproofing. Mainly using cast-in-place concrete, it is the volume that contains all the systems and instalments that the building needs to function. Once the construction of the Pontoon is finalized, the volume is towed with maritime transport, to the next fabrication site, where the assembling phase will be executed with the prefabricated volumes.
2. The prototype itself follows, from the design phase, a specific geometry that allows flexibility of connection when developing a floating community. The edges and the voids in between the volumes, play the role of leaving spaces where each Urban Rigger building

could be attached.
3. Building around the edges of the composition, creates spaces and conditions where the users could have exposure to the water and at the same time community privacy.
More or less, the external spaces that could be used as small docks to have contact with the water could be also considered as external private spaces of the units that are at the water level. The concept of having contact with the water is fundamental in the experience of floating unit users.
4. As a final consideration, it could be said that the Urban Rigger project, besides the "affordable" nature that pushes toward the use of containers as a material solution, carries with it key concepts that are useful when projecting for replicability, low time construction, and space creation without losing the floating principles of symmetry and balance.



Bottom Left: Figure C.33
Urban Rigger. Pictures that reflect the concepts involved in the final result of the construction.
Source: https://urbanrigger.com/architecture/

Amsterdam, Netherlands

Floating Neighborhood Masterplan

Year 2009

30 Floating Houses

Real Estate Subsidy

Collective Citizen's Inititative

Sustainable Community

Renewable Energy:
Solar Panels & Heat Exchange

Schoonschip, SPACE&MATTER

This floating neighbourhood started from the inspiration of the self-sufficient life on the water atmosphere that Marjan de Blok understood when visiting the GeWonnboot: a floating space for meetings. Consequently, a master plan was designed, and the realization process started.
The vision in this case, of building a sustainable neighbourhood over water, is very important as it is the inner drive of the whole development. The management and logistics really defined the parameters of the nature of this housing complex. Collaboration throughout a decade made this project possible, especially because there was a positive and proactive participation of the houses' owners, in the whole process.
The involvement of financing research and feasibility consultancy is a great example of how to approach the development of a neighbourhood of this type. Similarly, the different estate location, as a water-like site, is very interesting as it involves the city and "land ownership".

Bottom Right: Figure C.34
Schoonschip aerial view.
Source:
https://schoonschipamsterdam.org/

To illustrate this approach, we will develop further the reasoning behind the site and the execution, but in terms of the preparation and process that lasted a decade to achieve this realization.

Time list:
- 2008. Marjan de Bloak and Thomas Sykoran start their plan.
- 2009. Foundation Schooschip gets a subsidy to start feasibility.
- 2010. Johan Van Hasselt Canal is chosen as a development site.
- 2011. Space&Matter starts the feasibility studio for the group.
- 2016. The applications for the environmental permit for the construction were submitted.
- 2018. The first houses are towed and anchored.
- 2020. All the houses are anchored, and the neighbourhood is complete [N 3.12].

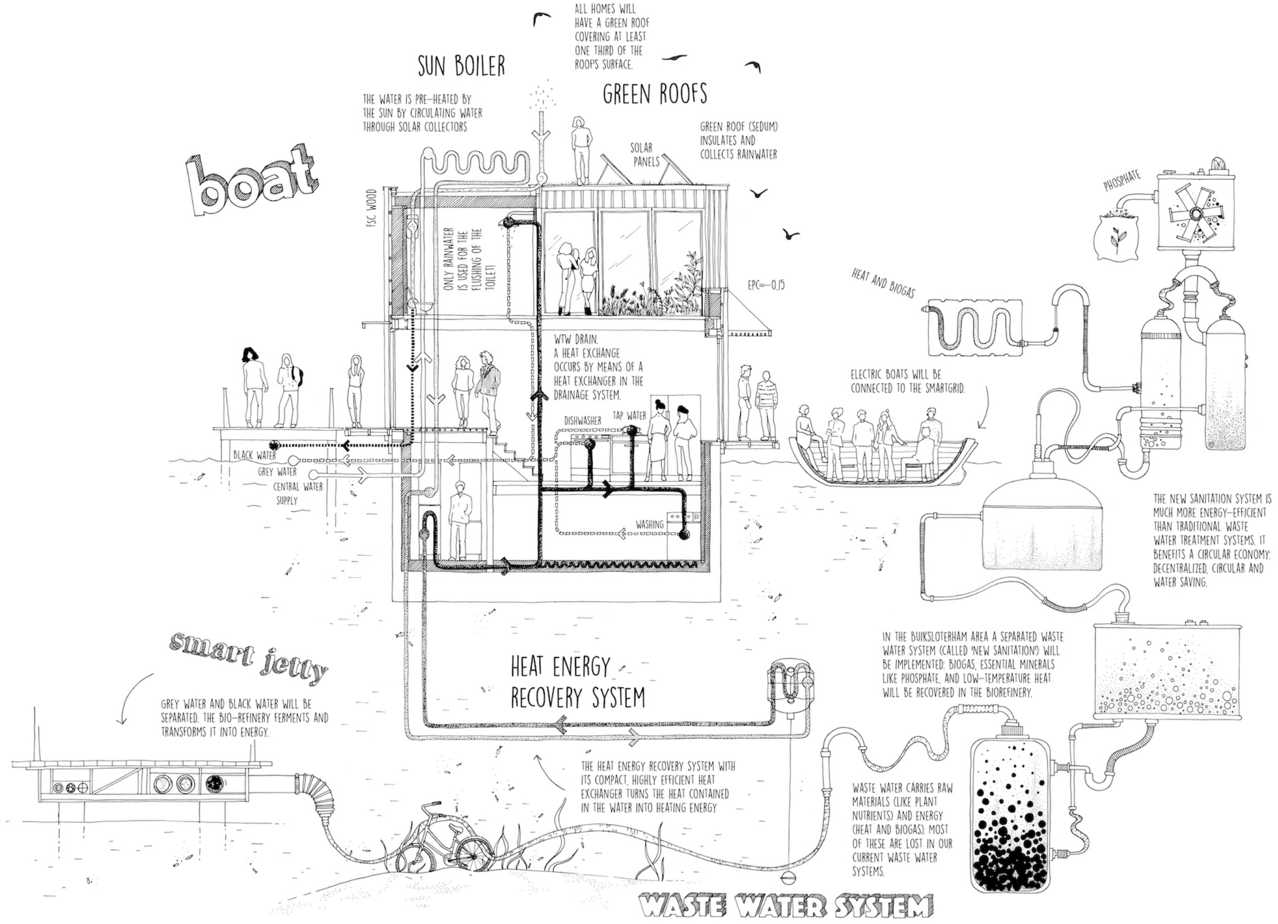
[N 3.12]
Text Source: Schoonschip.
https://schoonschipamsterdam.org/en/#historie

Top Left: Figure C.35
Site Plan for municipality permits.

Above: Figure C.36
Johan Van Hasselt canal aerial view.

Bottom Left: Figure C.37
First houses arriveal to be anchored.

Top Right: Figure C.38
Schoonschip sustainable section.
Source:
https://schoonschipamsterdam.org/



The completion of the development involved several parties, from consultants to designers, to smart services, and technology support. At the end of the project, the Schoonschip group even produced an open-source web page with all the lessons learned information about the development. This type of initiative from beginning to end, was careful enough about making a sustainable point through development, and more importantly, to use the media to create awareness and inspire other projects.

WaterlilliHaus, SYSHAUS

LilliHaus is a project that explores the development of prefabricated houses that can be on the grid or off the grid. That can be placed on land or water. Therefore, the name WaterlilliHaus.

By following the "Plug & Play" approach, the prefabrication production concept comes from Industry 4.0, by adding technology support to the systems of the building. The house systems involve the integration of energy, water, and waste systems, going further into the argument of systems included in prefabrication.

Nonetheless, other strategies could be found within the module prefabrication, such as a natural ventilation system that is composed of openings in the floor and ceiling. Although the project presents itself as very technological, it could be inferred that the automated processes for the scale of the building could be inefficient and expensive, and for this reason, other alternatives must be applied.

As a very simple project placed over a floating catamaran, many aspects are taken into account, but this case study focuses on the prefabrication and assembly process, which is the use of a single Module that arrives at the catamaran to be anchored and fixed.

Joanopolis, Brazil

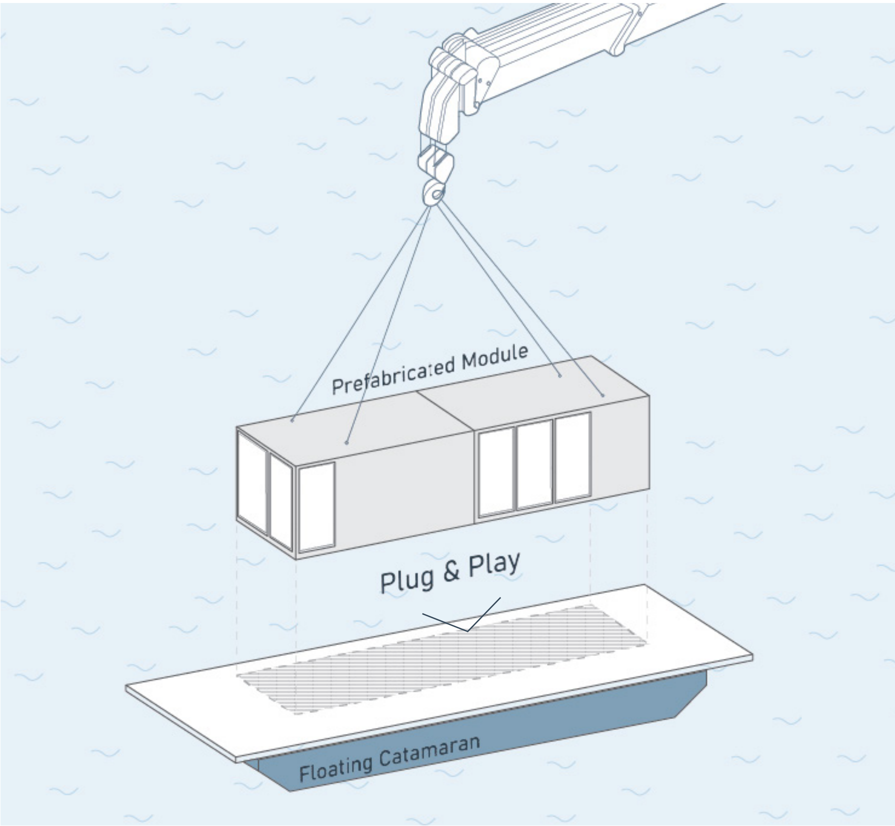
Rental Floating Housing

Year 2019

116 m²

Unique Prefabricated Module

Housing Production Concept



Bottom Left: Figure C.39
WaterlilliHaus.
Source: https://www.archdaily.com/940995/floating-house-waterlillihaus-syshaus

Above: Figure C.40
WaterlilliHaus, assembly procedure.
Source: https://www.archdaily.com/940995/floating-house-waterlillihaus-syshaus

Top Right: Figure C.41
Plug & Play Diagram.
Source: Created by the author.

As a concept, Plug & Play is quite simple but is only the tip of the iceberg. The efficiency of this approach, as understood with other case studies, saves time in the construction, and reduces the risk of execution when building over water.

Although the summary of the construction main procedure could be represented as simply as in the diagram above (Plug & Play Diagram), where a crane carrying the module places it over the fixing body, the logistics management behind this key moment of the project involves transportation and their limits, which is an important clue for the future designers of floating architecture.

IJburg Waterbuurt, Architectenbureau & Marlies Rohmer

In the historic context of the Netherlands, the cityscape is known to likely present life beside or over water. In the second decade of the 2000s, floating buildings became eligible as a significant solution for housing needs, thanks to two factors: the rising sea levels in the region, and land shortage.

Even though in many other places around the globe this approach was not common, the strategic consolidation and location of floating projects, as seen also with the Schoonschip case study, produces the effect of multiple uses of space, as some obsolete docking areas are enhanced with housing, plus the benefits of a sailing atmosphere that is likely to produce a sense of freedom thanks to the water [N 3.13].

This housing development in IJburg is an example of this practice, and similarly to other case studies, thanks to the composition of the units, the interest in this project relies on the transportation and the obstacles presented.

Amsterdam, Netherlands

75 Floating Houses Masterplan

Year 2011

10652 m²

Modules Prefabrication

Maritime Transportation & Design

[N 3.13]
Text Source: Rohmer.
https://rohmer.nl/en/projects/waterwoningen-ijburg/

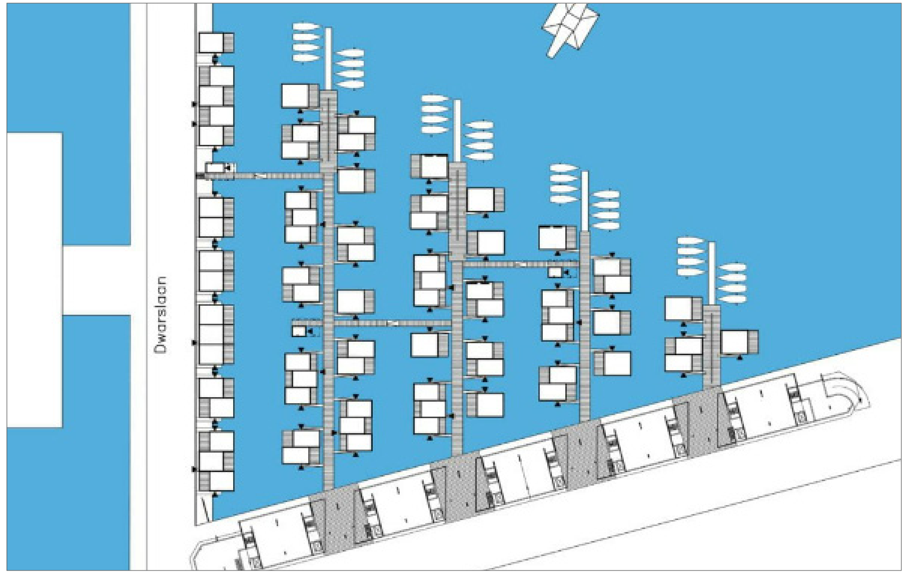
Bottom Left: Figure C.42
IJburg Waterbuurt, View from the water.
Source:https://rohmer.nl/en/projects/waterwoningen-ijburg/

Below: Figure C.43
House module passing a narrow canal.
Source:https://rohmer.nl/en/projects/waterwoningen-ijburg/

Bottom Right: Figure C.44
Complex Master Plan.
Source:https://rohmer.nl/en/projects/waterwoningen-ijburg/

The housing units of this development, due to the typologies proposed, were designed as prefabricated modules. The modules in terms of materials are similar to other case studies as they are composed of a floating concrete inhabitable Pontoon that supports a Dry Assemblage building over it. In this case, it was developed with timber framing techniques.

Nonetheless, as the houses have the same prefabrication approach of building, and assembling to later tow the finalized module, some obstacles were taken into account during the design of the project as the water canals' dimensions could become a problem in the maritime transportation phase.
In Figure C.40 (House module passing through a narrow canal), it could be seen that the width of the water canal was considered to accomplish the towing passage of the house. It could be said that the transportation logistics in this realm must be considered in order to practice a successful offsite approach.



Floating Farm Dairy, Goldsmith Company

As part of the M4H development zone in Rotterdam, a dairy floating farm was built as an example of the type of projects that could be built in this specific zone, as they stimulate and facilitate innovative and experimental activities.

In this specific case, a triple-stacked structure is the house of 40 dairy cows. Designed to enhance buoyancy and stability during the production of dairy products was one of the main concerns when designing this building. As a result, careful attention was given to the Circular approach of all the involved systems of such a complex program. The concept behind this is the "Foodstrip" as it adds urban recycling from organic products like potato scraps and grass clippings to feed the cows.
Most of the technical components are submerged in the lower level of the farm while all the transparent and significant activities are located on top.
Similarly to other floating projects, the transparency of the different

Rotterdam, Netherlands

Distribution Center

Year 2019

2000 m²

Integrated Technical Systems

Experimental Project

Circular Economy:
Rainwater Collection
Waste Recycling
Manure Production
Cow Feeding Production

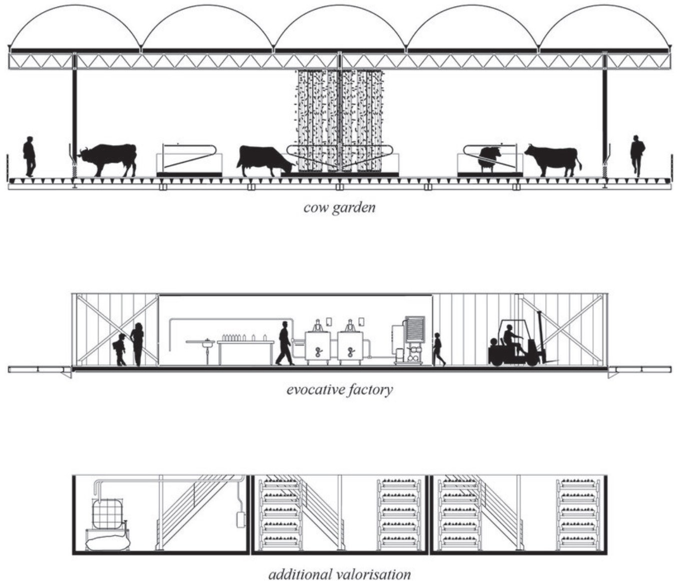
levels changes. In this case, the floating Pontoon, made of concrete, is followed by a translucent level where production activities are developed; finally, the last level is completely transparent as it is dedicated to the cow garden. Stacking is the main construction principle of this type of project, therefore, an important vertical communication between the program and the systems is the focus of this study [N 3.14].

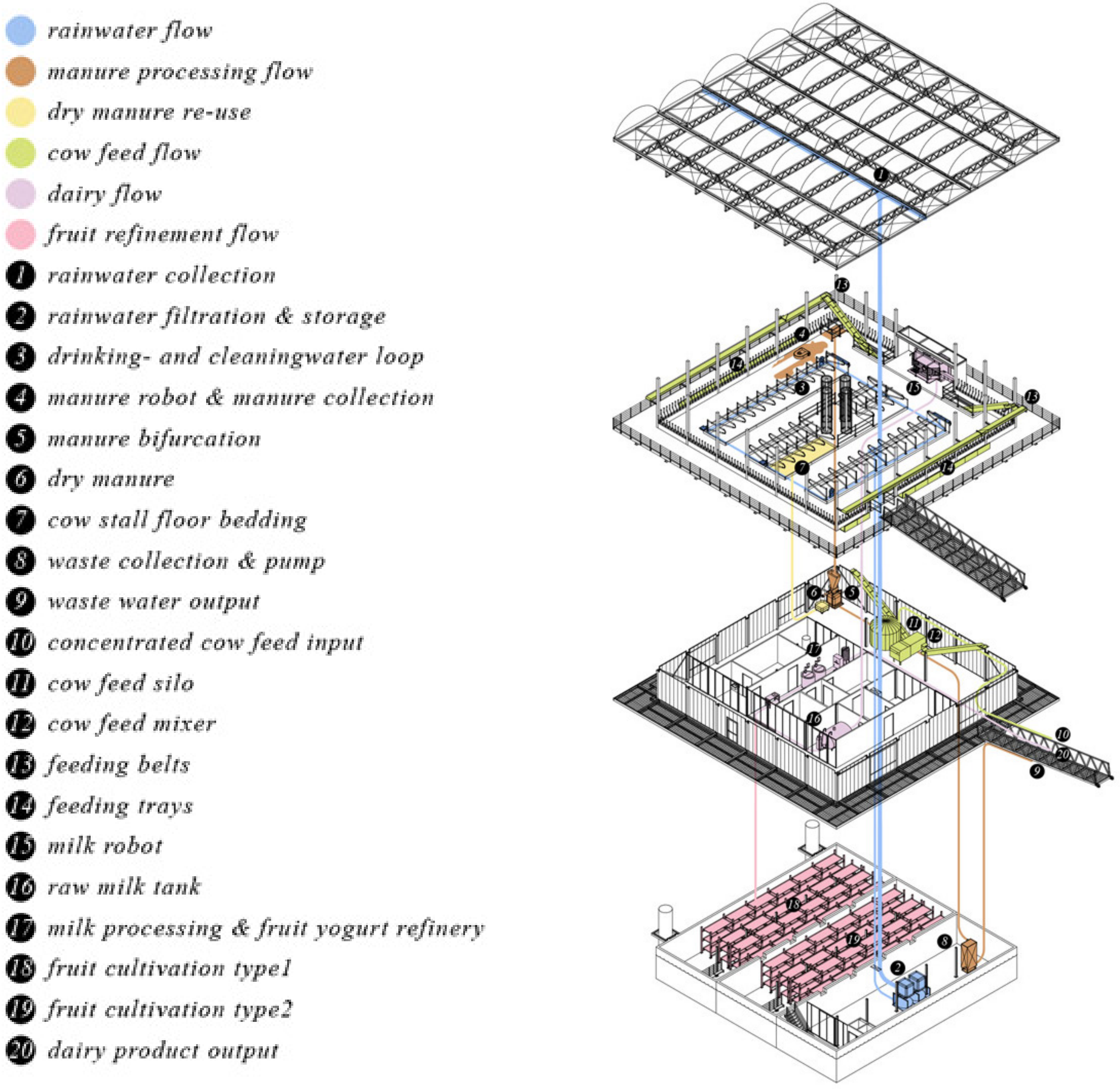
As previously mentioned, prefabricated floating structures, require more time in the design and development phases, where the technical solutions are resolved, especially when the concept of Circularity is so important.
A detailed program and workflow are key when designing prefabricated floating architecture. The reflection goes around designing the instalments in a way that every piece has a place and way of assembly. Even the systems that are necessary for the project to function.

[N 3.14]
Text Source: Goldsmith. https://goldsmith.company/floating-farm-dairy/

Bottom Left: Figure C.45
Farm view from pier.
Source: https://goldsmith.company/floating-farm-dairy/

Bottom Right: Figure C.46
Project Concept
Source: https://goldsmith.company/floating-farm-dairy/

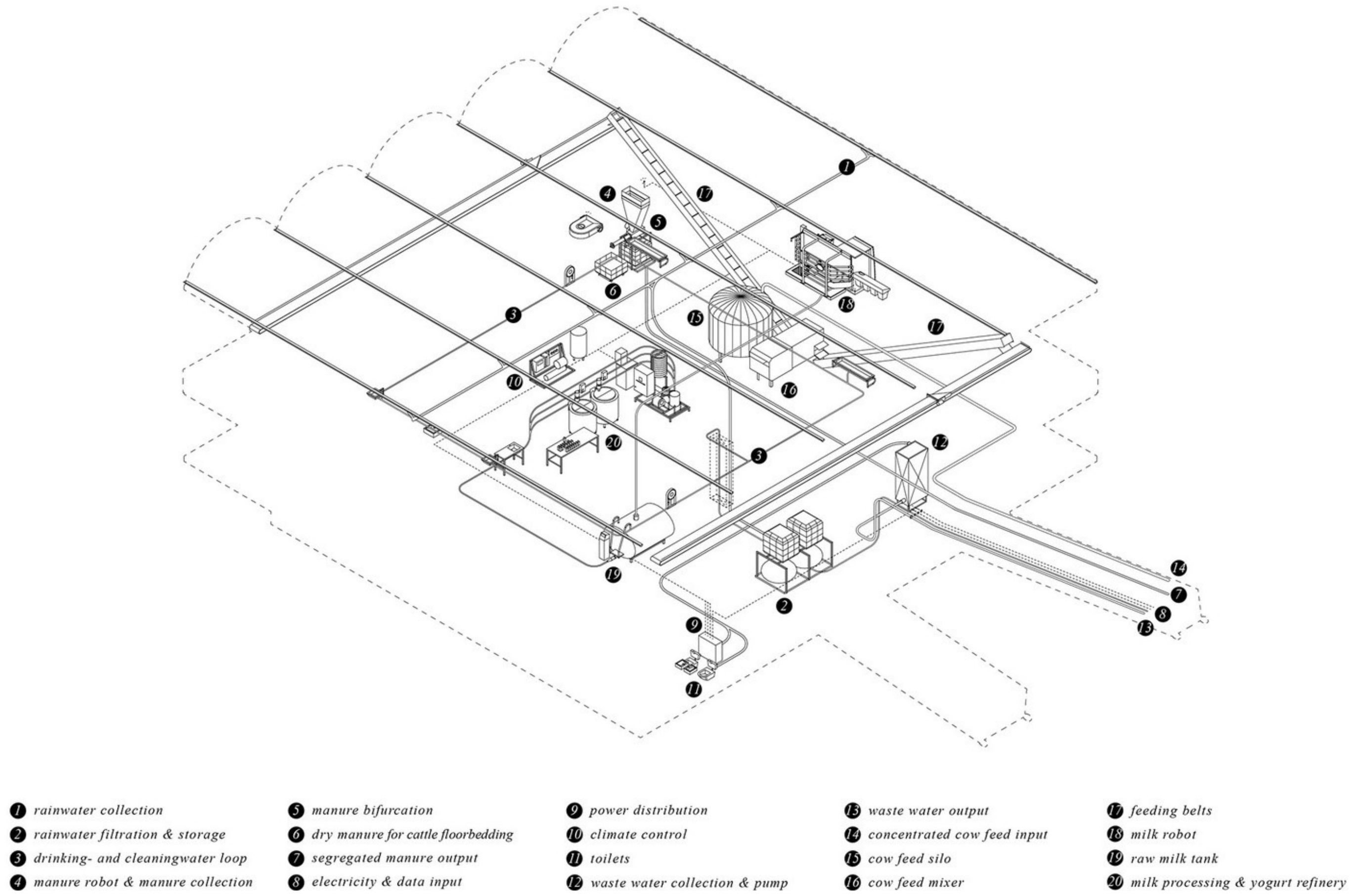


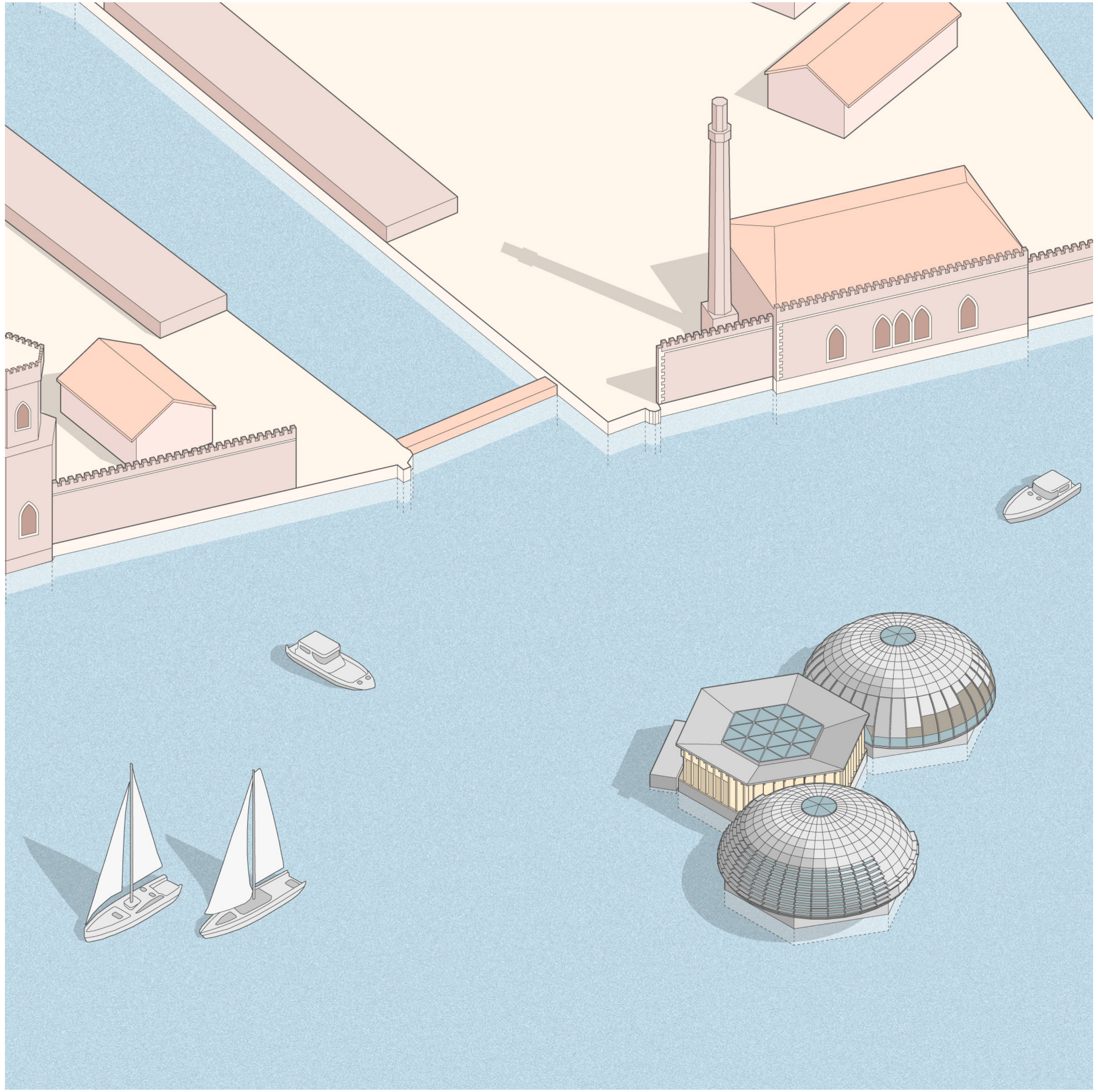


Left: Figure C.47
Circularity viewed in a Exploded Isometric, with legend.
Source: https://goldsmith.company/floating-farm-dairy/

Bottom Right: Figure C.48
Infrastructure Isometric.
Source: https://goldsmith.company/floating-farm-dairy/

A very important strategy in this farm to point out is the fact that Goldsmith does a great job by separating the understanding of the production, and recycling flows, with the instalments and devices needed for such a complex activity. Of course, both processes go back and forth in the design, or at least we could infer that. Nevertheless, the Development Design of these flows and devices makes the project successful, speaking in terms of production.





04
FLOATSCAPES

"For me, architecture is the means, not the end. It's a means of making different life forms possible."

Bjarke Ingels

This chapter presents the project for the Venice Floating Pavilion: FloatScapes, composed of three independent platforms that, together, constitute a single floating building. As seen before, the commission of this project started with a functional concept established by SEAform and picked up by our design group. This starting point of reflection was the base of the following research.

This chapter contains descriptions of the main principles and guidelines that gave life and defined the character of the building. In the same way, it is explained the message of this whole research. Why is it pertinent to explore a project of this kind? And, once it is consolidated, how it would be experienced, by both, visitors, and staff members?

In terms of functionality, a key point has been to define and clarify the pragmatic but very important aspects of the floating pavilion logistics. How it is connected to the land, the activities that will occur, the supply of basic goods, and how the standard visit tour would be organized, among other aspects. On several architectural levels, once the user's needs were settled, it is shown how clearly the project would be defined in terms of space, performance, and interactions.
Finally, the chapter ends by presenting the architectural character of the project with a Concept Design, explaining the genesis of the building's shape, dimensions, spatial organization, and physical features. As this chapter belongs to the concept phase, the following ones will go deeper into the different architectural strategies that correspond to a more detailed development of the project.

Cover: FloatScapes, The Floating Pavilion
Created by the Author

04.1 VISION STATEMENT

Climate Change, as we know, poses several challenges to communities around the globe. Nowadays the provision of food, water, and energy already struggles to meet the global demand, not to mention that the situation is expected to get worse, as the population will increase in the next decades. In this context, the Floating Pavilion for Venice: FloatScapes, enters the realm of Coastal Risk and experimentation on Floating Architecture, as seen in Chapter 2.

We, as inhabitants of the world, are far from being ready for extreme weather events or any other climate change-related challenges, such as coastal flooding or droughts. In fact, as IPCC's last report explains [N 4.1], we are behind schedule to mitigate Climate Change for the year 2030. The low efforts of the countries and governments, globally speaking, are not enough, even though some tools have been lately explored to be ready for the challenges of the future.
Unprepared and fragile communities all around the globe could crumble under the pressure of natural catastrophes, famines, and droughts. Population displacement will occur (and is already occurring), with people forced to look for a new place to live.

Even though this is a likely scenario, we still have hope of changing our future for the better. The search for feasible and valid alternatives as solutions for climate change instead of going forward with the 'traditional way' is active and promising, nevertheless, it requires attention and investment to reach results beyond the theoretical approach.

Architects and engineers are doing their part, theorizing, and testing innovative alternatives to traditional cities, looking for solutions that can provide new opportunities and that can better respond to the changing environmental conditions.
In the context of Venice (Italy), for example, some precautions and

[N 4.1]
On 19 March 2023 the IPCC finalized the Synthesis Report for the Sixth Assessment Report on Climate Change (AR6).
This report contains the current state of knowledge on Climate Change and its effects, as well as an advice Summary for Policymakers.

actions, such as the 'MOSE' wall, have already been developed and are in use. These are, however, temporary solutions that only postpone problems that will inevitably reappear in the future, without really tackling the core issues. Venice, like many other cities within the LECZ, will be strongly affected by climate change and might disappear below rising sea levels in a few decades.

Developing and perfecting new technologies and models and re imagining the way we currently live on our planet, is the only possible road to producing resilient cities and communities, metaphorically preventing them from falling into the water, instead of throwing them a lifebuoy.

FloatScapes (and SEAform's work in general) is a first step in this direction: a study and development of a potential response to contemporary and future challenges, with the goal of evaluating the true potential of this idea, and at the same time, identifying its main uncertainties and open points.

04.1.1 Pavilion's Role

The pavilion's project gains a double meaning for the thesis and for the broader development project.

On one end, the design of the structure and its program offers the perfect opportunity to put to the test the starting axioms of the project, as well as the pre-established choices adopted by SEAform. Materials, shapes, techniques, and technologies must be tested and evaluated, to understand which of them are more suitable for this use and to define choice guidelines. Functional plans and ideas need to be materialized and compared. Defining a detailed project (even if it is not realized) helps to identify the challenges and the obstacles,

distinguishing between good practices and problematic ones, and bringing to the surface aspects that otherwise would have been left untouched.

On the other side, the choice of designing an expositive pavilion was not defined by chance but represents a significant step for the development project. A pavilion, particularly if connected to a large event (as would be the Venice Art and Architecture Biennial), would give the chance to reach thousands of people, which would be directly visiting the structure. This would provide the opportunity to directly convey the desired message and the vision of our research group. The pavilion represents a manifest for floating architecture itself, showing its benefits and its potential, for SEAform and its model, but also for all the methods and technologies involved in its realization and functioning.

Here appears significant to strive for a highly symbolic and emotional design. The principle that floating architecture can be a low-impact and green practice, compared to traditional building techniques, must be conveyed by an equally green design and outlook of the structure. In this context, adopting more communicative images, materials and components becomes an important step of the project, as it helps to better convey the message and to create awareness. Renewable energy production and use, green and low-impact materials, prefabricated components and modular design, innovative systems and technologies, and attentive resource and waste management are all useful tools to create a sustainable and innovative image for the project, contributing to defining a positive and functional aura around the pavilion and its experience.

Materials, solutions, and practices would be implemented in the building, directly visible and touchable by the visitors, that would be put in contact with the principles of FloatScapes and with its methods.

Therefore, the pavilion would promote itself to a large group of interested tourists, potentially reaching researchers and investors. But, more than anything, it would present itself to the entire community as a promising innovative solution, attempting to transmit to the visitors that life on the water is possible, with the right development, and that it has great potential in presenting sustainable solutions for any city, neighborhood, or even any single building that adopts it.

The main role of FloatScapes, therefore, is to attempt to build a metaphorical bridge between people and these complex topics, promoting awareness of the problem and trying to convey the message that some responses exist and we, as a global community, are not necessarily at the mercy of the events.

04.1.2 Key Objectives

In this scenario, the design of this floating architecture project has the principle of being capable of providing an adaptive and feasible alternative for coastal urban areas in which Coastal Risk is imminent. FloatScapes and SEAform represent a step forward on this topic, and the specific proposal of our research group is the concrete communicator of our ideas and principles.

Once SEAform's model is developed and matured, it could be adopted diffusely as a starting point for floating projects, serving as a functional and structural example on which designs could be inspired and influenced by the research behind the project and the flexibility that the systems present when other types of floating buildings need to be designed and projected. It could be said that the main intention behind all these objectives is to give an active and

concrete contribution to the development of Floating Architecture for the sake of coastal communities, envisioning a brighter future where floods are easily resolved without jeopardizing the society and the settlements that have been there for decades.

Specifically, with the FloatScapes proposal, the group aims to reach the following key objectives:

- Promoting Awareness of Climate Change and Coastal Risk (particularly in the European context).

- Share research knowledge and awareness, specifically for the Venice case study.

- Explore and put to the test construction technologies and techniques like Engineered Wood for the maritime context.

- Develop a 'Know-how' competence in terms of Floating Architecture, to be shared with SEAform and with the entire community.

- Explore potential responses to Coastal Risk that could be scalable and replicable, helping cities and communities to face climate change and its consequences.

- Explore alternatives on how to provide food, water, and energy sources, at the same time growing and diversifying the offer, lowering the pressure on land-based production chains.

04.2 FUNCTIONAL FRAMEWORK

- *Users, Activities, and Required Spaces*
- *The Experience*
- *Off-Grid*

FloatScapes is designed to be an expositive pavilion, connected to an already-established expositive event, as it could be the Venice Art and Architecture Biennial (or any other analogue institution). The pavilion is to be intended as one of the possible experiences offered by a large organization and would be inserted in a longer visit route. Visitors of the Biennial, or even of Venice in general, could experience the pavilion in parallel with the visit to the city, of the Venice Arsenale, or during a tour of the lagoon.

The idea is for the pavilion to act as a prototype for floating architecture, hosting examples of those activities that could ideally be conducted on the water in the future. Starting from food production and processing (from the harvest to the cooking), the visitors will have the opportunity to see and experience energy production and careful water storing and management as well, occasionally taking an active role in these activities.

Through the visit to the expositive spaces, the guests could learn about (and understand) the peculiarities of floating architecture and the SEAform's model, while, at the same time, being completely immersed in an active reality, where technologies and techniques are implemented and tested, right before their eyes. This aims to produce a more immersive and comprehensive experience, which would ideally touch, on multiple levels, whoever sets foot on the pavilion.
The pavilion visit, being only reachable by boat, has to be organized with guided tours, as the space is very limited as well as the length of the visit. Visitors would, therefore, program their tour ahead of time and reach the pavilion in groups, with the help of a tourist guide, which will accompany them during the experience.

Starting from the definition of the key actors of the project, are defined the expected characteristics of the building, in terms of envisioned

activities, required spaces, elements and performances.
The aim of this paragraph is to explain how the author defined the functional program of the pavilion, describing the tour experience, how the pavilion would be reached and organized, and, on a broader scale, how the key aspects of the building activity would function and be organized.

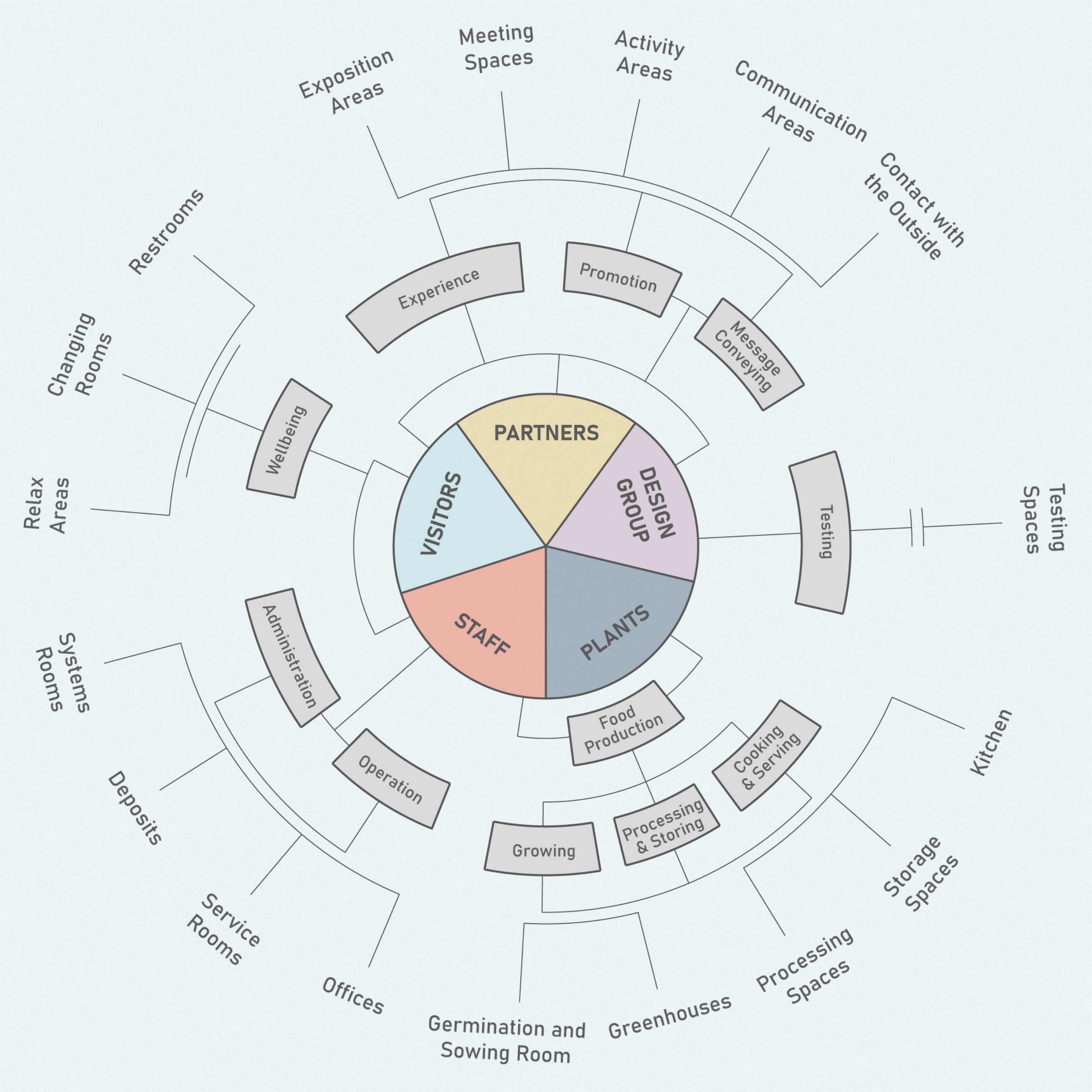
04.2.1 Users, Activities, and Required Spaces

Inside FloatScapes converge a multitude of actors and users, each of them with different characteristics, goals, ideas, and, particularly, different needs.

Figure D.1 reports the analysis and reasoning process that starts from the definition of the involved players of the structure (users) and brings to the individuation of the complex of activities that the structure hosts, and finally to the list of required spaces.

The first instances are brought by the visitors and the staff, the key and main users of the structure and the people that materially give life to it. Their interest here is respectively to live an interesting and immersive experience (visitors) and to provide that experience in the best way possible (staff).
However, the involved players are not limited to the active users of the pavilion. Academic and commercial partners of the project find here a place where to test their ideas and products and the perfect stage to show and promote their work.
The FloatScapes reality itself has a strong interest connected to the structure, which not only represents the result of a design process but also a prototype of the SEAform model, the concrete application of MORE Lab's technology, and the perfect opportunity to convey a strong message to the visitors, about the research group, the

Right: Figure D.1
Reasoning process for the definition of the required spaces and elements of the building, starting from the individuation of the active players of the project and the activities they would conduct inside the pavilion.
Source: Created by the author.



development of this system, floating architecture, and the risks of climate change.

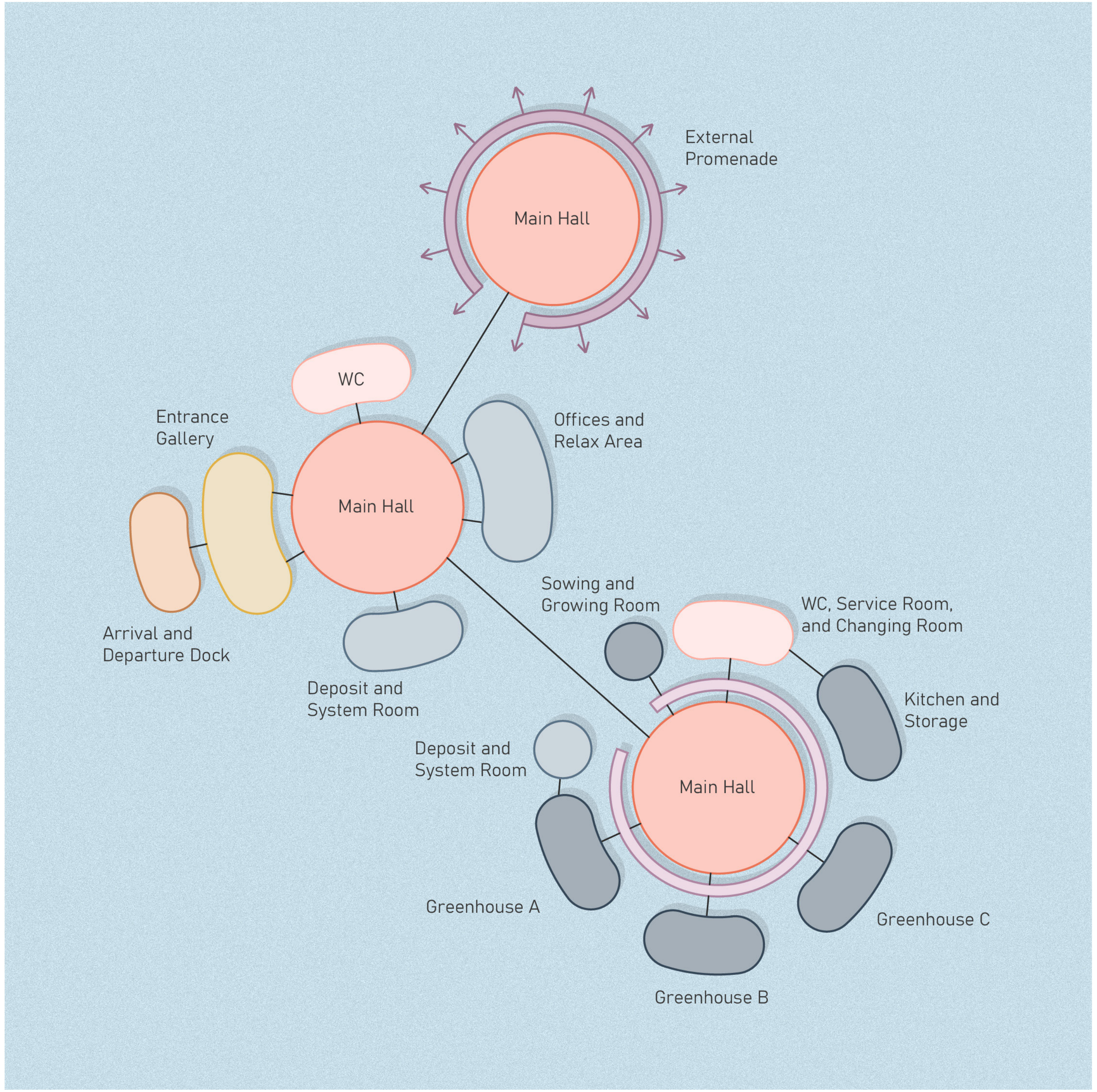
All of these different points of view, come with particular needs and pose different requirements to the structure and its design, which has to be capable of satisfying all of them and condensate them into a single end result, satisfying all the initial goals.
Materially, this translates into a multitude of required performances for the structure, which has, for example, to provide sufficient spaces for a guided tour, allowing at the same time the correct operation of the building, with a strong communicative design.

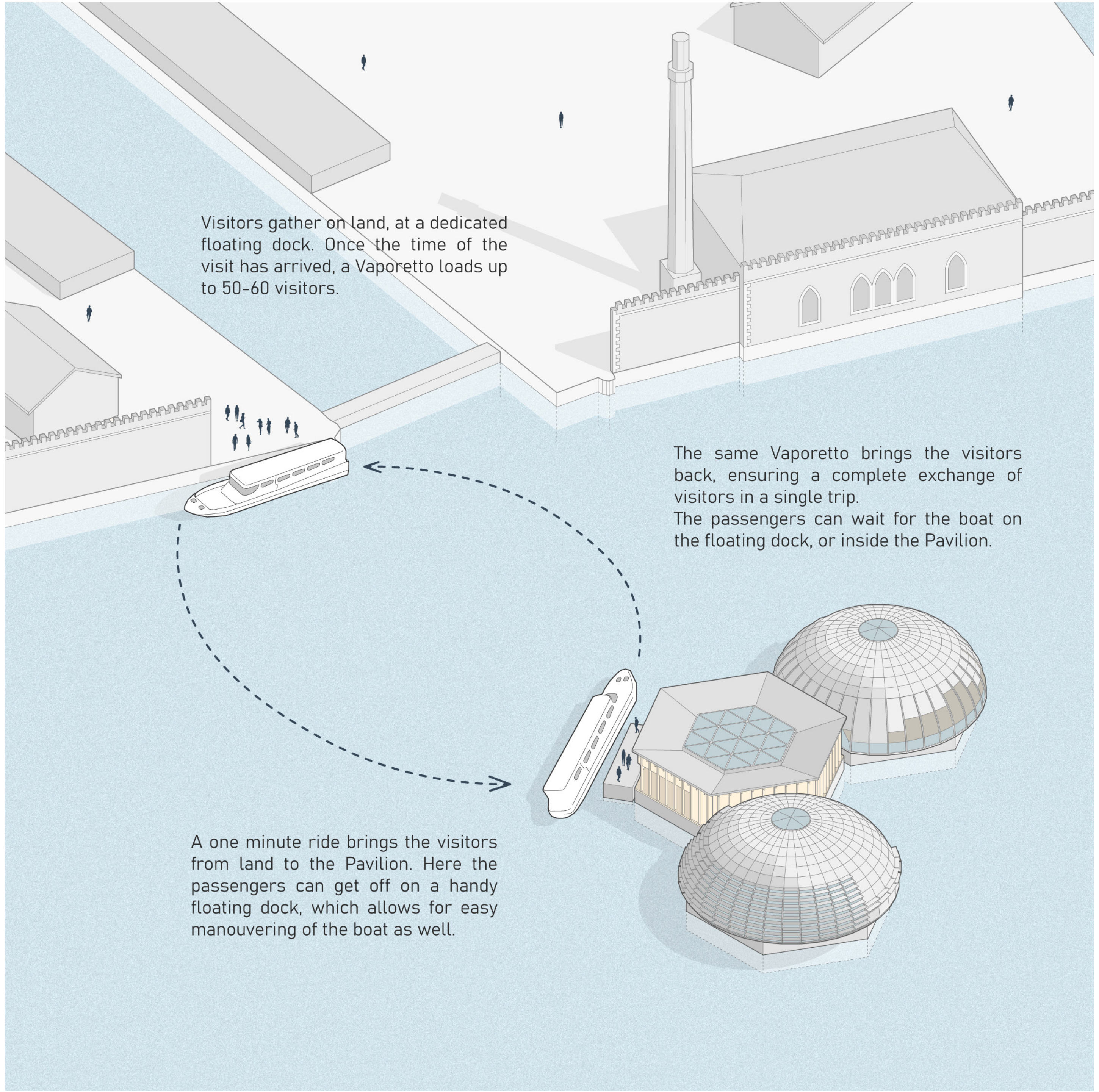
Here, also the plants are indicated as one of the active users of the pavilion, since they bring strict requirements to the structure, often completely different from those brought by the human users.

Figure D.2 contains a representation of the required spaces, following the approach of a bubble diagram. The previously identified rooms are represented here as simple volumes, with no specific architectural character, reporting only relative position, connections, and relation with the exterior.
Three main central rooms, directly connected to each other, define the core of each platform, generating a first main organization level. Around these, are articulated all the other spaces, defining if these are open to everyone or with access limited to the staff members.

This visualization procedure allows us to understand how the required spaces could be divided between the three available platforms, and how they could be connected to each other. Finally, this opens to the following, more detailed, analysis of the paths and visit tours inside the pavilion and provides a starting point for the definition of the floor plan of the structure.

Right: Figure D.2
Bubble diagram for the definition of the spatial organization of the required rooms and elements of the structure, to understand position, connections, and relations.
Source: Created by the author.





[N 4.2]
Vaporetto: traditional boat used for public transport in Venice, using the navigable canal of the city.

Left: Figure D.3
Standard path to reach the Floating Pavilion and corresponding path to leave and return to land.
Source: Created by the author.

04.2.2 The Experience

Reaching the Pavilion

The movement of people to and from the pavilion represents a complex logistic challenge.

Figure D.3 represents the standard path to reach the pavilion and describes the average timings and numbers of both the tour and the trip. The dotted red line indicates the standard path of the dedicated Vaporetto, while the yellow dotted lines represent the potentially diverted public water transport lines.

Ideally, during a single day, the pavilion, which is capable of hosting approximately 50 visitors at any time, would welcome multiple visit groups, each following a mostly standardized tour. At the end of every visit, therefore, 50 people need to be picked up from the pavilion and brought back to land. Simultaneously, as many new visitors need to land on the platforms, to start the following tour. Thus, a continuous turnover of visitors has to happen for the pavilion to properly function.

To ensure reliable transportation of the visitors, FloatScapes could rely on a private Vaporetto [N 4.2], which, every half an hour, would make a trip to the platform, transporting the visitors. With this kind of organization, the pavilion might require a land reception point, where the visitors would gather and be introduced to the project and the tour. The departure dock would in this case be situated in the terminal part of Venice Arsenale, reachable by foot from the city.

This method would have the advantage of being extremely reliable since the Vaporetto would be completely dedicated to the pavilion and always available. This would also provide more flexibility for the tour timetables, allowing for changes and last-minute variations or delays. However, it would probably come with high costs, requiring at least two additional full-time employees (one to operate the boat and one to interact with the passengers).

An alternative would be to include the pavilion in the already existing and well-developed (thanks to the strong touristic character of the city) public transport grid. The water lines n. 4, n. 5, n. 7, n. 10, and n. 22 transit a few meters off the chosen location. The pavilion could be transformed into one of the stops for the "Vaporetto lines," completely relying on those to transport the visitors.
The necessary space for the gathering of visitors would be represented by the existing stops. To solve the problems linked to the unreliability of timings of public transport, the central platform should be used as the final gathering area and as a waiting point for the visitors that await to leave or begin the tour.

This solution could be less costly and better tested and tried. The actual feasibility of the system would have to be evaluated and discussed with the public transport company.

Upon leaving land, the visitors get in close contact with the water and the Lagoon. The brief boat trip that escorts them to the pavilion, offers the guides the opportunity to introduce them to the tour. This represents a symbolic passage as well, allowing the visitors to leave the chaos of the city, and to completely dedicate themselves to this unique adventure.

Once they reach FloatScapes and land on the front floating dock, the boat leaves, and the group enters the central platform and begins the visit.

Living the Pavilion

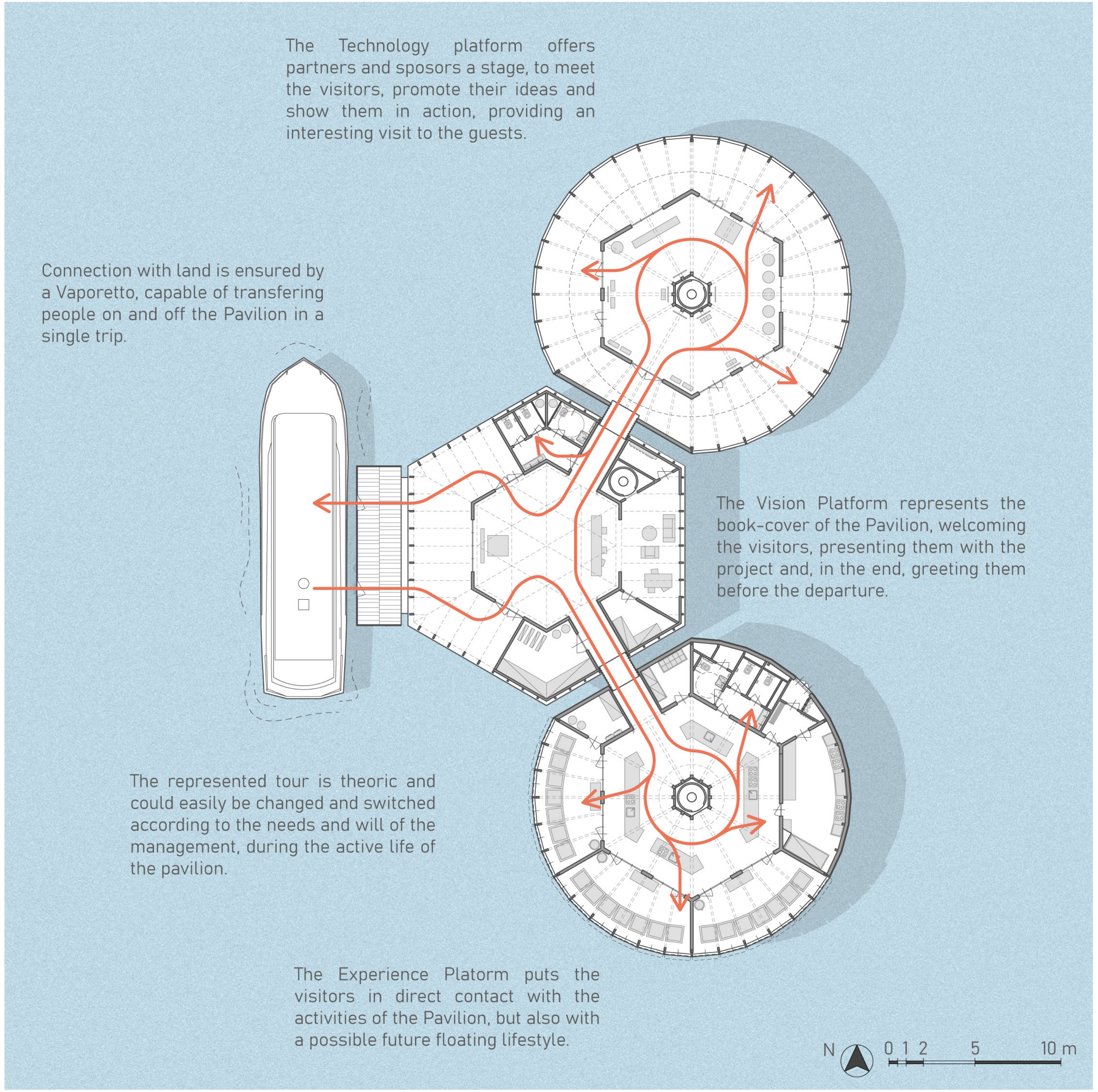
Figure D.4 (next page) contains the pavilion floor plan, highlighting the envisioned standard visit path for the guided tours, representing, therefore, how the average visitor would experience the structure, from arrival to departure.

The arrival and departure from the Pavilion happen through a small independently floating dock, similar to the traditional Venetian public transport stops. This is anchored to the central platform, along the coast-facing side, to ensure easy maneuvering and docking for the passenger's boats, which can maintain a safe distance from both the pavilion and the underwater anchor cables. This also provides waiting space for the loading and unloading of the Vaporetto.

Upon arrival, visitors enter the pavilion through a front portico, which opens to the sea and gives a first glance of the interior, while offering a covered shelter. This introduces them to the central main hall, through a double side entrance, which can divide entering and exiting fluxes, that might cross each other at the end (and beginning) of a tour.

The hexagonal central hall hosts an introduction space, where the visitors are presented with FloatScapes and the activities that compose the tour. From here, a long hallway leads to the Experience Platform, providing a sheltered passage through the interstice between the platforms.

The Experience Platform, dedicated to the growing, processing, storing, and serving of food is divided into two primary areas. A central hexagonal space welcomes the visitors, where they are free to wander, interacting with the staff of the pavilion, which would be



Left: Figure D.4
Pavilion general floor plan and definition of the main visit tour path, starting and ending in the Vision platform.
Source: Created by the author.

conducting demonstrative activities, both in the surrounding rooms and on a hexagonal table. Around this main area, six perimeter rooms host the functional spaces of the platform: three glass greenhouses, a kitchen, and smaller service rooms. Here the staff conducts most of the platform activities. Access to these rooms is forbidden to the visitors, which are however in close contact with them, through transparent walls, that allow for an easy and complete view of everything that is happening inside.
The central wooden beam cluster encloses the elevator, which connects to the underwater floor, and invites the visitors to go around it, producing a circular path, which brings back to the hallway.

The guests spend here 15-20 minutes following the circular hall. Rotating around the central pillars they encounter all the phases of floating food production. They observe staff members that take care of the vertical farms, sow and fertilize the seeds, harvest the crops and process them. Additionally, during each tour, the staff offers the opportunity to take part in some of these activities, transferring them (if possible) inside the central hall, to share them with the public.
Finally, the visitors are also offered a little snack/drink prepared (in the kitchen) with the platform products, completing the sensitive experience.

From here, the visitors traverse the central platform again and, through a twin hallway, reach the third northern Technology Platform, dedicated to exposition spaces for partners of the project.
This platform presents the same space organization as the Experience one, with a central hexagonal space, which holds the main exposition area and can be visited along a circular path. Here partners and sponsors can not only expose their products and ideas, but also directly interact with the visitors, potentially organizing small events, or actively promoting themselves by talking directly to the guests.

In this platform, the peripheral spaces, connected to the interior through glass walls, are open to the exterior and form a circular gallery/portico. Visitors can walk on this promenade, which directly looks out on the lagoon and puts them in close contact with the water and the winds, offering a view of Venice and, on the horizon, of the sea. This area tries to build a strong connection between the building and the water, allowing people to enjoy both of them at the same time.
Once the visitors have gone around both the inside and the outside of the platform, they can retrace their steps, through the hallway, to the Vision Platform. Here they are greeted by the staff and can wait for the boat to arrive, before returning to land.

The idea is that this route would allow for multiple tour groups to visit the pavilion simultaneously, accompanied by tourist guides, which would explain the features and functioning of the structure and, at the same time, regulate the "traffic" inside of the building.

The spaces try to provide a mixed experience, allowing entrance in some of them and only permitting a look in others. Both inside and outside define the experience of this pavilion, allowing for complete functioning even during rainy days, without giving up on a strong connection with the water.

04.2.3 Off-Grid

The pavilion, floating 50 meters off the coast of Venice, is completely isolated from the land and not reachable by foot or by car. This is a great challenge for the program, which forces it to reinvent every functional aspect of the pavilion. This is not a traditional building and cannot be treated as one. Every movement of people or things to the platforms or from the platforms must happen by boat.

The fact that the project is located in Venice is a blessing from a functional point of view. Venice is a city where most of the goods' transport and public services, such as public transport (which relies on the traditional "Vaporetto", as the standard vehicle), ambulances, firefighter and police corps, garbage collection or taxis, already travel by boat, to be able to reach the neighbourhoods surrounded by water. This means that the pavilion could, to a great extent, become part of an already existing water-based system.

However, being situated in the middle of the lagoon waters, the pavilion cannot be linked to traditional urban services grids but requires different solutions to provide all the necessary services to the building.

Piping System

Since connecting pipes through the water would be highly problematic for both the water traffic and the pipes themselves (requiring costly components and intense energy use for pumping, to compensate for the distance and the extremely low altitude of the platforms), fresh sanitary water can't be provided by the aqueduct and waste waters can't be simply directly dumped in the traditional sewer system. Water tanks are needed to make up for this.
This also highlights the strong necessity for a reliable system of loading and unloading the tanks, which is here solved with a service boat, capable of transporting fresh drinkable water to the pavilion (almost every day) and discharging the waste tanks and transferring to land black and grey waters to be properly treated.

This off-grid approach would be needed also for goods' transportation to the pavilion, providing anything that could be needed on the platforms, from food to agricultural nutrients or tools and equipment.

Garbage disposal could, instead, rely on the already existing collection system of the city, requiring the authority the introduction of a new stop point on the pavilion.

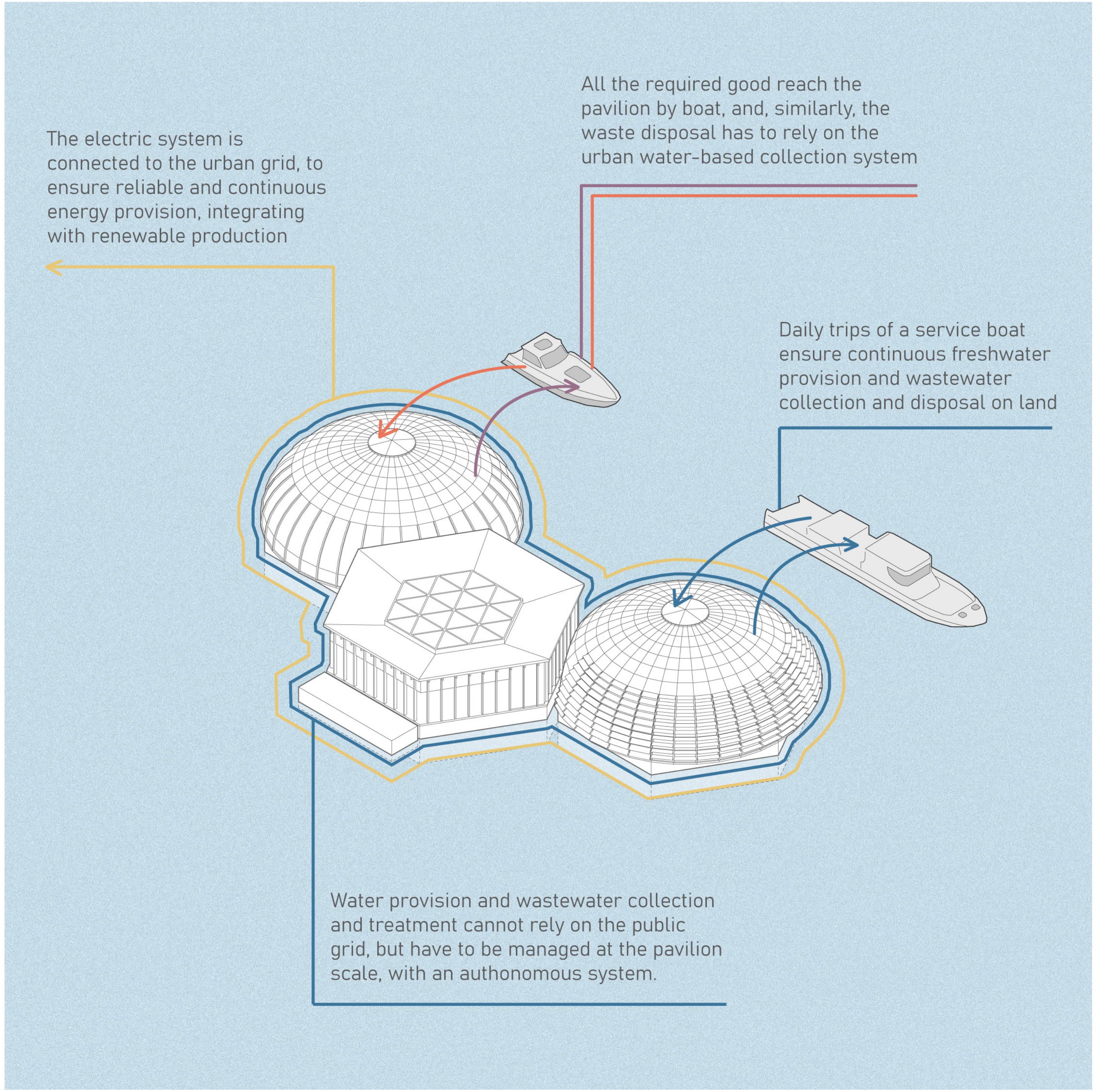
Again, given the difficulty of laying pipes in the water, cooking and heating cannot depend on natural gas, which would require a connection to the urban grid, or large fuel tanks, with great costs and risks. Instead, it is necessary to find alternative solutions. In this case, relying on electricity-based cooking and conditioning methods allows detaching from the use of carbon-based fuels, directly using, instead, energy from sustainable and renewable sources.

Electric System

The provision of electricity, on the contrary, makes for the exception. The electricity requirements of the pavilion are significant since they have to cover the demand of intense activities with a large number of users. To ensure energetic autonomy for such a building would be necessary large renewable energy production systems, as well as enormous storage batteries (and efficiency-improving ones). This would require large investments and a lot of space, which is not necessarily available on limited platforms. The building is therefore connected to the urban grid, through aerial or underwater cables, greatly reducing costs and risks, and reliably providing energy. Renewable energy production can still be integrated into the pavilion, covering part of the building's demand, and even exporting the eventual surplus.

Figure D.5 visualizes the complexity of the connection to the existing urban service grids, and the need to envision unusual solutions for many required services, such as freshwater provision, and waste management.

Right: Figure D.5
Visualization of the Off-Grid approach for the service provision on the Floating Pavilion.
Source: Created by the author.



04.3 DESIGN COMPOSITION

- *Design Strategies*
- *Compositive Concept*
- *Modular Composition*

04.3.1 Design Strategies

Water Design

A floating building poses a much harder challenge, from a compositive point of view, than traditional land buildings.

On one side it gives no true limitation to the imagination, as open water is a completely “white canvas”, where no preexisting elements drive toward certain design choices. No adjacent buildings, no road system, and no nearby clear architectural reference offer a starting point for the project.

The standard elements that generally orient architectural designs here are not present. This means that almost any compositive choice becomes viable, and not many can be clearly defined as “wrong”. Some other rule has to be adopted.

On the other hand, the aquatic environment is much more prohibitive than land locations. The absence of obstacles and nearby objects leaves floating buildings much more exposed to natural elements. Sun, water, and wind all have strong effects on the pavilion, which has to respond to all of them with its design.
This, on the contrary, poses strong requirements to the chosen design, which has to be resistant to the environment and resilient.

Design Guidelines

Here are defined some compositive guidelines, which represent the key aspects that were taken into account while defining the concept design of the Floating Pavilion, and guided the definition of shape, volumes, and materials.

Main Design Strategies:

- Choose shapes and volumes capable of better responding to the open aquatic environment.

- Adopt an architectural language and materials capable of conveying a message of sustainability and innovation, with captivating elements and a positive aura.

- Choose shapes and materials that recall and re-elaborate some elements of traditional Venetian architecture, to better suit the city atmosphere.

- Strive for a design capable of mitigating the negative effects of the building on the surrounding ecosystems (described in detail in paragraph 2.3).

- Adopt designs capable of working with the environment and better exploiting the resources provided by the aquatic location.

These principles are then elaborated and interpreted in the following chapters, and form the base for the specific decisions of the project.

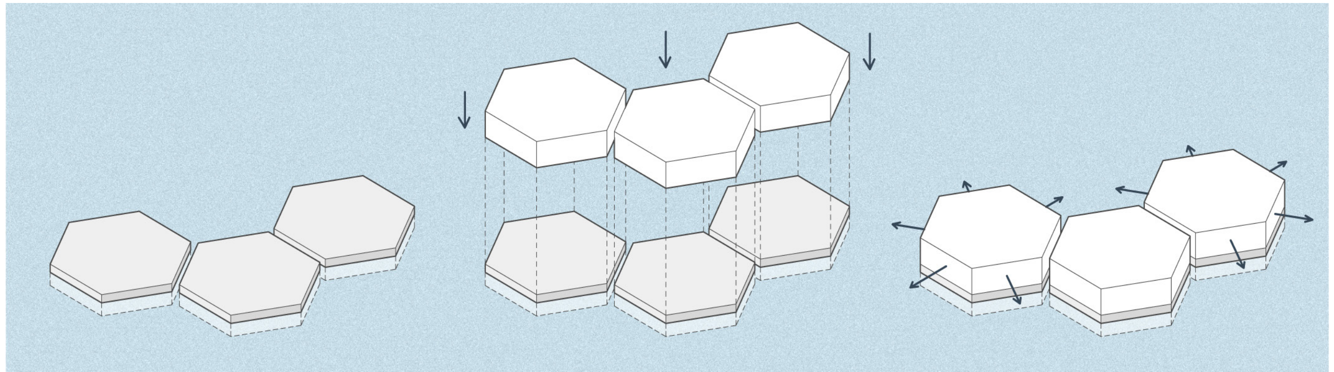
04.3.2 Compositive Design

The hexagonal shape of the floating platforms posed another strong indication for the design. With this kind of available footprint, the chosen geometry of the pavilion was strongly oriented toward concentric and symmetrical shapes.
The final design comprises two different solutions, one adopted for the central Vision Platform and the other used in both the Experience and the Technology platforms.

The three hexagonal platforms offer the initial footprint for the pavilion, providing an unusual base, which cannot be solved with traditional rules, and, particularly, refuse any easy interaction with the preferred rectangular system of land architecture, which simply does not suit the footprint, as it would result in poor space efficiency. Symmetry and concentric play, therefore, an important role, as allow for a good use of the available room, and better suit the new environment and its requirements.

The central platform acts as the front entrance and main facade of the entire building, recalling the image of the Venetian portico. Here is the interface between interior and exterior, and here people can find refuge, in an area which is not inside nor outside.
Wooden pillars, with regular spacing, transmit vertical loads and sustain the roof, generating a basic rhythm for the platform, defining a module, and highlighting the openings.
From every direction, three sides are visible (except for those that compose the contact with the other platforms), offering a complex outlook of the structure, and declaring the unusual concentric system.
The hexagon defines the inner spaces as well, starting from a central hall and extending to the peripheral rooms. A single-pitched roof provides a cover which can't be seen from the outside and maintains a pure image for the central platform.

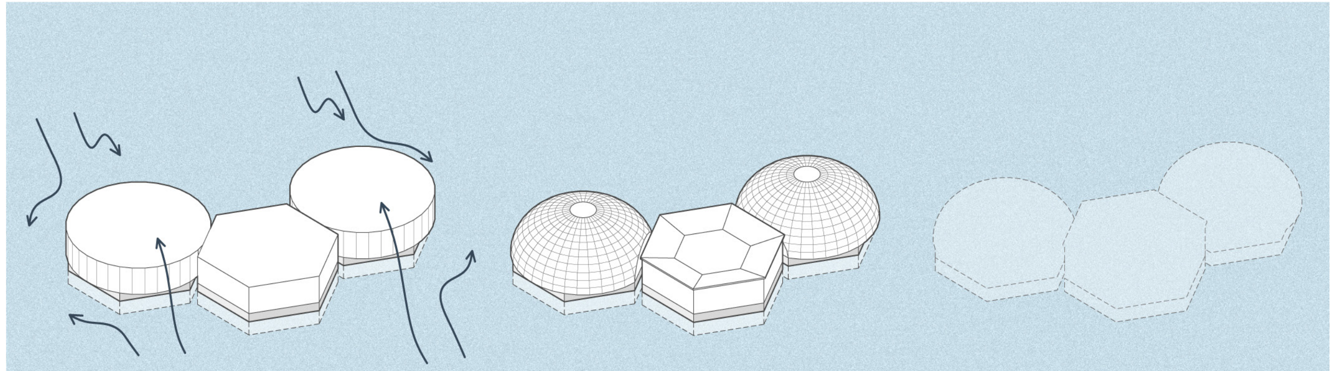
The simplicity and strong geometry of this first volume, are counteracted by the much softer volumes of the two lateral platforms, which embrace the entrance from the sides.
The Experience and Technology platforms, articulated around the same inner hexagon, present themselves as two twin domes, which overcome the limitations of the hexagonal footprint and strive for a more organic shape, capable of better suiting a more fluid environment, such as the lagoon.



The dome presents an extremely tight and uniform shape, perfect to realize a simple external surface, capable of responding to external challenges. The image of the domes is extremely regular and offers a profusion of transparent (or empty) surfaces, allowing for a strong connection between inside and outside.

Figure D.6 reports the key steps of the concept definition, which brings from the starting hexagonal bases to the end volumetric result of the pavilion, trying to highlight the aim of the compositive choices that define the shape. No specific detail of the structure is reported here, as all of them will be described, discussed, and motivated in the following chapters, allowing for a more complete and valuable explanation of the design process.
The compositive inspiration comes from the religious architecture tradition of Venice, particularly from San Marco church, arguably the most representative building of the city. Just as in the Basilica, here domes, arches, and curves, encounter and come to terms with straight lines and polyhedric shapes, producing a new composition, where geometry plays a key role.
The richness, colourfulness, and complexity of surfaces that

Top Left and Top Right: Figure D.6
Compositive concept of the Floating Pavilion: FloatScapes.
Source: Created by the author.



represent a key representative character of San Marco and Venice in general, here disappear and are substituted by clean elements and simple surfaces, which are expected to better interact with the water location. FloatScapes aims to present a contemporary and communicative image, which somewhat distances itself from the image of the city while maintaining a strong and significant connection with traditional architecture, its shapes, and principles.
The following images represent the pavilion in its entirety, to provide a first outlook of its final image envisioned by the author.

Figure D.7 (following page) contains the basic floor plan of the pavilion.
Figure D.8 (following page) represents a front view of the main western facade, where the entrance is located, useful to understand the image provided to the visitors and to the city.
Figure D.9 and Figure D.10 (following pages) contain two cross section views of the entire pavilion, passing through the center of both the Technology and Experience Platforms, providing a definition of the internal volumes of the two typologies of the platform.
Figure D.10 and Figure D.11 (following pages) report two isometric axonometric views from above, during the day and the night.

Figure D.7
Floating Pavilion Floorplan.
(No specific Scale)
Source: Created by the author.

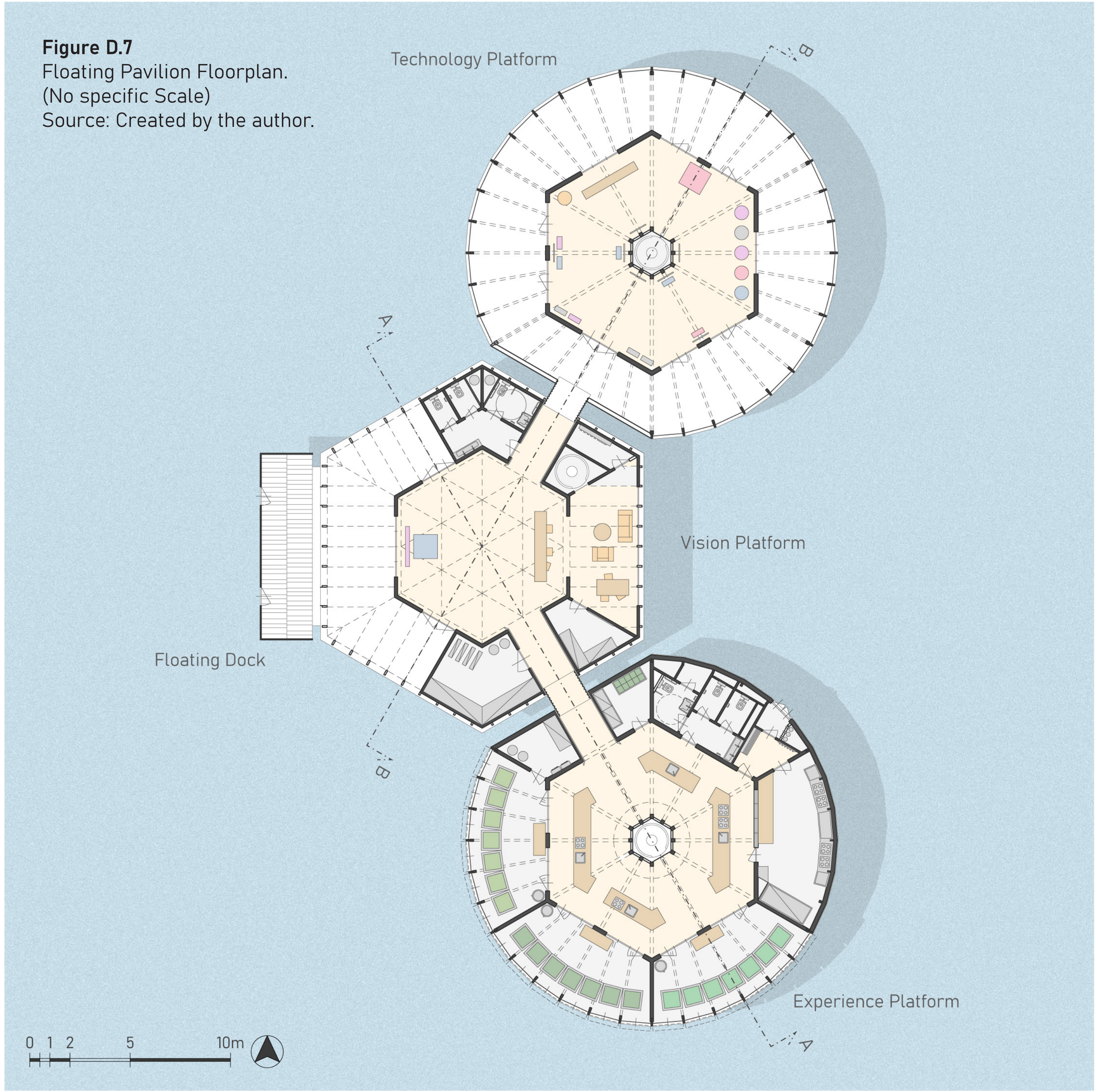
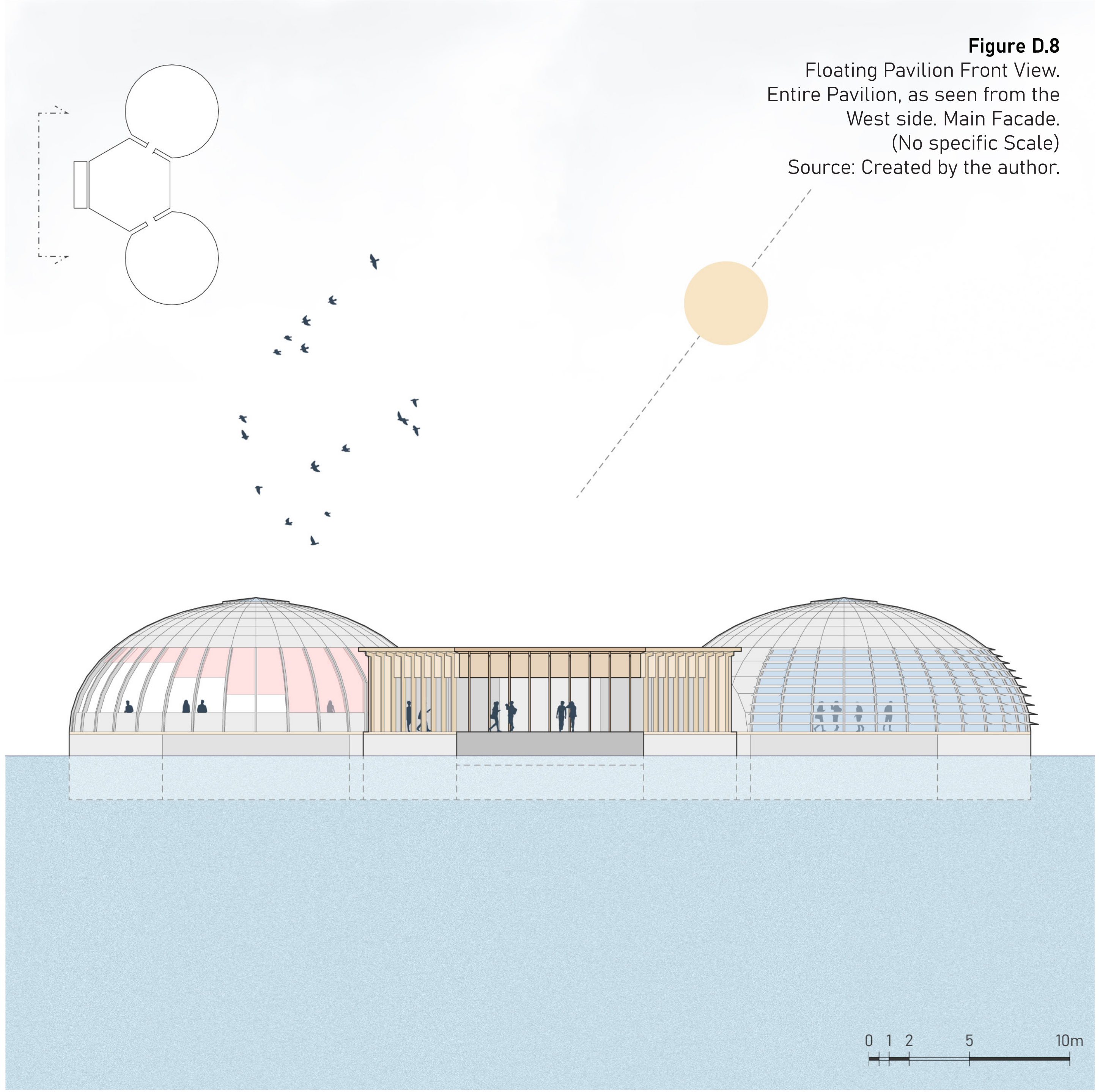


Figure D.8
Floating Pavilion Front View.
Entire Pavilion, as seen from the
West side. Main Facade.
(No specific Scale)
Source: Created by the author.



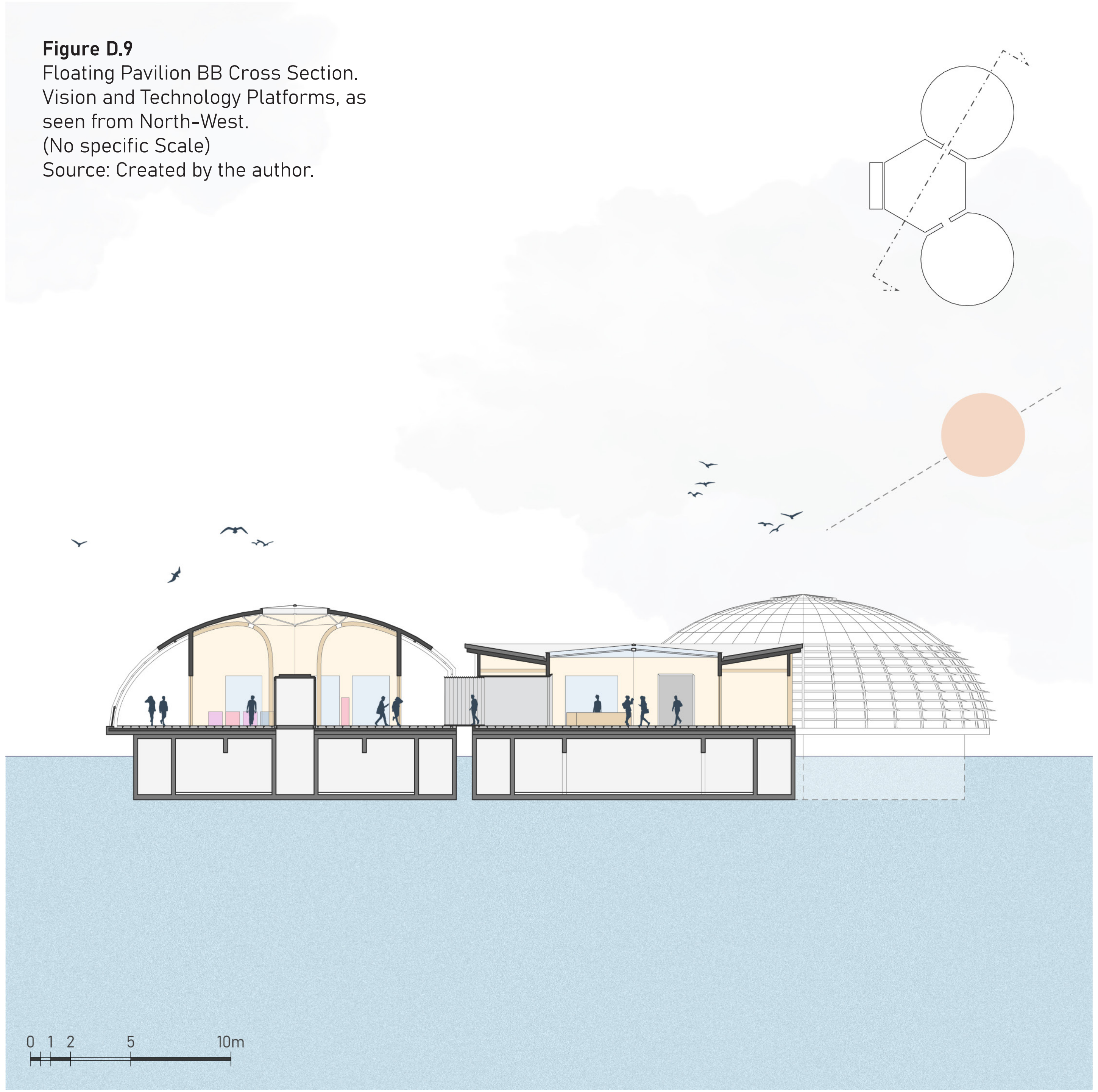


Figure D.9
Floating Pavilion BB Cross Section.
Vision and Technology Platforms, as seen from North-West.
(No specific Scale)
Source: Created by the author.

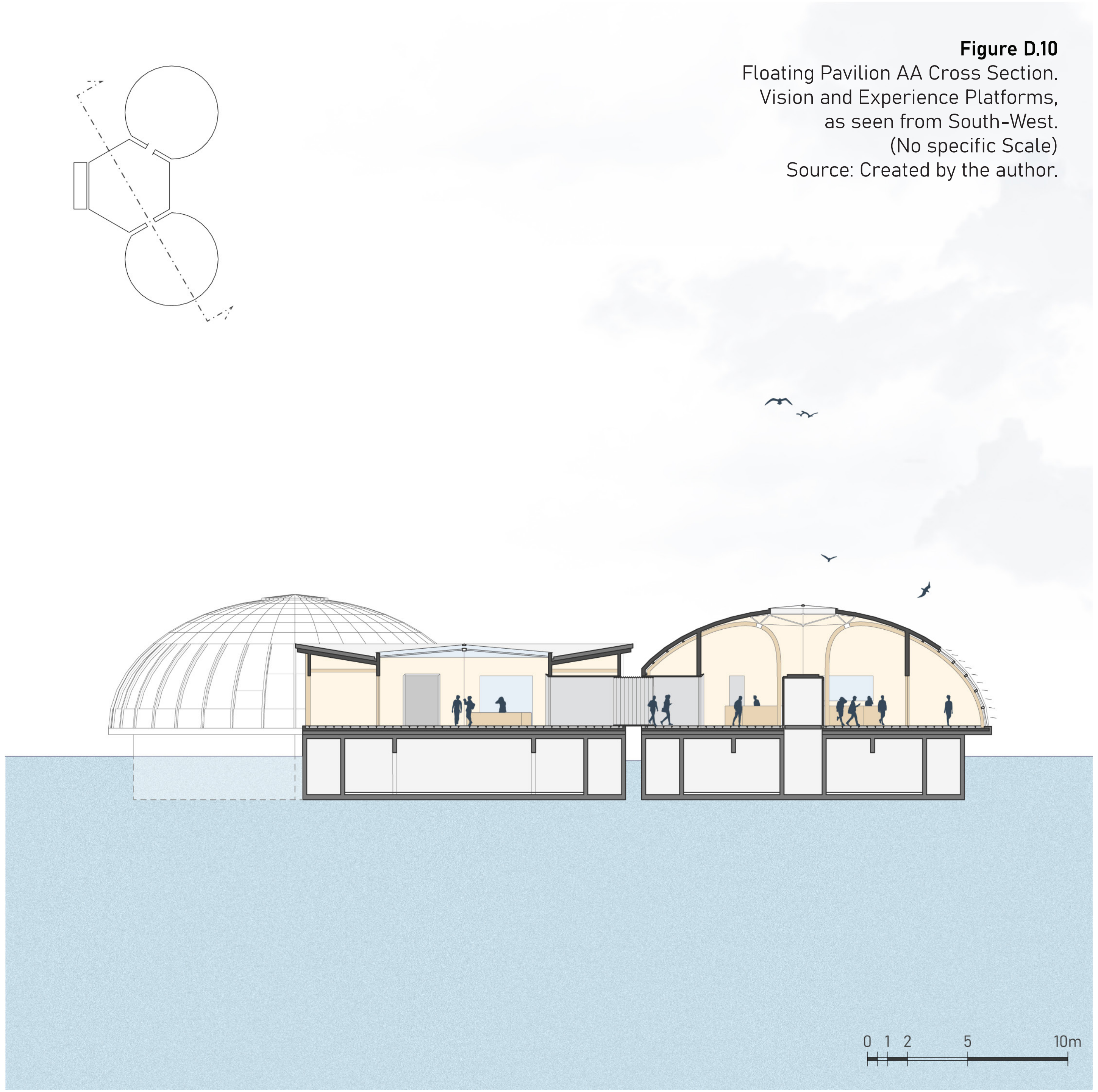


Figure D.10
Floating Pavilion AA Cross Section.
Vision and Experience Platforms, as seen from South-West.
(No specific Scale)
Source: Created by the author.

Figure D.11
Floating Pavilion aerial view from South-East (Daytime)
Source: Created by the author.

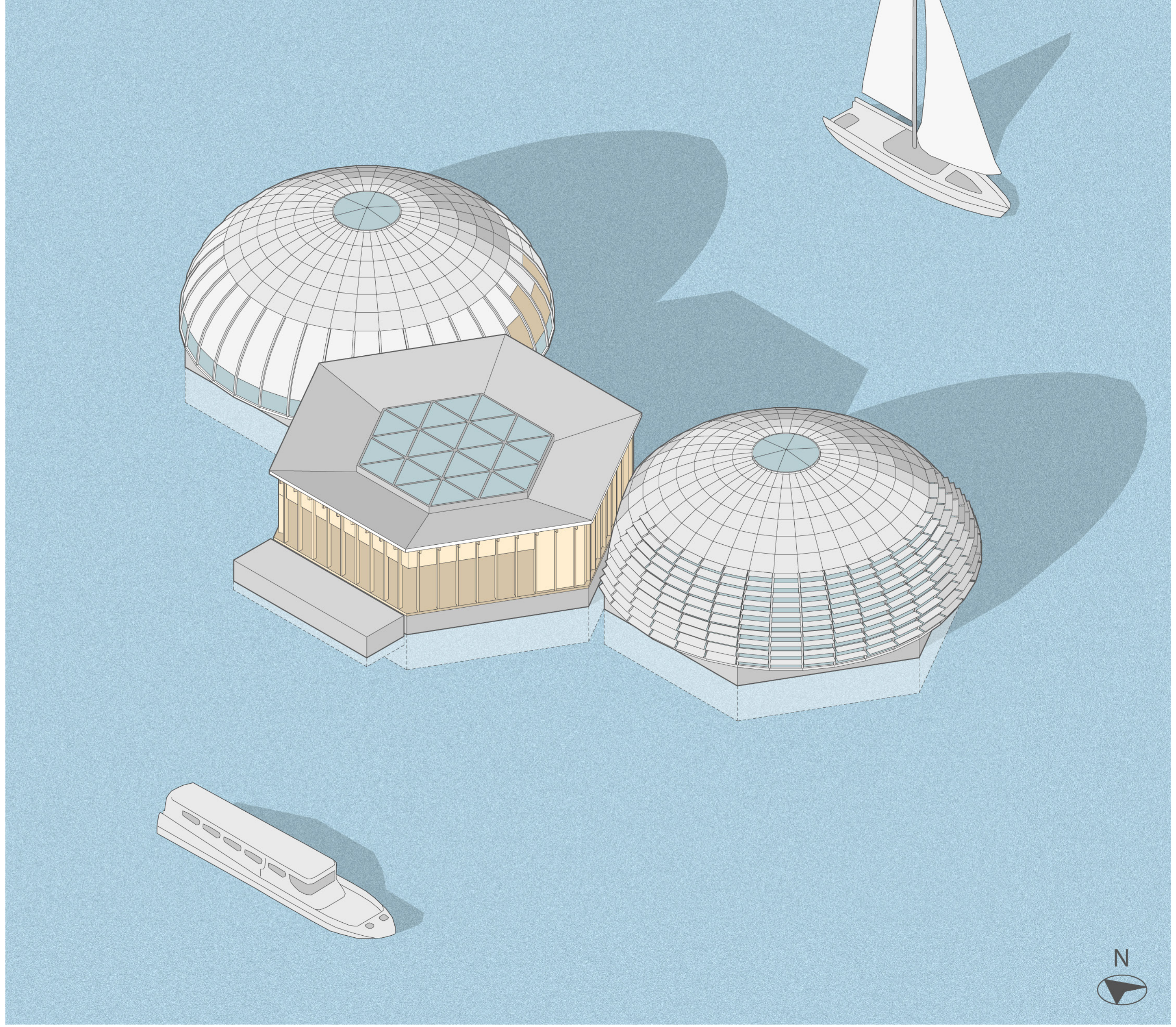
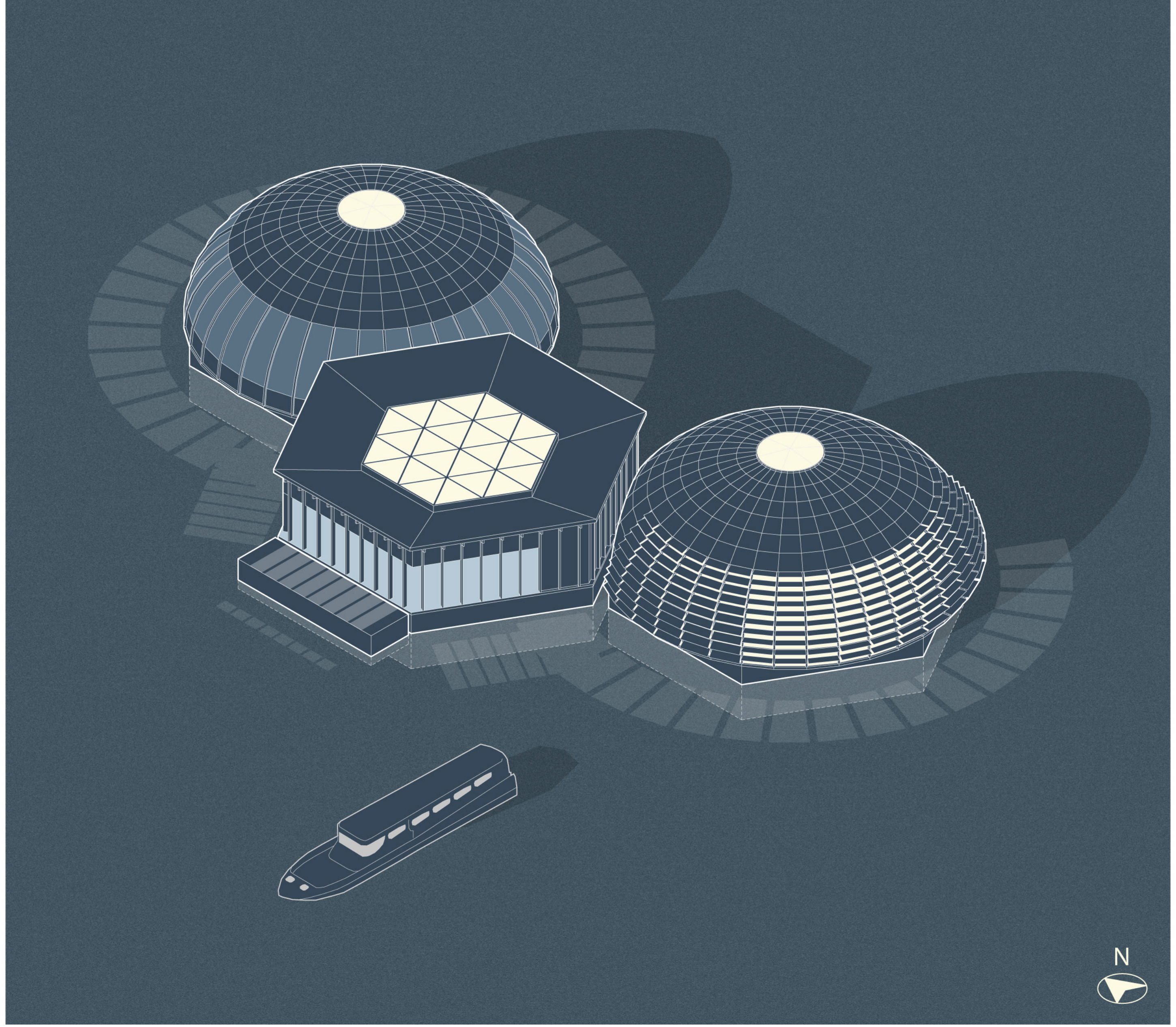


Figure D.12
Floating Pavilion aerial view from South-East (Nightime)
Source: Created by the author.



04.3.3 Modular Composition

As previously said, quicker and easier building site procedures could significantly reduce the impact produced on the local ecosystem, as it would minimize in-situ disruptive activities. Furthermore, here construction has to happen on water (or potentially inside a shipyard), with much more complex procedures and logistics, compared to land architecture.

Prefabricated modular construction becomes the perfect tool for this purpose. Most of the loud, damaging, and potentially dangerous tasks can be carried out inside the production plant, in a controlled and more efficient environment, limiting emissions and waste, and ensuring a high-quality final product.

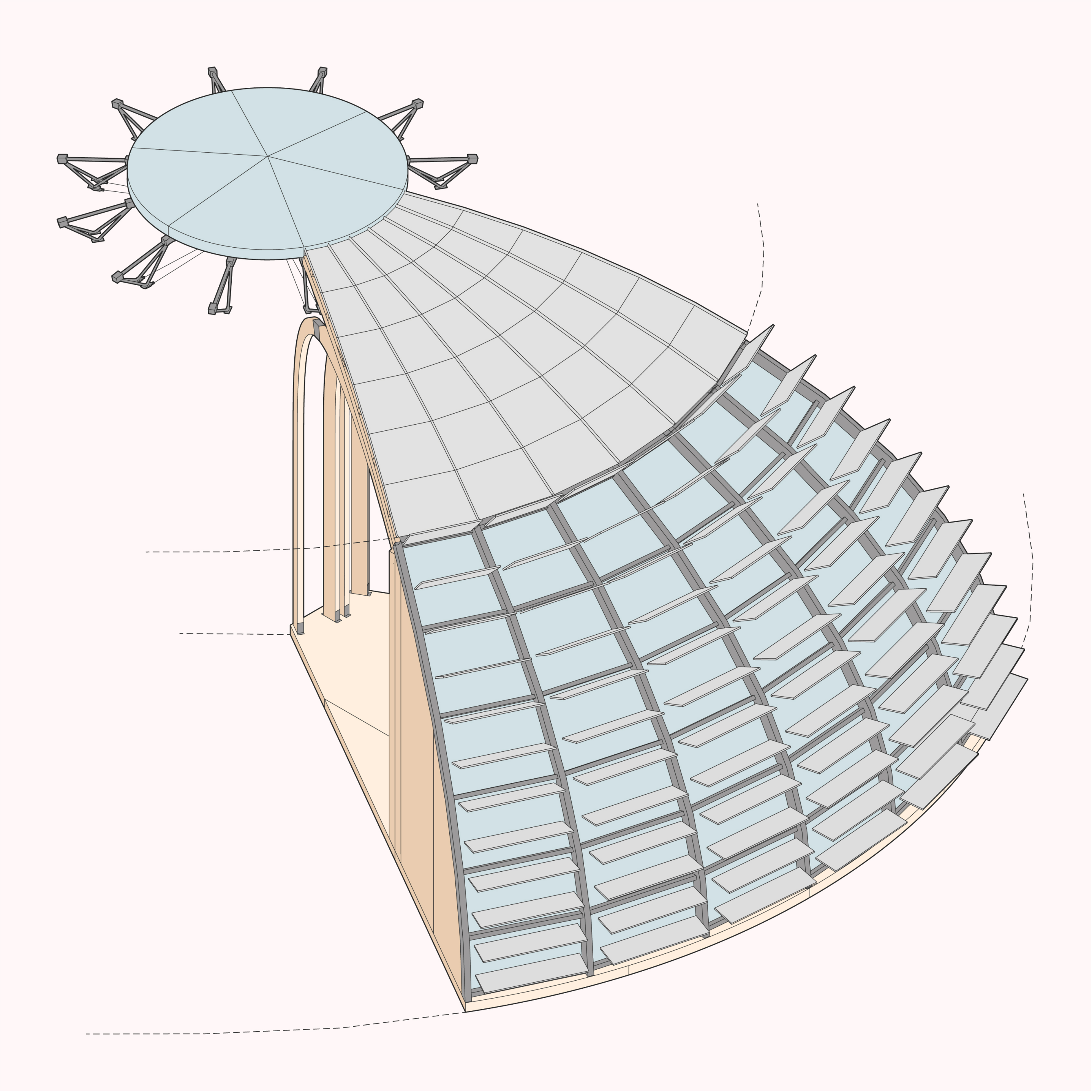
Each of the platforms is divided into modules, prefabricated in the plant, already comprising of most the key components and systems, which can be later transported to the chosen location and easily dry assembled. The transport on the water of these modules would, furthermore, be logistically easier compared to the transfer and assemblage of the same individual components, and at the same time much more manageable, compared to the movement of the entire building from a shipyard to the open water.

A multi-year building site could be solved in a few months, only requiring the connection of the bearing structure to the floating base (which would be prefabricated as well), and the installation of the finishing components, systems, and furniture.
Another significant benefit of this procedure is that it provides the opportunity to completely disassemble the structure at the end of its life, thanks to the dry connections, and easily dispatch it to land, again, transporting the modules individually.

In our case study, the hexagonal floating base strongly determines the character of the upper-structure, effectively translating into a hexagonal setting for the pavilion. This provides a first suggestion for the modular base of the structure.
Six triangular concentric sectors are defined, each of them corresponding to one of the six sides of the hexagonal floating platform. Each sector is then divided into two structural modules: one internal and one external, leaving the tip of the triangle empty. This generates a central gap in the platform, which is solved by a single central module. Each bearing structure module is then covered by a corresponding façade/roof module, producing a continuous external skin for the building.

The hexagonal base of this system provides a simple concentric and symmetric organization, allowing for the standardization of the modules, which can be produced with analogous components. Identical beams and walls can be used in more structural modules, and the same fixtures and glass panes can compose all the transparent facade modules. This, however, does not compromise the design freedom of the pavilion, leaving a large action space.

Further explanations can be found in the chapter 06 Modular Design where these topics are explained and illustrated with more detail.



05
EXPERIENCE PLATFORM

“Whenever your preparations for the sea are poor; the sea worms its way in and finds the problems."

Francis Stokes (american screenwriter and director)

Defined the concept design for the whole pavilion, the project turns the attention to a smaller scale, with the aim of defining a development design, with a first look at some more detailed definitions.
Thoroughly analyzing all the themes of interest for all three platforms, however, would have required an intense effort and would probably not have been feasible in this thesis experience, given the limited time and the vastness of the topics.

This chapter, therefore, limits its attention to one of the three floating platforms, choosing the Experience Platform (the southern one) as the case study for the thesis development. It starts by describing the program of the building and proceeds to define its key functional aspects. The chapter’s core contains a detailed description of all the design steps, ranging from the choice of the building techniques, components, and materials to the reasoning behind the systems’ design. All the considerations and explanations are paired with the technical drawings and specific details of the structure, as well as evocative images, produced to transmit the outlook of the building.
Most of the specifics reported here, even if are specifically referred to only one of the structures, are, however, mostly valid for the other two platforms as well, with the necessary adjustments, considering their different design and character. Therefore, the description of the Experience Platform can be considered representative of the entire pavilion, at least from a technical point of view.

Cover: Experience Platform Module
Created by the Author

05.1 DESIGN BRIEF

- The Experience
- The Spaces

The idea behind the Experience Platform, and the entire pavilion, is to provide the visitor with engaging activities, to convey the desired message in a more thrilling and moving way. Here people will have the opportunity, not only to see how FloatScapes envisions the future of floating food production, but also to take an active part in the productive activities, and to taste the pavilion's products. This will create a playful environment, where the visitors will be called to participate and to "get their hands dirty", in an experience based on the principle of "learning by doing".

Given this principle, the platform is conceptually and materially divided into three concentric rings, with different functions.
The outer section, divided from the central area by a hexagonal wall, hosts all the productive and "functional" spaces, the rooms where all the platform's key productive activities are carried out. Here we find the greenhouses, the sowing room, a kitchen, and all the technical rooms required for the correct operation of the building.

The central hexagonal space, instead, is the true visit area. Here the visitors are free to walk in the inner ring and observe what happens around them, and even take part in some of the tasks, thanks to a hexagonal table, shared between visitors and staff, which is used as a displayed workbench.

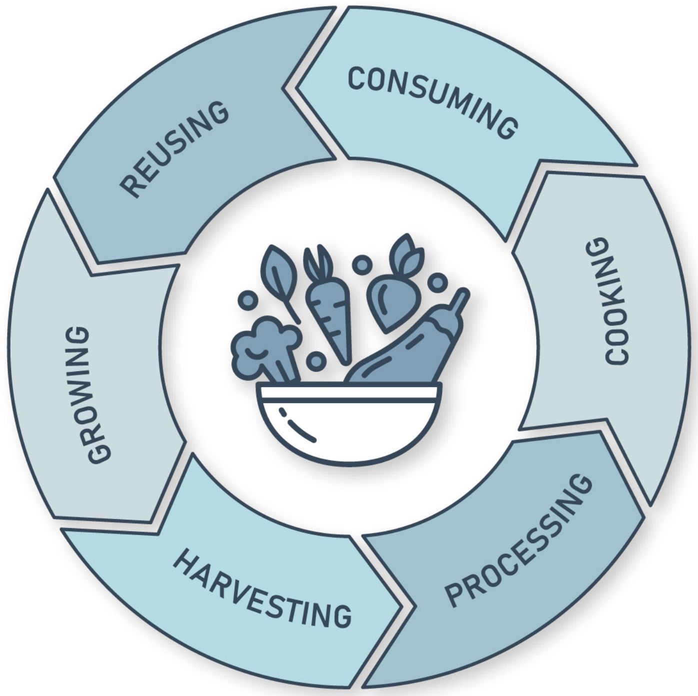
This last area sits between the previous two and acts as a link between them, bringing directly to the guests what they normally wouldn't be able to experience.

This paragraph aims to briefly present how the authors imagined the functioning of the platform and its activities, from which originated the definition of the spaces and of the building itself.

05.1.1 The Experience

Entering the platform, the visitors are introduced to a representation (more communicative than realistic) of how food production could happen inside floating farms. The circular path envisioned for the tour would bring them to see and experience each one of the key passages that, starting from the substrate preparation and the seeding, bring to the final product consumption.

Figure E.1 represents the concept idea for the experience of the platform, which is then used as starting point for the definition of the spaces as well.



Bottom Left: Figure E.1
Food Experience on the pavilion, the Experience Platform functional concept.
Source: Created by the author.

The platform would present the visitor with all the following significant aspects:

- **Sowing and Growing** vegetables, fruit, and greens, thanks to innovative agricultural techniques (in this case vertical farming), which allow for important production even with small requirements and available space.

- **Harvesting** the platform's products, with emphasis on productivity, seasonality, timings, and on the opportunity to multiply the productive cycles in a short period of time.

- **Processing** the crops to prepare them for consumption or storing, pointing at the produced waste.

- **Storing** the surplus production (symbolically, given the small production, compared to the effective demand of the pavilion) for future use, highlighting the different techniques with the respective pros and cons.

- **Cooking** of the platform products, inside the kitchen but also shared with the visitors.

- **Consuming** the prepared dishes, as the ending and most communicative part of the experience.

- **Reusing** the produced waste as a resource for the other steps (for example for nutrient production), also highlighting the necessity to properly manage what cannot be used. This effectively closes the circular path and the experience, opening a new cycle.

The idea is that participating in these activities would help receive the message of the pavilion. While seeing how the staff operates the greenhouses, would also be provided the opportunity to understand how the platform is designed and to get in contact with all the innovative technologies and strategies that are deployed in the pavilion.

By just making one tour around the central hall the visitors live a complete experience, which involves all of their senses, for a deeper message. Once the tour of the platform is ended, guests can simply go back on their steps, through the entrance hallway to the Vision Platform, to proceed with the visit.

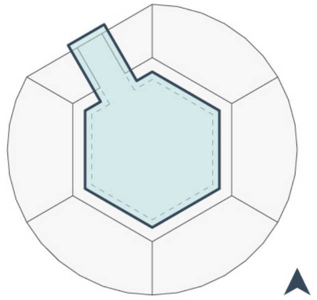
05.1.2 The Spaces

Figure E.2 reports the plan view of the Experience Platform, highlighting the main choices concerning the spatial organization, the passages, and the interior design.
The following pages go into detail about each main area of the pavilion, one at a time, explaining their characteristics and the reasoning behind the adopted solutions.

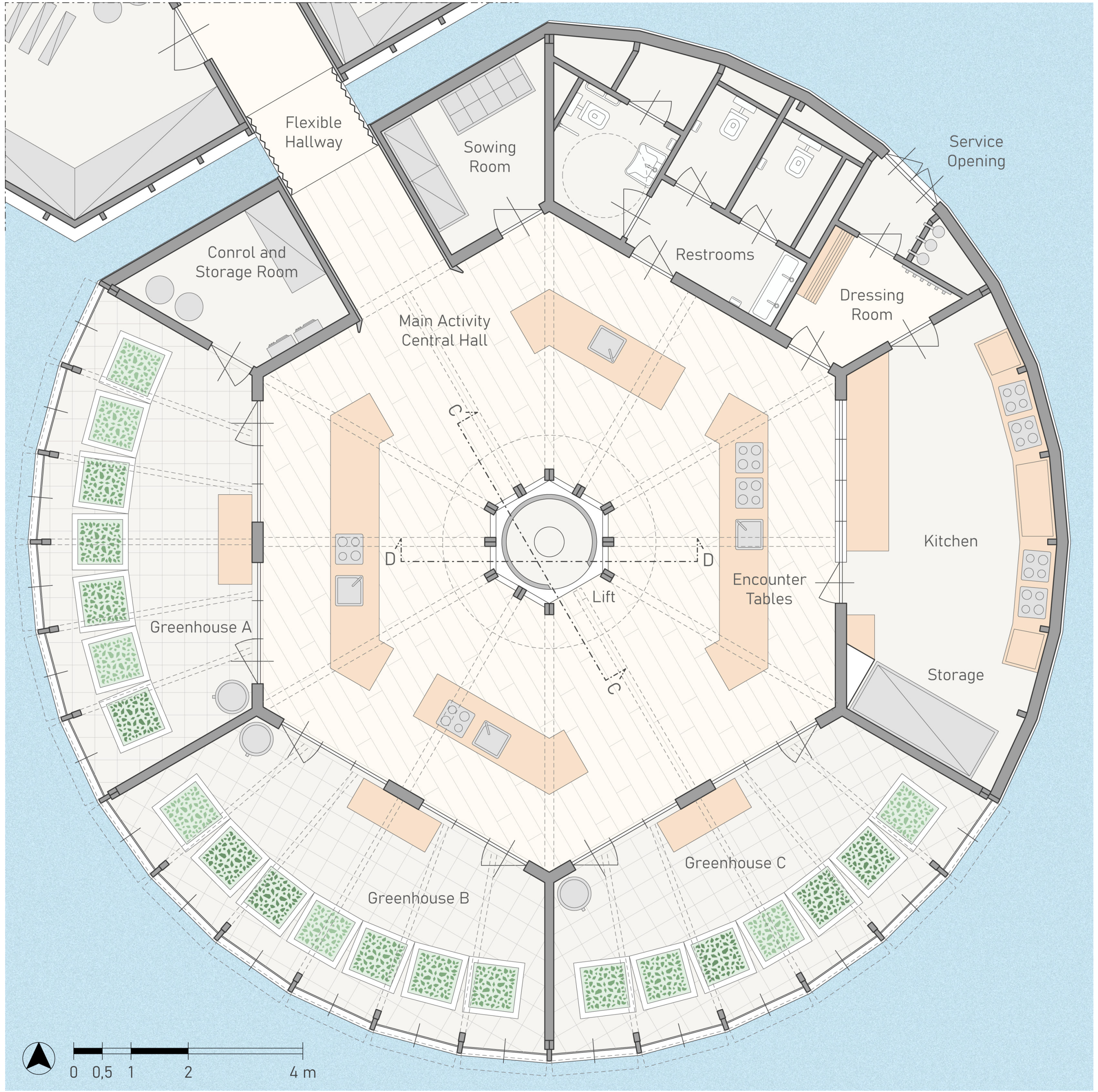
The central hall

The center of the platform is constituted by a single large hexagonal hall, defined on the outside by a CLT divider wall and on the inside by a bundle of wooden beams, which creates a central symbolic core for the platform. This central structural element recalls the image of a tree, with branches and ramifications that originate from the main trunk and sustain the foliage (roof). Light filters from the top, through a central skylight and inundates the room from above, also offering a glimpse of the sky.

The inner trunk invites the visitor to move around the platform, offering a fixed obstacle, which, however, does not block the sight. Inside it, a transparent circular lift allows the staff to reach the



Right: Figure E.2
Experience Platform Floorplan.
Ground (water) Floor.
Scale 1:100.
Source: Created by the author.



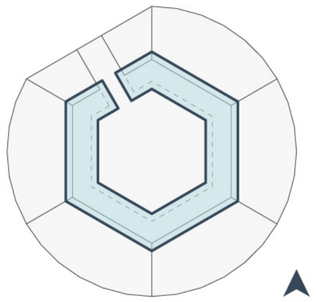
underwater floor, ensuring accessibility in every room.
Facing outwards, the visitors have a 360° view of the platform. The hexagonal wall is pierced by a large number of internal windows and glass doors, which offer a direct view of the outer rooms and of what is happening inside them. This allows the guests to experience even the areas where they do not have direct access.
Along the outer edge of the hall, a long hexagonal table acts as the meeting point between the more "public" visit area and the "private" outer spaces.

The Encounter Table

The will to provide the guests with an opportunity to participate in the pavilion operation materialized in the hexagonal workbench. This becomes the meeting space between visitors and staff members and the place where most of the communication happens.
While most of the actual food production and processing would happen in the outer rooms, if not directly off the pavilion (given the limited productive potential of such a small agricultural space), during every visit tour, members of the staff will transfer some of their activities to the central table. Here the visitors will be able to see up close how the platform is operated and help in first person the staff.
Some of the shared activities could be:

- Sowing of the vertical planters
- Preparation of the fertilizer water
- Cleaning and processing of the greens and vegetables
- Storing and conservation of the products
- Cooking and other preparations

Obviously, not all these would be carried out during every tour, but the shared activities would depend on the timing and the season,



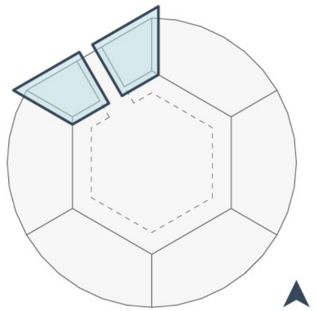
just as would happen for the grown products. Meanwhile, visitors would also be able to see what is happening around them, in the more private rooms, living a more comprehensive experience.
Finally, here the guests would also have the opportunity to sit down and taste some of the pavilion's products, to complete the tour with a small meal, directly prepared on the floating platform.

The hexagonal table, therefore, has to respond to a variety of requirements, to adapt to its complex role inside the tour.
First of all, it is provided with everything that could be necessary to perform the required tasks. Electric stoves, sinks, power outlets, and kitchen aspiration hoods are arranged around the table, to allow for multiple activities to carry out simultaneously. Large tables offer space for visitors to gather around and participate, doubling as dining tables. Finally, this same piece of furniture acts as a display storage, to hold materials, stored food, and all the required tools, for a more efficient use of the small available space.
The table does not complete the hexagon but is divided into multiple components, leaving room for the passage and also multiple openings to allow the visitors to view the surrounding rooms.

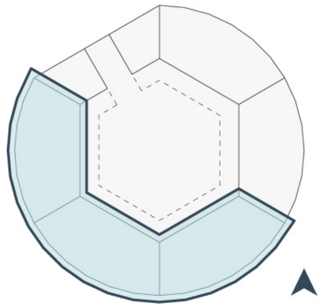
The Productive Rooms

Around the central hexagon lays an outer ring of rooms. These spaces directly face the outside and, while presenting a "circular" façade, are all based on the hexagonal scheme of the platform. Each of the six sides hosts a sector, corresponding to one of the prefabricated modules, divided from the surrounding ones by perimeter walls. These rooms, therefore, have a trapezoidal-like basic shape and are then subdivided into secondary spaces by internal walls.
Starting from the north-western side, and following the circular counterclockwise path of the visit, the outer modules host:

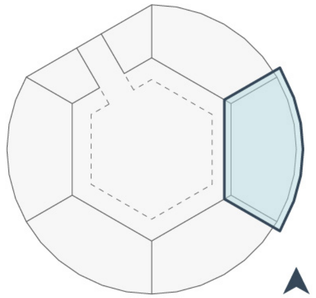
- NW side: two small rooms, respectively dedicated to a sowing and germination room, and a tech and material storage room, where most of the control units are located.
The sowing and germination room conceptually opens the platform tour, with the first vertical farming activity, immediately displayed on the right upon entering the hall.
On the contrary, the tech room on the left does not offer an extremely open view of the inside (similar to what is done with the entire left side of the platform), promoting a counterclockwise path, without negating the opposite route.



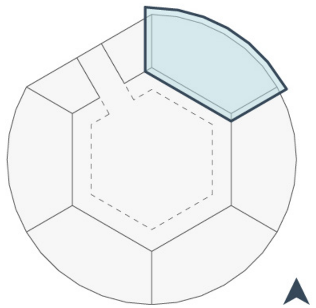
- W, SW, and SE sides: three independent greenhouses dedicated to vertical farming, food production, and processing. These take advantage of the southern edge of the pavilion, which offers the most favorable orientation, in terms of solar incident radiation.
Their outer edge is composed of a transparent glass curtain wall, which allows for the entrance of light and heat and provides a direct view of the outside and of the lagoon water.
In front of this transparent dome, vertical farming supports are positioned on an arch, following the façade. These provide a large growing area over a small available footprint, leaving at the same time sufficient space for the staff to move and operate the floating farm. The arched placement of these supports creates a green scene, together with the growing vegetables, offering a strongly communicative image.
Against the central divider wall, is then positioned a table, which offers a workbench for any activity linked to farming and a place to store tools and materials. This defines a central empty passage to allow for movement. Occasionally visitors might even enter the greenhouses for a more immersive experience.
Each of the three greenhouses is thermally independent, being



separated from the others, and from the rest of the building, allowing to set up three different growing conditions on the same platform.



- E side: an open view kitchen, where most of the food processing, storing, and cooking activities would take place. The inner windows permit the view of both the work plans and the stoves.
The façade is here opaque, to limit the entering radiation, avoiding excessive natural heat gains.
Most of the consumed food would be prepared here and transported to the central hall through sliding windows, before being offered to the visitors, which could then taste it while sitting at the hexagonal table. The entrance to the kitchen is reserved for the staff and happens through a small filter room, located on the eastern side, required by the legislation, which also acts as a small dressing room, to allow to change shoes and wash their hands before entering. The main dressing rooms (where staff could change clothes and store their belongings) are instead located on the underwater floor.



- NE side: filter room, "charge and discharge" room, public bathrooms, and deposits. Following the usual counterclockwise path, we can find the above-described filter room of the kitchen, which also gives access to a back area, dedicated to the docking of the service boats, for loading and unloading of the tanks and waste disposal. A small area is also provided for temporary waste collection, waiting for the arrival of the garbage boat.
A unisex bathroom serves the platform, with two standard toilets and an accessible one, which are reached through an anteroom, provided with a washbasin. The choice of not differentiating bathrooms for sex is motivated by a lack of space, which wouldn't fit two separate areas. Another complex space, originated by the bathrooms and the curved façade, is this time used as storage for cleaning equipment and materials.

Figure E.3
Experience Platform Cross Section.
Section DD, Greenhouse and Kitchen
Scale 1:100.
Source: Created by the author.

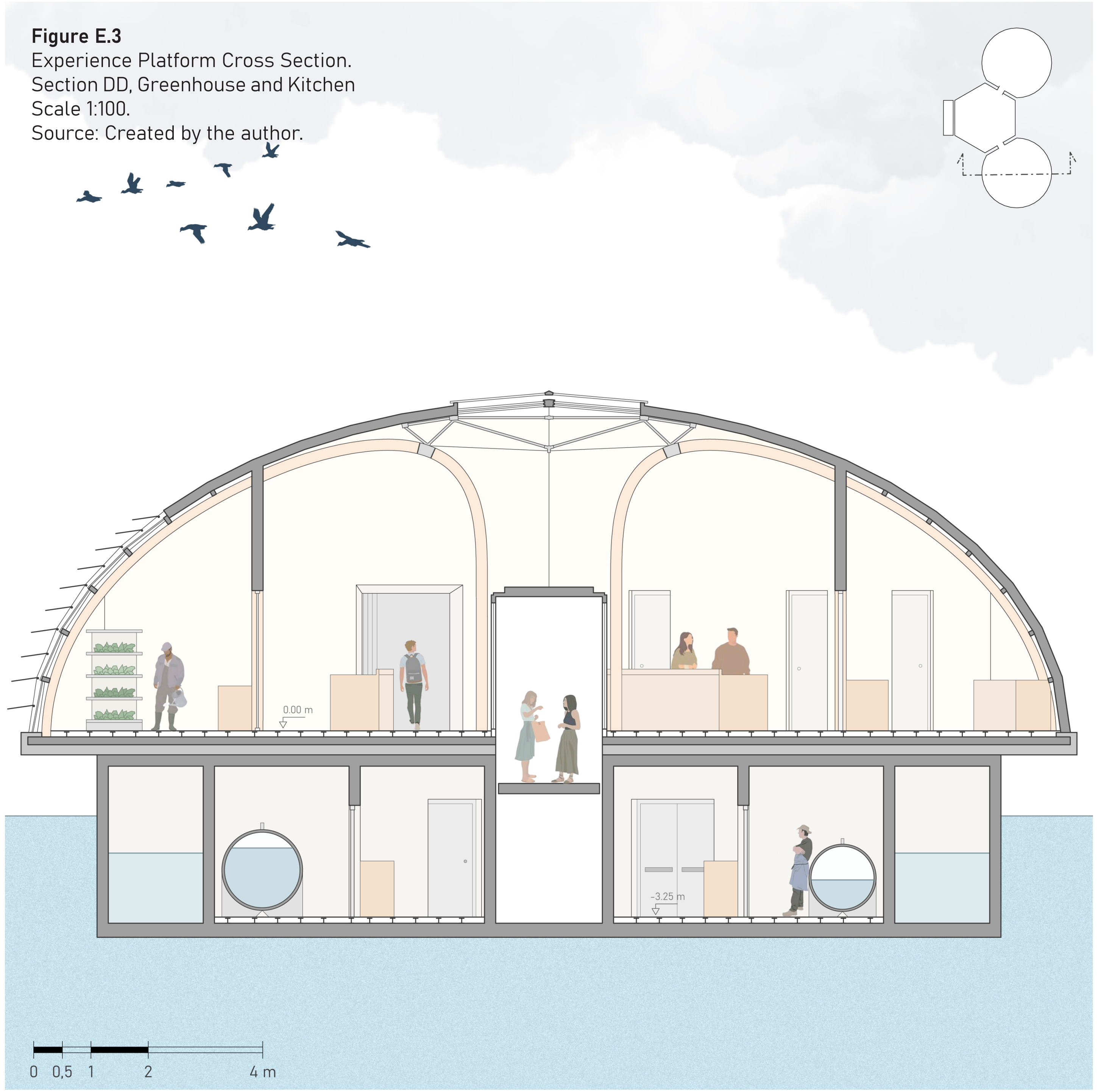
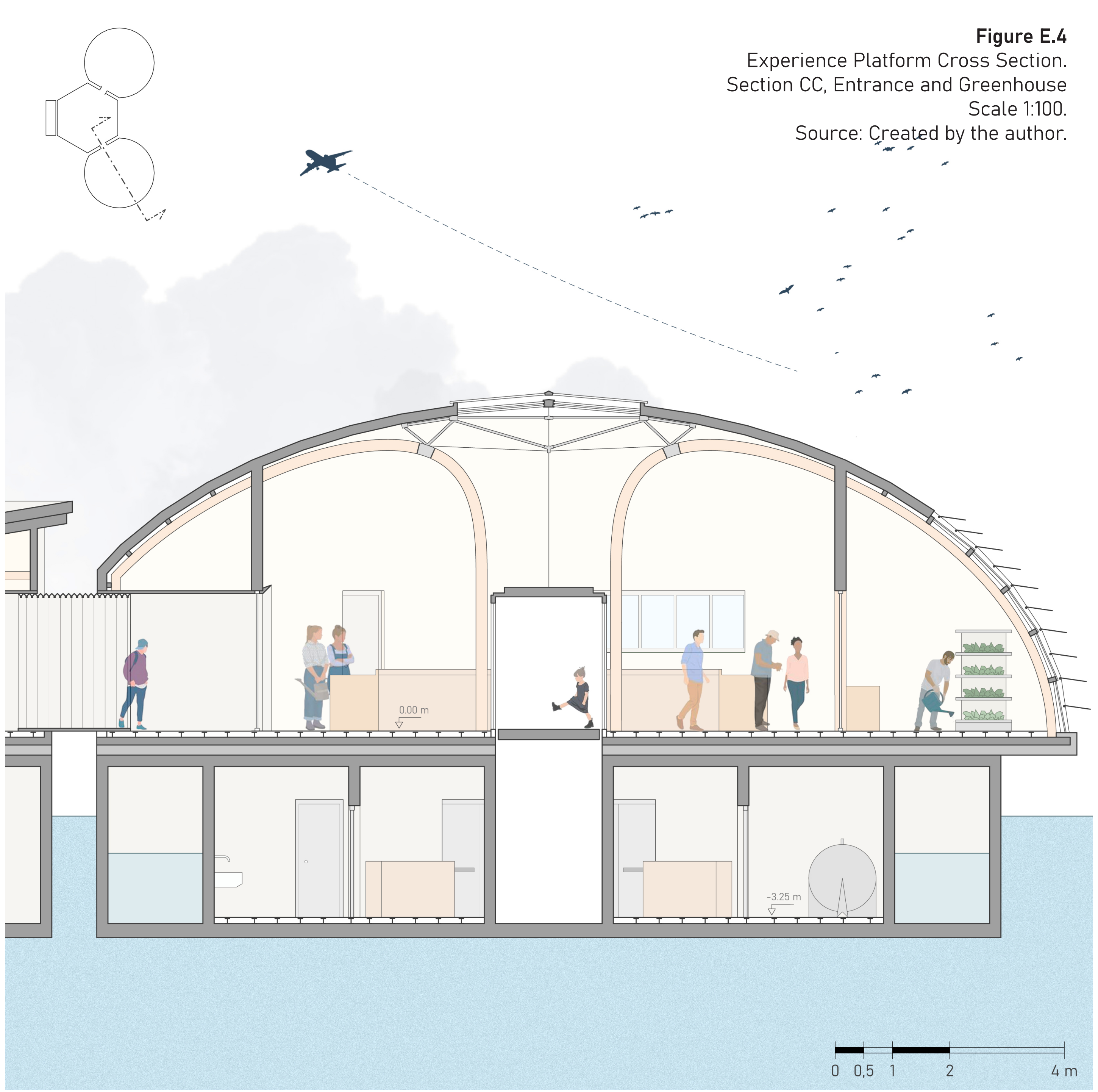


Figure E.4
Experience Platform Cross Section.
Section CC, Entrance and Greenhouse
Scale 1:100.
Source: Created by the author.



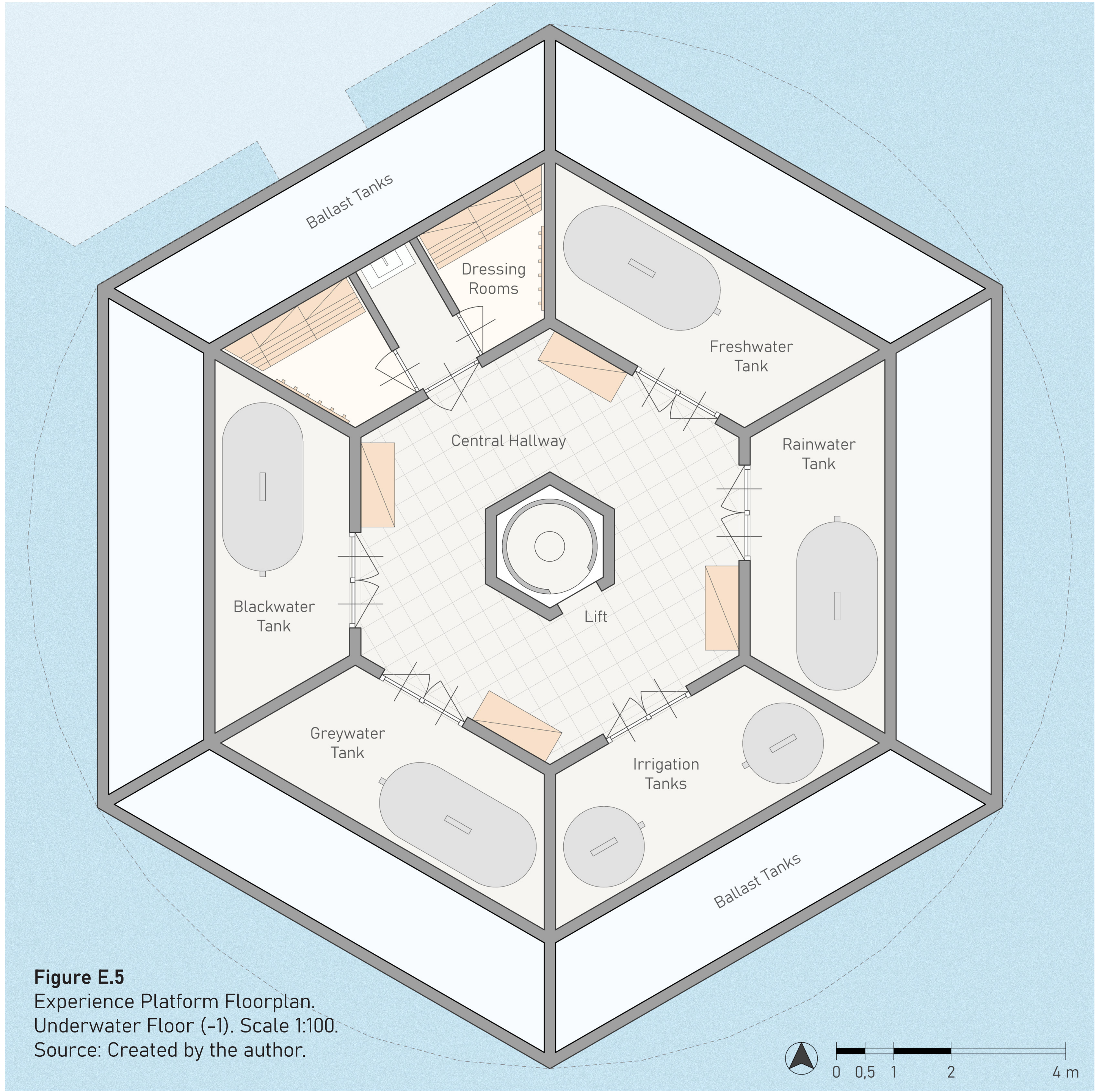


Figure E.5
Experience Platform Floorplan.
Underwater Floor (-1). Scale 1:100.
Source: Created by the author.

05.2 DEVELOPMENT DESIGN

- *Dome Building*
- *Wooden Bearing Structure*
- *External Skin*
- *Bottom Floor of the Upper-Structure*
- *Internal Spaces and Finishes*
- *Loads Compliance*
- *Mechanical & Electrical Systems Reasoning*

This paragraph aims to explain the main design solutions implemented by the authors, going into detail about both the concrete results of this project phase and the reasons that moved every choice and oriented toward a certain option rather than others.

The paragraph is divided into sections, according to the main building elements, starting from the loads bearing structure and finishing with the external skin, and the treatment of the internal surfaces. As said, any section is correlated by an explanation of the main factors that characterized the design and is accompanied by detailed drawings of the portion of interest (or of a representative area).
Again, here, only the Experience Platform is described in detail, but most of the contents can be considered almost equally valid for the other two platforms as well.

05.2.1 Dome Structure

The basic shape of the Experience (and Technology) Platform originates from a halved oblate ellipsoid, which defines all the external surfaces, as well as the basic shape of the curved LVL beams. This shape choice, although might appear problematic at first glance, actually responds to numerous specific functional and technical requirements, becoming what definitely seems a viable alternative.

Hexagonal Complexity

As explained, the design of the upper-structure is strongly dependent on the shape and dimensions of the concrete floating understructure. The available space is limited, the perimeter and divider walls offer specific points where vertical loads can be directly transmitted, and, more than anything, the hexagonal footprint pushes toward some

kind of concentric/hexagonal setting for the pavilion spaces and components.

The first hypothesis for the upper-structure was to embrace the hexagonal system and produce a six-sided pavilion, which would have been characterized by simpler shapes and volume.
However, it posed important functional problems. First of all, it produced a large quantity of 30° and 60° corners in the room footprints, creating hard-to-use spaces, and in the structural elements, greatly increasing the production complexity.
Secondly, the platforms' size was slightly too small to actually host all the required spaces, while also allowing for easy movement inside the rooms, for both the visitors and the staff members. The presence of a central space, indeed, limited the outer rooms to a max width of less than 3 meters.

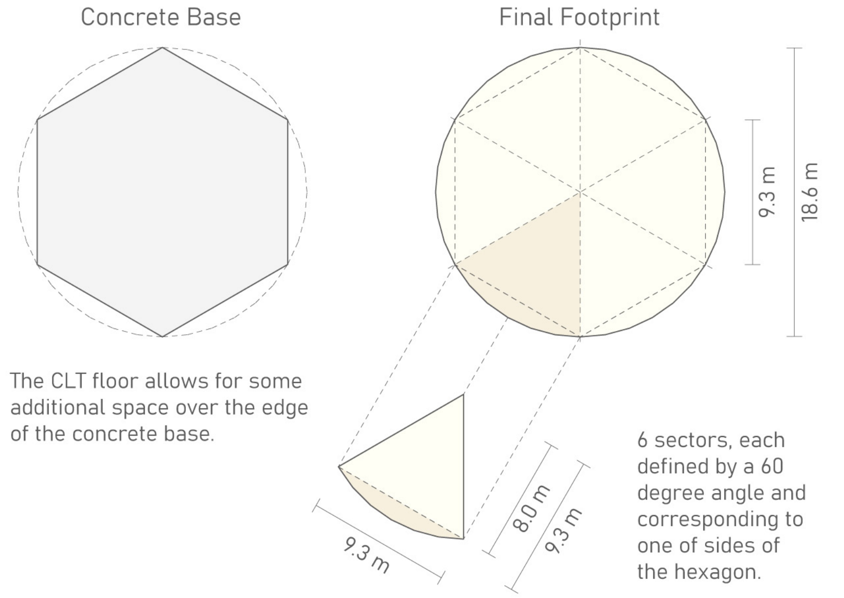
Another possibility was to somewhat accept the hexagonal footprint but use it as a starting point, while the actually built volumes would be rectangular (or squared), giving up on some of the available space. This however was considered a not practicable choice, as it would represent an inefficient use of the already small footprint.

Circular (Polygonal) Footprint

The proposal of a similar-circular footprint, which circumscribes the hexagonal base, overhanging with small circular sectors over the sides of the platform (about 1,6 m off the hexagonal limit in the central point of each side), allowed responding to most of the above-cited challenges.

To start, it provided some additional space to the outer rooms, also increasing their width, so each of them can more easily host a central empty hallway, for easier movement and maneuvering. The total width of the external rooms, indeed, reaches 3,9 meters in the centre of the module, allowing for example the insertion of vertical farming supports of a satisfying size, leaving enough room for the staff to move around, and transport tools, materials, and machinery.

A polygonal (36 sides) footprint also significantly limits the dead spaces inside the pavilion, which were, instead, extremely frequent with other shape configurations.
Each of the concentric divider walls (necessary for the modular prefabrication of the structure) meets the façade with an angle of 90°, rendering the internal spaces easier to furnish, as rectangular furniture much better suits the rooms. For the same reason, the structural nodes are much easier to produce, given most of the connections have to happen between perpendicular elements.



Bottom Left: Figure E.6
Geometric evolution of the pavilion footprint, starting from an hexagonal concrete base, to end up to a polygonal shape.
Source: Created by the author.

Figure E.6 contains a plan view of the platform footprint, and represents its basic geometry and dimensions, comparing it with the available concrete platform.

Another key advantage of polygonal shape is the opportunity to highly standardize the building components. The platform is composed of 36 wedges, which are substantially identical to each other, with the exception of the six that form the connection with the Vision Platform. This means that each one of them can be produced with the same standard components, regarding the bearing structure, the transparent and the opaque façade, and the finish materials. Identical window panels can be used for all the greenhouse wedges, and identical solar screens can be used to protect them. This greatly reduces costs, facilitates, and speeds up assemblage, and greatly helps with future maintenance and particularly with the substitution of the components.

The similar-circular shape, also mirrors the envisioned visit path of the tour, allowing for a consistent and direct view of the outside, with the sight always meeting the façade perpendicularly.

The Ellipsoid Dome

Given the choice of a circular footprint, the vertical development of the building is defined as a polyedric dome, based on the 36 wedged, which follow the guideline of a pure geometric shape: an oblate ellipsoid.

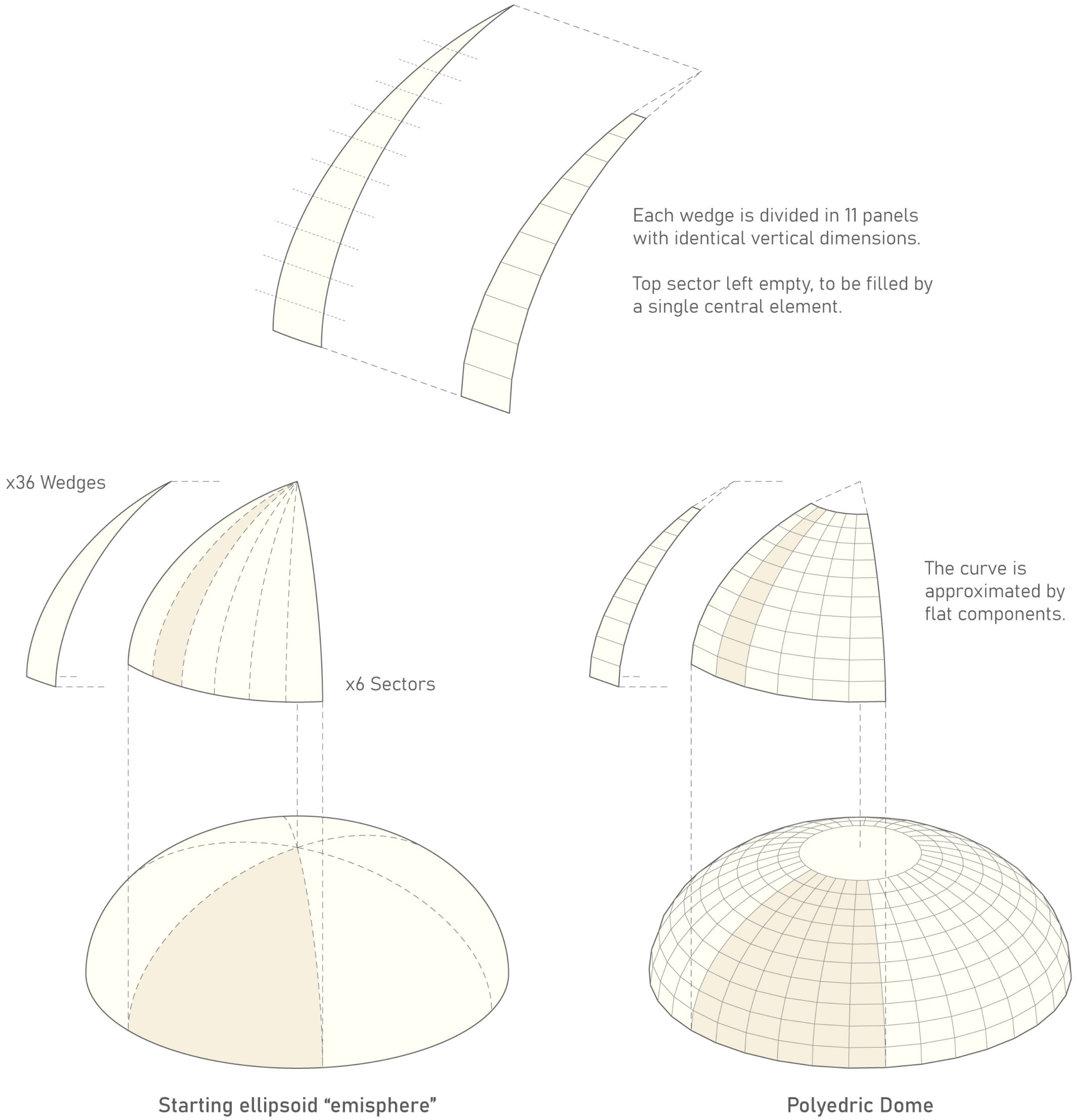
As opposed to a spherical dome, which would have reached a central height of more than 9 meters, the ellipsoid maintains a lower elevation in the central area, approaching 6,5 meters, while achieving sufficient internal ceiling heights even close to the façade. This provides more enclosed spaces for the external rooms, while offering a much more open and spacious hall for the central hexagonal room, rendering it much more enjoyable for the visitors, even in the more crowded hours.

The inner bearing structure bends together with the ellipsoid, to offer continuous support points for most of the vertical development of the dome. As both the transparent and opaque components of the façade cannot easily bend to precisely follow the curvature, the ellipsoid is here approximated, dividing each given cross-section into 11 planar components, each with the same vertical length of 0,96 meters. This allows us to follow the curve, concretely producing it with flat elements, which are far less expensive, more durable, and easier to maintain or substitute.
The 36 wedges get progressively narrower toward the upper center of the dome. The façade components are therefore trapezoidal, with constant height and progressively smaller bases.

The dome shape offers the great advantage of an extremely compact and uniform surface, with little to no exposed edge. Everything is completely encapsulated on the external protective skin, with no degradable component exposed to the external elements. This is particularly important in such a prohibitive environment such as the lagoon waters.
Furthermore, it offers a strongly communicative image of the pavilion, with an emotional and scenographic look, where innovation and "green" practices can be at the center of the attention, with a look at the local architectural tradition.

Figure E.7 contains the geometric evolution of the dome, starting from the basic ellipsoid shape to the end result of the polyedric wedged dome.

Right: Figure E.7
Geometric evolution of the pavilion basic shape, from an ellipsoid to a polyedric dome.
Source: Created by the author.



05.2.2 Wooden Bearing Structure

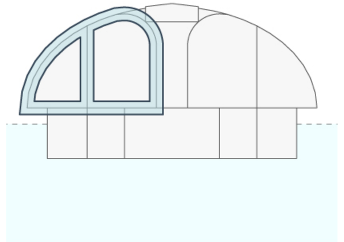
Why wood

The concrete platform is the only element that sustains the structure and allows it to float. No additional buoy is provided, and the platform, following Archimedes' Principle, floats on water due to being impermeable and hollow.

The platform is capable of bearing a determined load (defined by the volume of water it can potentially dislocate), but a large portion of it is already devoted to sustaining its own weight, consisting primarily of the concrete walls and floors, which, despite being relatively thin, weigh 270 tons, limiting the available additional load to 161 tons. Considering the presence of the ballast system (weighing 43 tons), SEAform's engineers defined an indicative value for the weight of the upper-structure of 118 tons, which comprises the upper-structure's permanent and variable loads, as well as the weight of the tech equipment.

This limit represented one of the main factors in the choice of the material and building technique.
Indeed, the first indicative analysis made clear the impossibility of adopting any high-mass construction technique (excluding for example brick and concrete structures), as the weight of these solutions would, most likely, abundantly surpass the limit. This limitation, instead, oriented us towards lightweight and punctual techniques, primarily pushing for wood and steel, both more suitable to achieve satisfying results with moderate permanent loads.

At this point, the choice of wood over steel was motivated by the following characteristics:



- Engineered wood is a high-performance and extremely versatile material, perfectly able to adapt to the complexity of such a project.

- A wood-based structure with steel connections is capable of sustaining all foreseen loads and stresses, without the need for concrete castings (required in most of the steel-based structures), as rigidity and mass are provided by wooden elements themselves.

- None of the two materials is truly suited to the marine environment on its own. Both need to be as isolated as possible from water and saline corrosion, with a possibly required surface protective treatments and finishes (protective paints and impregnations).

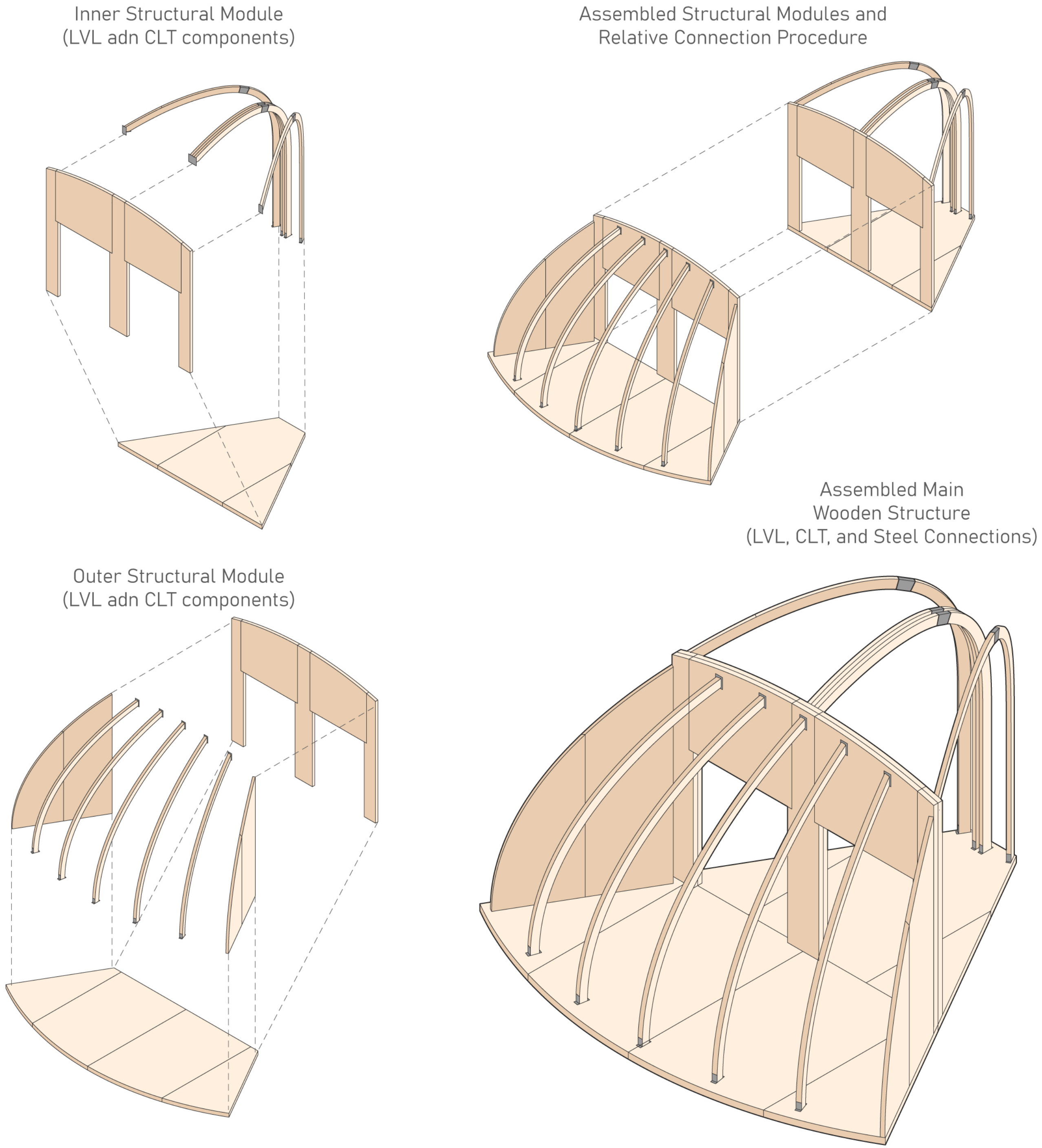
- Wood presents a much higher communicative potential than steel. Its use is symbolic of the attention to environmental consequences and, therefore, more suitable than steel to convey the message of sustainability of the pavilion.

In simple terms, wood is seen as an equally valid choice as steel, in terms of structural and technical capabilities, but appears as a more interesting opportunity from a design and composition point of view, as it better links with both the aura of the pavilion and with the lagoon location, where wood is traditionally used as a building material for most water structures.

A mixed structure

The wooden structure of the pavilion has to perform its role of bearing the loads which stress the building. At the same time, however, it has to respond to some additional structural and functional requirements.

The inside spaces of the pavilion need to be ample, to ensure easy movement and accessibility, and, simultaneously, offer an open view



Left: Figure E.8
Main wooden structural components of FloatScapes.
Source: Created by the author.

of both the surrounding rooms (to ensure that the pavilion activities are easily visible) and of the exterior (to allow to see the water).
The necessity to subdivide the building into prefabricated modules requires all of the sections to be structurally autonomous and to have sufficient rigidity on their own, to allow for transportation and easy installation.

The bearing structure is therefore not solved with a single building technique but is instead defined by a combination of different engineered wood technologies. Punctual curved LVL beams provide vertical distribution of the loads while ensuring a very open and versatile structure, and CLT panels, used in both the floors and the dividing walls, ensure sufficient mass and rigidity for all of the modules, effectively responding to most of the lateral stresses.
The presence of these solid 2D elements, together with the external skin, reduces the need for wind bracings, thanks also to the extremely concentric and symmetric character of the building.

Structural Elements

Figure E.8 contains a representation of the basic structural components of the building, highlighting the modular composition and the subdivision into six basic sectors.

The basic ellipsoid shape of the pavilion is achieved with curved LVL beams, arranged radially, to cover the polygonal (circular-like) floor plan. An external set of curved pillars is devoted to sustaining the external façade. Five beams per module, with a standard section of 10 x 16 cm, stand on the 14 cm thick CLT floor and curve themselves to reach an inner CLT divider wall, 10 cm thick, which offers the second foothold for the pillars and closes the module. On the sides, the module is completed by two arch-shaped CLT walls, that offer another anchor point for the façade and increase the module rigidity, also dividing the inside spaces.

Adjacent to the first CLT wall, another identical one (again 10 cm thick), offers the foothold for a second inner set of curved beams, which curve toward the center of the platform, reaching again the wooden floor, and completing the curve. These elements, with a section of 10 x 20 cm, are 4 on each side, arranged in pairs (one central couple for every side and two on the corners, coupled with the supports of the adjacent sectors), which attest to the center and corners of each module.

The resulting volume is of a doughnut-like circular tunnel, sustained in the center by a hexagonal divider wall. This creates an external ring of rooms, facing the exterior, with six main areas, which are then subdivided according to the specific necessities. In the center, a single main hall creates a large visit space, opened to the sky with a large polycarbonate skylight, supported by a tridimensional steel truss beam, which lays on the central curved pillars.

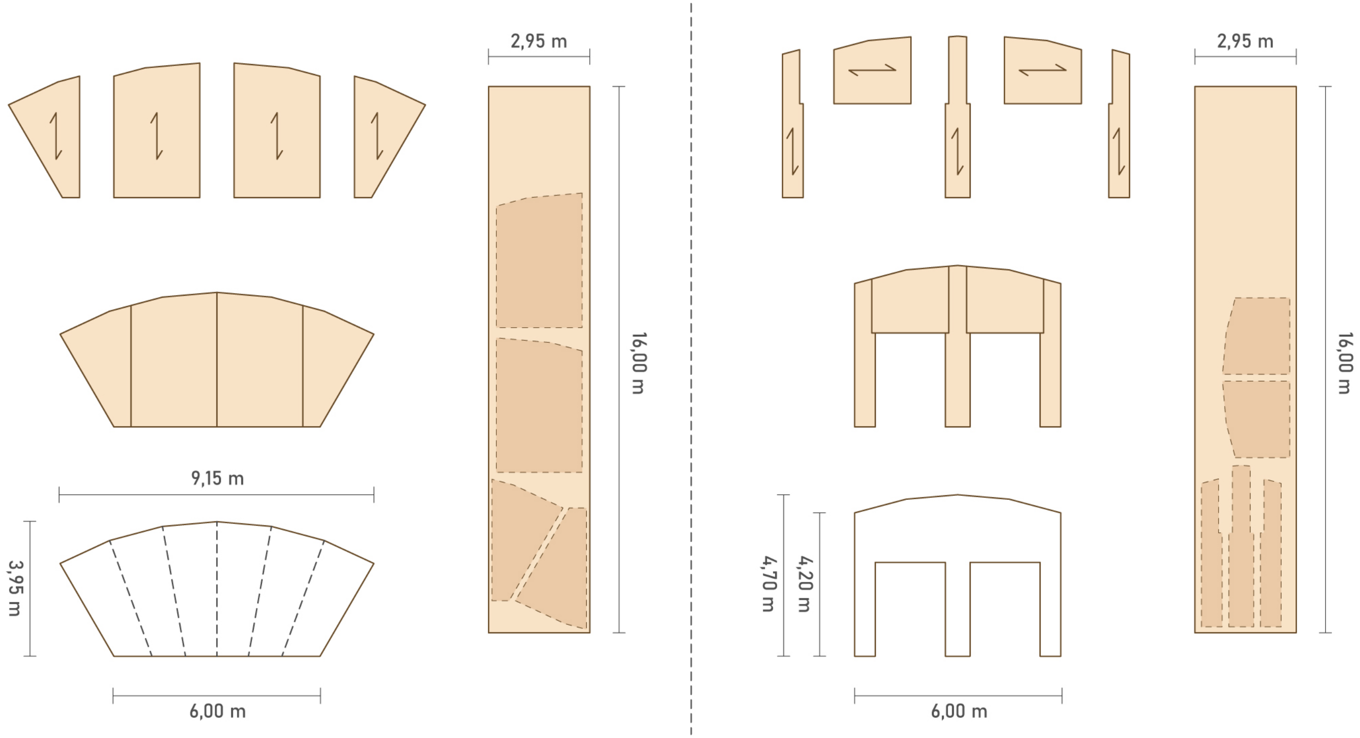
The CLT components of the floors extend over the hexagonal platform limit, giving a point of support for the external beams, creating a curved overhang, with a maximum ledge of 1,2 meters. This allows for the realization of the circular floor plan on an effectively hexagonal base.

Finally, in the central divider wall are opened large internal windows, and transparent doors, offering the opportunity to enter the surrounding rooms, while offering an extremely open view, meeting a basic requirement for the visit tour.

All the CLT components, both walls and floors, are most of the time

too large to be produced in a single piece since most manufacturers offer standardized maximal dimensions. Therefore, these are subdivided into smaller pieces, properly assembled and connected in the production plant, and subsequently used for the structural modules.

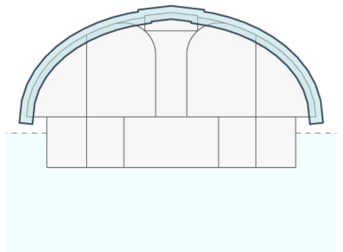
Figure E.9 reports an analysis of the standard CLT components (one wall and one floor), indicating the subdivision in pieces, the orientation of the fibers, the connection points, and how the single parts would be produced from a standard panel (14,5 x 4 m).



Bottom Right: Figure E.9
X-lam components for a standard floor module and a standard wall module.
Source: Created by the author.

05.2.3 External Skin

Prerequisites



As said, all the structural components of the building need to be as isolated as possible from the external elements, given the very harsh and aggressive marine environment, often referred to as one of the most forbidding. Water and saltiness would put to high risk both the wooden and steel components of the structure.

Therefore, to reduce the need for intensive protective treatments (which could compromise the recyclability of the materials), the external skin of the building needs to completely encase the inner structure, acting as a protective barrier, offering an inert and resistant skin.

The solution chosen for the external façade also has to satisfy compositive and functional aspects.

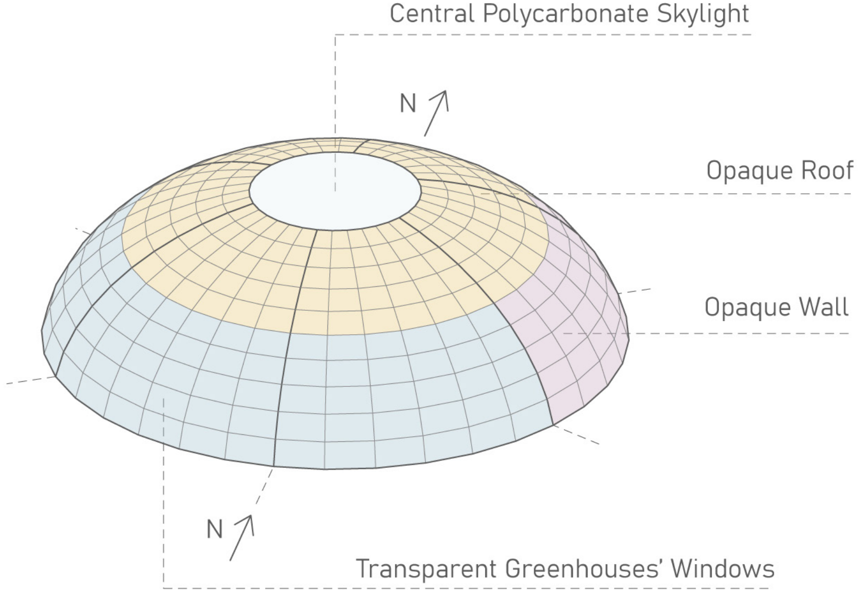
First of all, similarly to the inner modules, the skin has to be prefabricated and easy to transport and assemble, to ensure quick and low-impact building procedures. This also strongly drives towards a dry-assembled system.
Its weight has to be limited, again to comply with the floating potential of the concrete base.
It has to be highly adaptable and customizable, to produce different sections with the same technologies, solving both transparent and opaque surfaces. This is required by the plurality of activities carried out inside the pavilion, needing different spaces and different interactions with the exterior.

The façade

The basic ellipsoid shape unifies the walls with the roof in a single curved surface and therefore requires an external skin capable of solving this complex shape. At the same time, both the "walls" and the "roof" need to be perfectly impermeable and provide a water-draining system.

The curved shape also provides a single rest point for the façade, on the external limit of the CLT floor. The skin, curving toward the inside needs to find other support points, and is, therefore, anchored to the wooden beams, following their curvature.

Figure E.10 reports a schematic illustration of the different solutions adopted for every building sector, in the example of the experience platform.



Bottom Right: Figure E.10
Different facade solutions adopted for the standard skin modules of the dome.
Source: Created by the author.

The façade is then composed of different solutions, based on the same system, which is adapted to the specific local requirements.

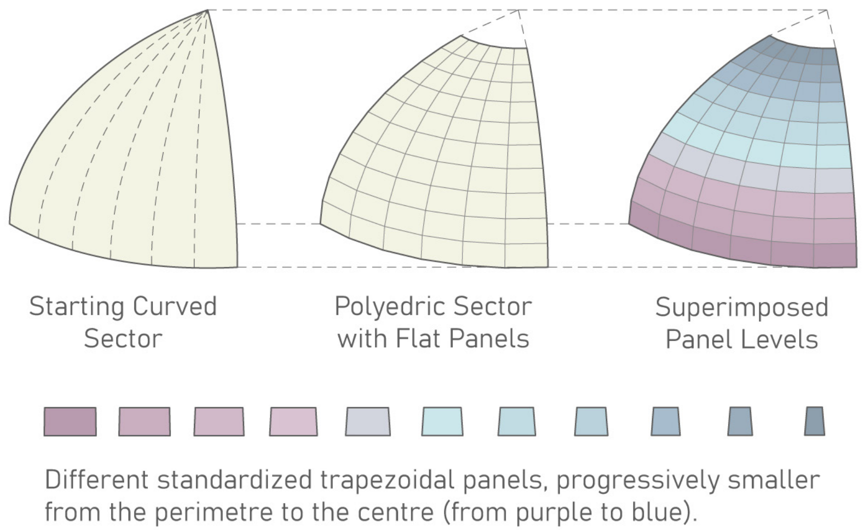
- Transparent walls, used for the external greenhouses (SE, SW, and W sides), correlated by an external system of automated solar screens.

- Opaque roof, adopted for the upper area of the ellipsoid.

- Opaque walls, used for the more closed spaces, such as the kitchen or the restrooms (E, NE, and NW sides), with the same technology used for the opaque roof.

- Central skylight, at the very top of the platform, which acts as a closing termination for the whole façade.

All these systems resolve the necessity of producing a curved shape approximating it with planar components, meaning that the resulting



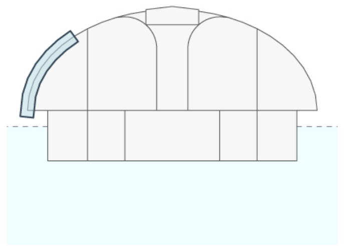
Bottom Left: Figure E.11
Subdivision of a sector in concentric superimposed orders of identical components.
Source: Created by the author.

volume is not a true ellipsoid, but a polyhedron, based on trapezoid elements, which get smaller toward the center of the dome. This results in an organization with consecutive ring levels one above the other.

Figure E.11 shows an example of the subdivision of a sector in concentric superimposed orders of identical components, which get progressively smaller toward the center of the dome.

During the design, great attention was given in the effort of standardizing the components. For example, any glass pane is identical to the ones on its sides (provided it is on the same level) and could potentially be produced in series, reducing costs, and facilitating the assemblage and eventually the substitution of the pieces.

Transparent Facade



The three sectors of the platform which are oriented towards SE, SW, and W host three independent greenhouses, dedicated to the production of food. Here, high-density vertical farming allows for the cultivation of close to 67 square meters of farmland, on a total footprint of the greenhouses of 84 meters (this data is extremely far from efficient use of the space for vertical farming but is due to the necessity of allowing movement and, more than anything, direct view for the visitors).

These spaces are located in a favorable position, to gain access to large amounts of free solar radiation, which, integrated with artificial lighting for the night hours, provides sufficient illumination to achieve high production inside the greenhouses. The facade of these rooms, therefore, must be designed to let in a significant portion of the

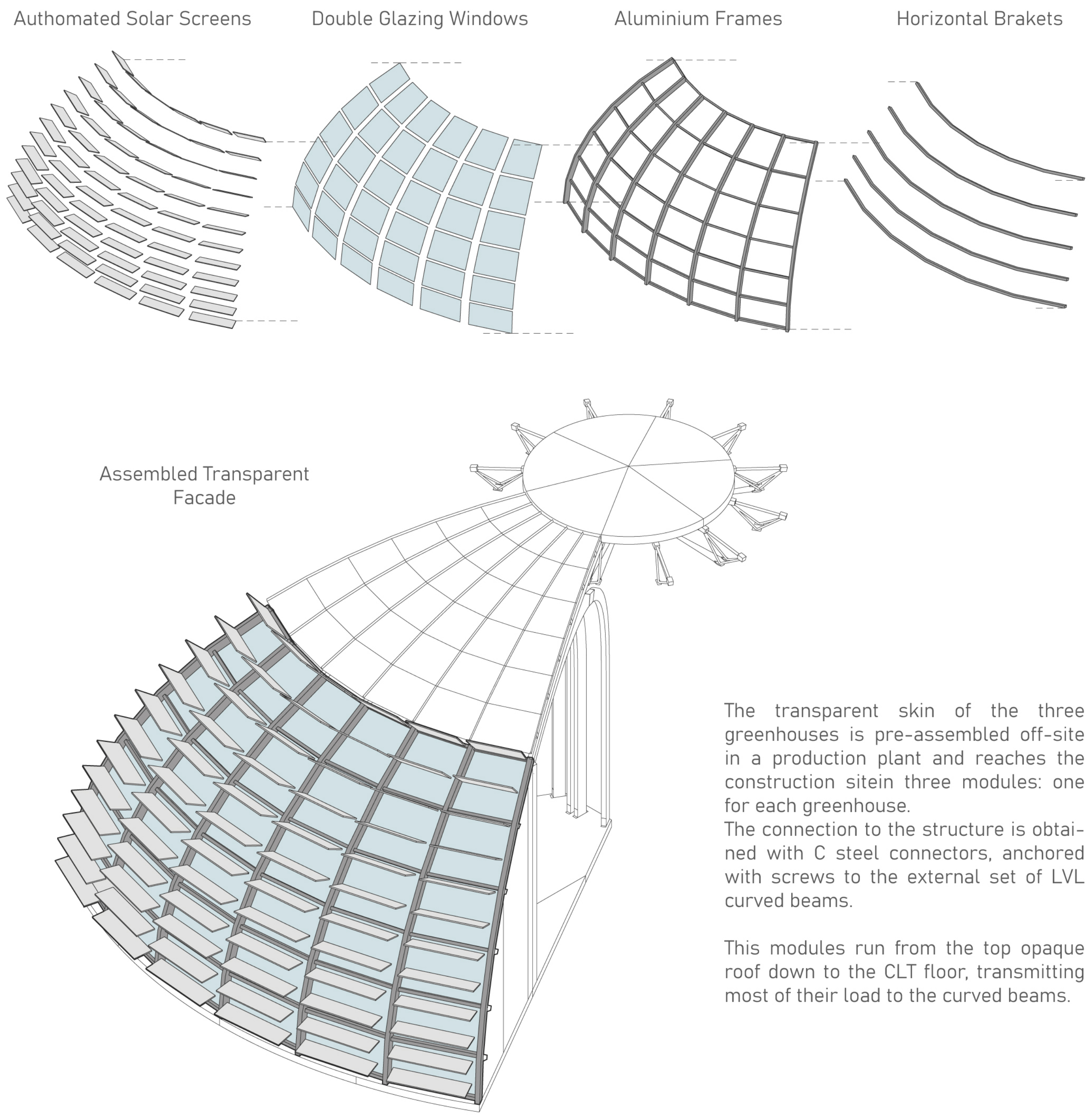
incident solar radiation. This could also significantly help during wintertime, to help with heating the greenhouses.
Furthermore, from the central hall of the platform, to reach the outside, the view has to traverse these rooms, as well as the façade.

These criteria oriented us towards the choice of an almost completely transparent curtain wall realized with a metallic structure (organized in three levels of posts) and trapezoidal glass panes.

Figure E.12 represents the different components of a standard section of transparent façade, starting from the structural metal posts, to end with the glass panes and solar screens.

One first order of horizontal posts is anchored to the curved wooden beam, thanks to steel connectors fixed by nuts and bolts, for quick construction and deconstruction. This first order of supports subdivides the curve of the dome into eleven segments, defining what would also be the structure followed by the glass components.
A second level of posts, this time vertical, represents the main structure of the curtain wall, running from the bottom CLT floor to the top opaque roof. This supports divide radially each sector into 6 wedges, being aligned with each wooden beam (ensuring a smaller view obstruction), of which they also follow the shape, approximating it to a polyline. These vertical components are dry-connected to the horizontal ones.
A third and final order of horizontal posts, aligned with the first ones, offers the anchor point for glass components. The section of these elements is much smaller, as they only need to bear the load of a single glass pane.

The glass elements, as said, are trapezoidal, and their dimensions get progressively smaller from bottom to top. Each window element

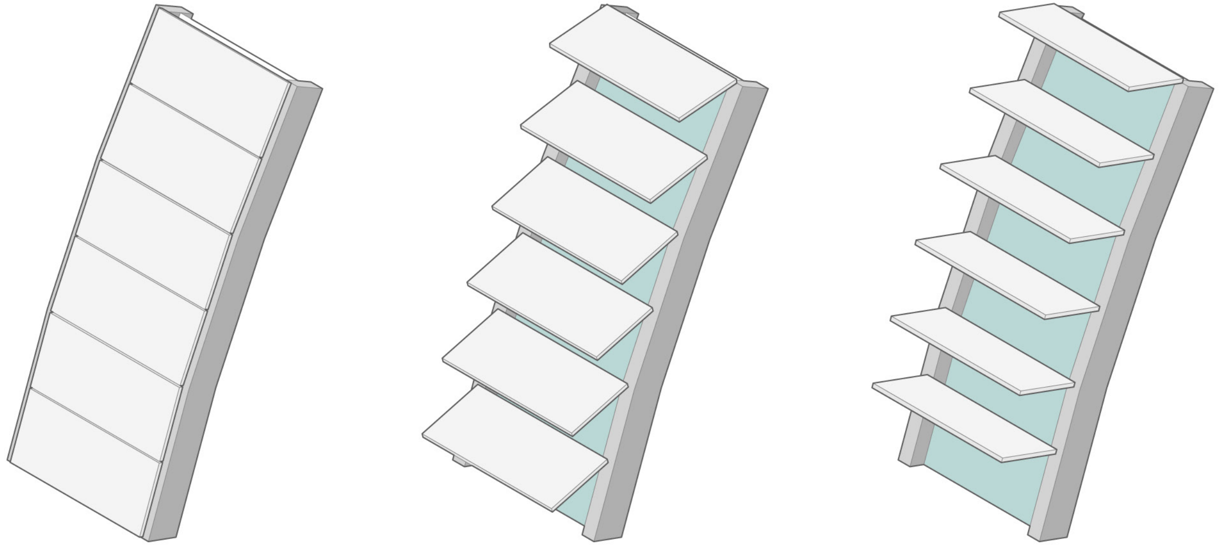


Right: Figure E.12
Components and assembly of a standard transparent facade sector.
Source: Created by the author.

is held in place by the last two orders of supports and is positioned so that it overlaps with the window (and steel post) below. This ensures quick and easy drainage of rainwater and solid material, which would, otherwise, deposit in the interstices offered by standard transparent structures. In this sense, this surface is treated as both a wall and a roof contemporarily.

The final result is an almost completely transparent façade, only interrupted by the wooden beams and the first order of horizontal steel supports, leaving large uninterrupted glass surfaces.

The amount of entering solar radiation ensured by such a transparent design might, however, be excessive, especially during the summer months, when the temperature inside the greenhouses could grow



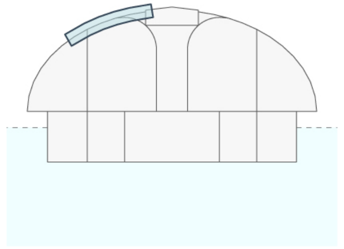
way above comfort levels. To limit and effectively control the amount of radiation that enters these spaces, the building is provided with an automated solar screens system, remotely controlled thanks to specific environmental sensors.
Two horizontal screens for each glass panel can be closed or opened according to the specific needs of the moment. If the temperature is growing excessively, the screens can be closed, limiting entering light and heat, or vice versa. All these screens, being completely independent of each other, can also be selectively opened, closed, and ajar.

The same vertical beams that sustain the glass panes from the sides (second-level posts), function as anchor points for all the solar screens and the small engines that activate them, which are anchored to the very outer surface of the supports.

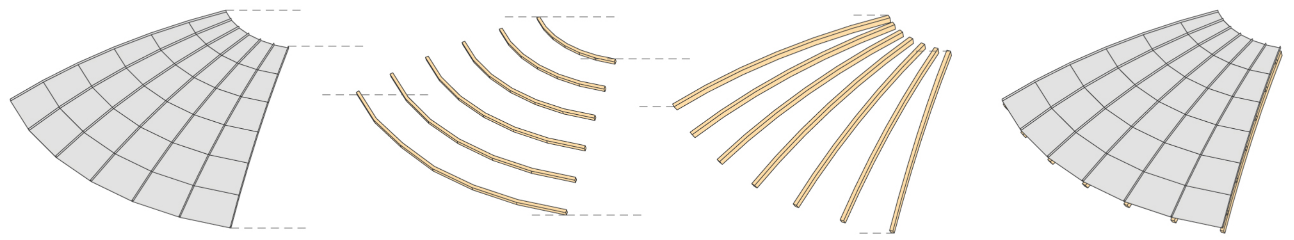
Opaque Facade

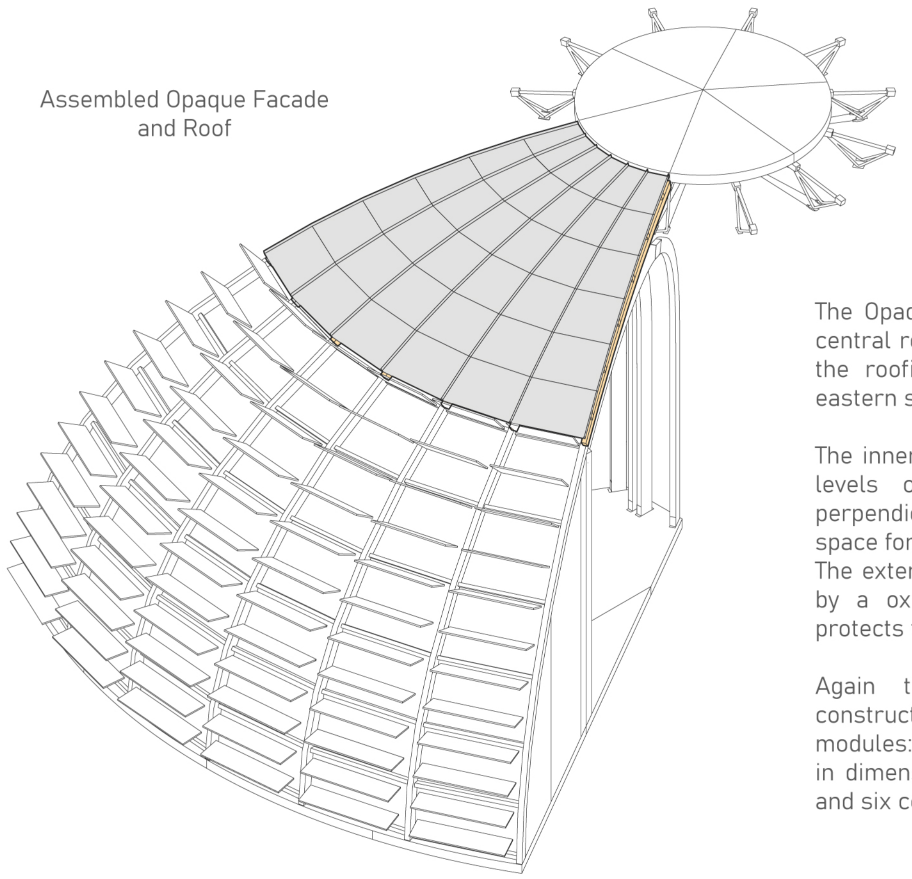
The opaque solution is adopted for both the upper part of the dome (what could be considered the roof) and the western and northern sectors, in the area which is not occupied by the windows.
The choice of an opaque façade aims to achieve higher thermal performances, providing the opportunity to insert significant layers of insulation, indeed it is adopted in the areas less favorable from an exposition point of view. The small transparent surface also limits significantly the entering solar radiation, resulting in generally lower energy consumption throughout the year.

Furthermore, opaque surfaces can ensure privacy for certain areas of the pavilion, such as the restrooms or the technical rooms, hiding them from direct view from the outside.



Bottom Left: Figure E.13
Adaptive solar screen functioning and possible configurations.
Source: Created by the author.





The Opaque facade is used both in the central rows of components, to produce the roofing, and in the northern and eastern sides, to produce the “walls”.

The inner structure is composed of two levels of wooden beams, disposed perpendicularly to each other, generating space for a double insulation layer.
The external finish is instead composed by a oxidized aluminium sheet, wich protects the components below.

Again this components reach the construction site as prefabricated modules: three “wall” modules (identical in dimensions to the transparent ones) and six central triangular roof moules.

Left: Figure E.14
Components and assembly of a standard opaque facade sector.
Source: Created by the author.

Similarly to what happens for the transparent skin, the opaque surfaces have to approximate the curve of the pavilion to a polyline, rendering feasible the production of the components.

To give continuity and uniformity, the subdivision of the curve follows the same rules defined for the glass façade, resulting in components with analogue dimensions and shapes. This allows for a single compositive language for the entire building, without giving up on customization.

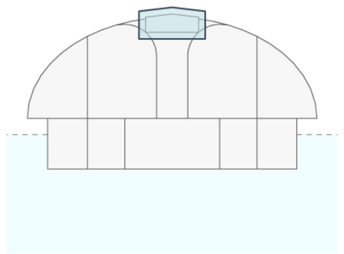
The general format is again of a curtain wall, anchored to the curved beams. This time however the structure is produced in wood. Two orders of posts are placed perpendicularly to each other.

The main level of supports is vertical (with horizontal horizontal post in between), with a section of 12 x 5 cm. These are the ones that follow the curve and have a polyline profile. Between these posts is inserted a first layer of wooden wool insulation.
The secondary level is placed horizontally and generates space for a second layer of insulation and, at the same time, offers an anchor point for the external metallic skin. This is composed of seamed aluminum sheets, which are compositionally borrowed from the roofs of Venetian domes, used in most of the churches of the city. These metallic sheets, as happens for the glass panes, overlap with the ones below, ensuring water drainage.
The double insulation layer, being oriented in two perpendicular directions, greatly reduces thermal bridges.

Figure E.14 represents the different components of a standard section of opaque façade, starting from the structural wooden posts, to end with the glass panes and solar screens.

Central Skylight

The center of the platform is occupied by the large main hall, defined by the hexagonal wall and the central pillar bundle. This space has no direct contact with the exterior and is only partially illuminated through the surrounding rooms. This produces the need for an additional opening, which is solved with a large central skylight. This lights the room from above and offers a view of the sky.



The total span, with a mean radius of 3,25 m, is therefore covered by a single polygonal transparent polycarbonate component, which ensures high thermal performance (much more virtuous than correspondent glass components) and provides diffuse lighting, preventing glare inside the pavilion.

Three layers of polycarbonate are used to realize this skylight. The external one (2,5 cm thick), provided with a minimal slope, protects the structure from intense solar radiation, rain, and other precipitations. The two inner ones, much thicker (2 x 4 cm), are coupled and placed in continuity with the opaque insulation, and provide the thermal performance of the solution, greatly reducing thermal bridges as well.

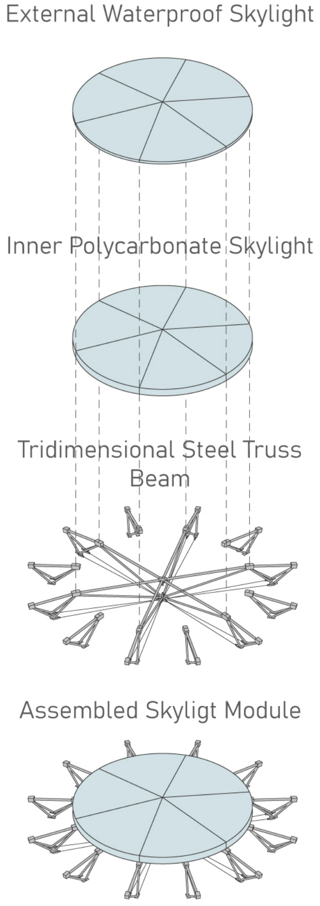
This solution, provided as a prefabricated module by many manufacturers, would be transported as a single piece and connected as the last main element of the building. Because of the curved shape of the inner pillars, they cannot directly hold up the skylight, which, in turn, rests on the steel truss beam. This could also provide a central support point, reducing the span of this element.

In the center, automated gratings are opened and closed to allow for natural air movement from the central room to the space between

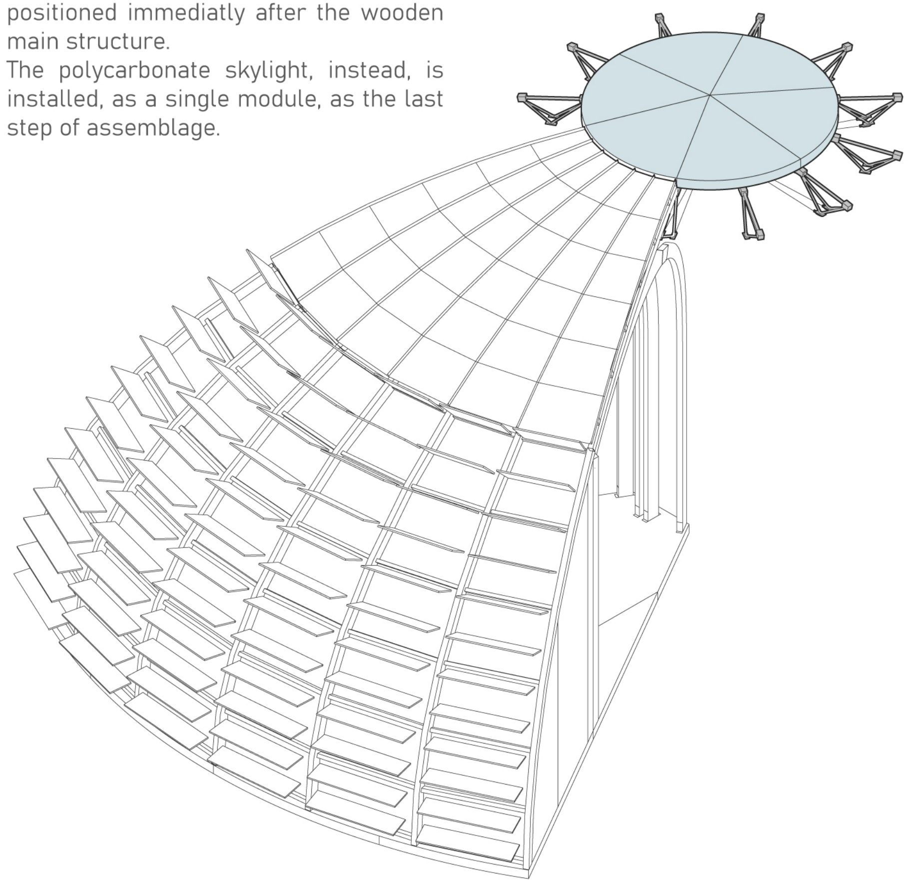
the polycarbonate layers and then to the exterior. This assists the automated air circulation and is to be intended as a way to reduce energy consumption.

Bottom Right: Figure E.15
Components and assembly of a the central skylight.
Source: Created by the author.

Figure E.15 represents the different components of the central skylight, starting from the structural steel truss beam, to end with the polycarbonate roofing.



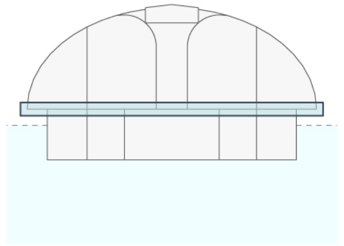
The tridimensional truss beam is positioned immediatly after the wooden main structure.
The polycarbonate skylight, instead, is installed, as a single module, as the last step of assemblage.



05.2.4 Upper-Structure Bottom Floor

Prerequisites

The concrete floating platform offers a flat hexagonal foothold, which is the only available space for the upper-structure. This area was, however, rather limiting, as its dimensions struggled to contain all the required spaces and its shape was an extremely limiting factor, which forced the design.



The choice of a semi-circular footprint, oriented to overcome these stringent limits, needed a backup from the bearing structure (which had to sustain the overhang) but also implies a much more complex solution for the bottom floor.

The upper-structure, however, cannot simply lay on the concrete base, but it has to be solidly connected to it, to avoid any undesired movement and ensure the correct behavior to the external forces and stresses.

The concrete base is almost completely impermeable, but the presence of water inside the ballast system, and the fact that the structure is almost completely immersed in the lagoon, would most likely result in significant levels of humidity in the underwater structure. The bottom floor of the upper-structure, therefore, needs to completely waterproof everything that sits above the concrete base. Furthermore, the under-structure is not thermally insulated, except for the central space and the two locker rooms. Hence, the bottom floor must contain enough insulation to ensure the proper thermic performance of the building, reducing the dispersions towards the base.

The floor

As explained previously, the structural component of the floor is a CLT panel (14 cm thick). Below this structural element, a double layer of wooden wool insulation 8 + 8 cm thick is sustained by a double horizontal steel structure and is enclosed on the bottom by a wooden OSB panel, resulting in a drywall-like solution. This insulation ensures thermal discontinuity between the conditioned upper-structure and the non-heated under-structure.

The bottom panel also offers a solid surface to properly secure one waterproofing layer, which is then integrated with another one, this time attached to the bottom concrete floor. This double barrier could be an overkill but is motivated by the harshness of the lagoon environment and by the complexity of the overhang node, which could represent a fragile area, potentially exposing the whole floor to water intrusion.

Above the CLT panel, the floor layers had to provide space for pipes, cables, and ducts to run in. Therefore, the design includes a floating floor, which lays on steel footholds and offers a surface composed of 40 x 40 cm panels, which serve as a base for the floor finish.
The floating floor produces a 15 cm gap, where system channels can be easily positioned, conserving inspection and maintenance hatches. The gap also allows for the realization of the required slope for the drainage pipes. Holes are realized in both the CLT and concrete floors, allowing cables and pipes to reach all the required locations and to move freely between the upper-structure and under-structure.

Finally, the upper layer hosts the final finish, which consists of two different solutions: an industrial self-laying linoleum for the greenhouses and the other "technical" rooms, where the main goal is

to provide a resistant, impermeable, and easy-to-clean surface, and a more elegant wooden floor for the central area, where most of the visit activity will take place.
Both these solutions are dry-assembled and can easily be prefabricated together with the rest of the floor structure. They do not require the use of glues and can easily be substituted and disassembled.

No specific acoustic insulation is provided on the floor, as the CLT panels, together with the thermal insulation, are enough massive and thick to provide a sufficient acoustic performance to the structure (further research and precise modeling of the structure would be required to confirm this assumption).
The CLT panels are also considered rigid enough to sustain most lateral stresses, rendering superfluous the presence of horizontal wind braces inside the floor.

The anchorage system

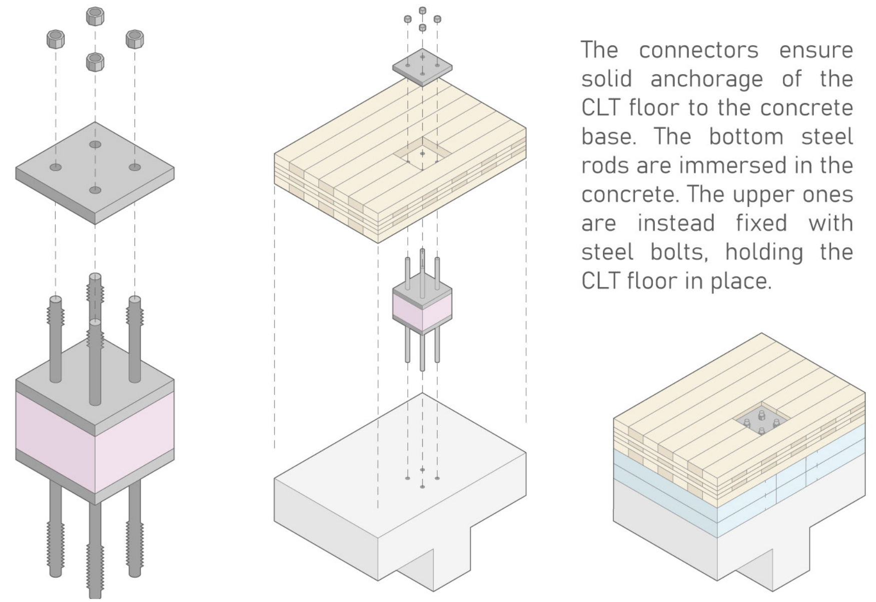
As explained the contact between the upper-structure and under-structure has to be solid and extremely reliable, effectively ensuring that they move and react together. The connection also had to be made with a dry assemblage, to allow for prefabrication of the upper-structure and future disassembly.
The link has to happen between two floors: the lower concrete one with the CLT upper one, always allowing for waterproofing and thermal insulation (containing the thermal bridges).

The chosen solution consists of punctual steel connectors with thermal break (this kind of component is usually seen in metallic structures and is often used for pillar-beam connections), each of them composed of 4 metal rods, which are immersed in the concrete

on one side and can be bolted on the other. Once the prefabricated upper-structure is completed, it can be lowered in position, ensuring the metal rods fit into pre-drilled holes in the CLT. Once everything is correctly located, the structure is locked in place with steel plates, anchored to the rods with threaded bolts.

The connectors are contained in the thickness of the insulation layers, which closely surround them, ensuring continuity in the insulation and almost completely avoiding any thermal bridge phenomena.
Further spray insulation could be injected into the remaining slits, to further improve the performance of the solution, at the expense of a certain degree of reversibility of the construction.

Figure E.16 contains a small technical zoom regarding the thermal-break anchorage system of the floor, connecting it to the concrete base.



Bottom Right: Figure E.16
Thermal break anchorage system betwenn CLT floor and concrete floating base.
Source: Created by the author.

Each of these connectors is positioned directly above one of the concrete walls of the under-structure, ensuring a larger resisting section to anchor the rods, but also a direct and clear vertical loads transmission. Additional connectors are positioned directly below the internal divider CLT wall, to allow for a vertical discharge of the structure weight, despite the absence of a concrete wall directly below.

Every prefabricated module is held in place by 12/18 (internal/ external modules) connectors, allowing for a mostly uniform stress repartition and effectively connecting every CLT component to the floating platform. The vertical stresses are counteracted by every connector, while de hexagonal scheme ensures a good response to the lateral forces as well, reacting in every direction.

The overhang

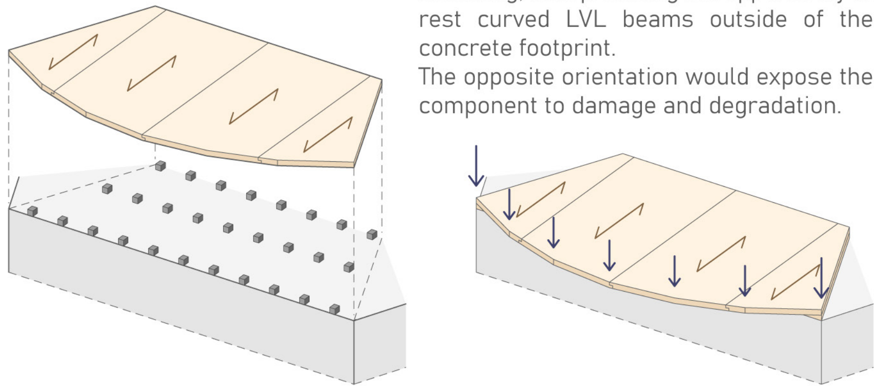
The choice of designing a circular-like footprint for the upper-structure answers the problem of lack of space, as it extends the building beyond the concrete platform limit. This however poses important challenges for the structural components and in general for the technical design of the building.

First of all, stretching out in the open for 1,23 meters it finds no other support. The bearing structure, therefore, needs to be designed to render feasible this overhang. By orienting the main fiber direction of the CLT components perpendicular to the perimeter of the platform, the CLT floors are able to sustain this gap, as they are provided with 3 additional meters of foothold above the concrete structure. Furthermore, being completely jointed with the floating base, the shear and moment stresses produced by the loads that weigh on the overhang are divided among the numerous anchor points.

Being CLT a non-isotropic material, it offers different responses to the external stresses depending on the direction those act on it. Orienting the CLT main fiber direction in parallel with the platform sides would offer much lower performance and expose the wooden components to bending and breaking. This characteristic can, however, be exploited, starting with proper orientation, or even providing a strongly unbalanced distribution of the CLT layers.

Figure E.17 represents the main fiber orientation of the floor CLT components of one of the overhanging modules, showing the subdivision of each floor in smaller components.

As the inner curved beams of each façade module rest on the overhang, these are undersized, to reduce the load that they transmit to the floor. To compensate for that, the two CLT walls that close each of the modules, are instead partially oversized (10 + 10 cm thick) so they can act as the main supports, directly transmitting the loads to regions of the floor that completely lay on the concrete base.



The chosen fiber orientation for the CLT floors, allows for the realization of the overhang, also providing the opportunity to rest curved LVL beams outside of the concrete footprint.
The opposite orientation would expose the component to damage and degradation.

Bottom Right: Figure E.17
Standard CLT floor division in components and main fiber orientation.
Source: Created by the author.

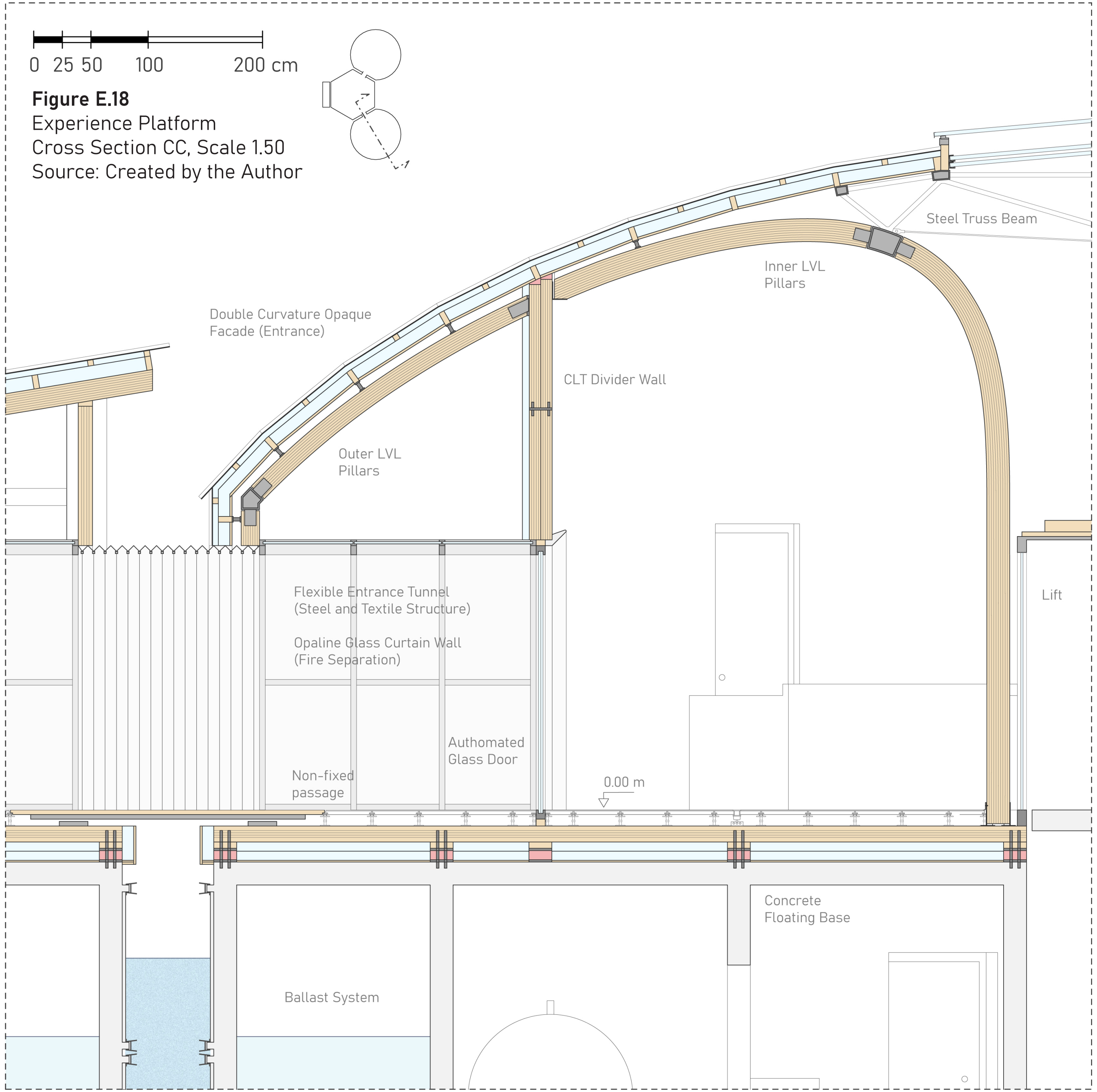


Figure E.18
Experience Platform
Cross Section CC, Scale 1.50
Source: Created by the Author

The overhang also generates an anomaly in the floor standard section. This outer element of the CLT panel has to be completely insulated and waterproofed, ensuring that both insulation and water barriers fold over the edge of the floor, up to the point of reaching the transparent or opaque façade.

For what concerns thermal insulation, the same system used in the space between the CLT and concrete floors, simply continues beyond the floating platform, reaching the outer edge of the structure, before turning up and toward the centre, completely wrapping the floor and ending once it has reached the wall.
The waterproofing is slightly more complex. The same impermeable sheet, which is attached to the bottom of the upper-structure, continues on the overhang, again completely covering the whole floor section. A third sheet is then used to cover the remaining slit, produced by the two waterproofing layers described in the previous paragraphs. This component prevents the infiltration of any water or humidity between the upper-structure and the under-structure.

Finally, a folded aluminum sheet covers the outer edge of the pavilion's floor. This component, first of all, acts as an external gutter, redirecting all the rainwater draining from the walls, directly into the lagoon, but serves as well as a protective element for the insulation and waterproofing layers.

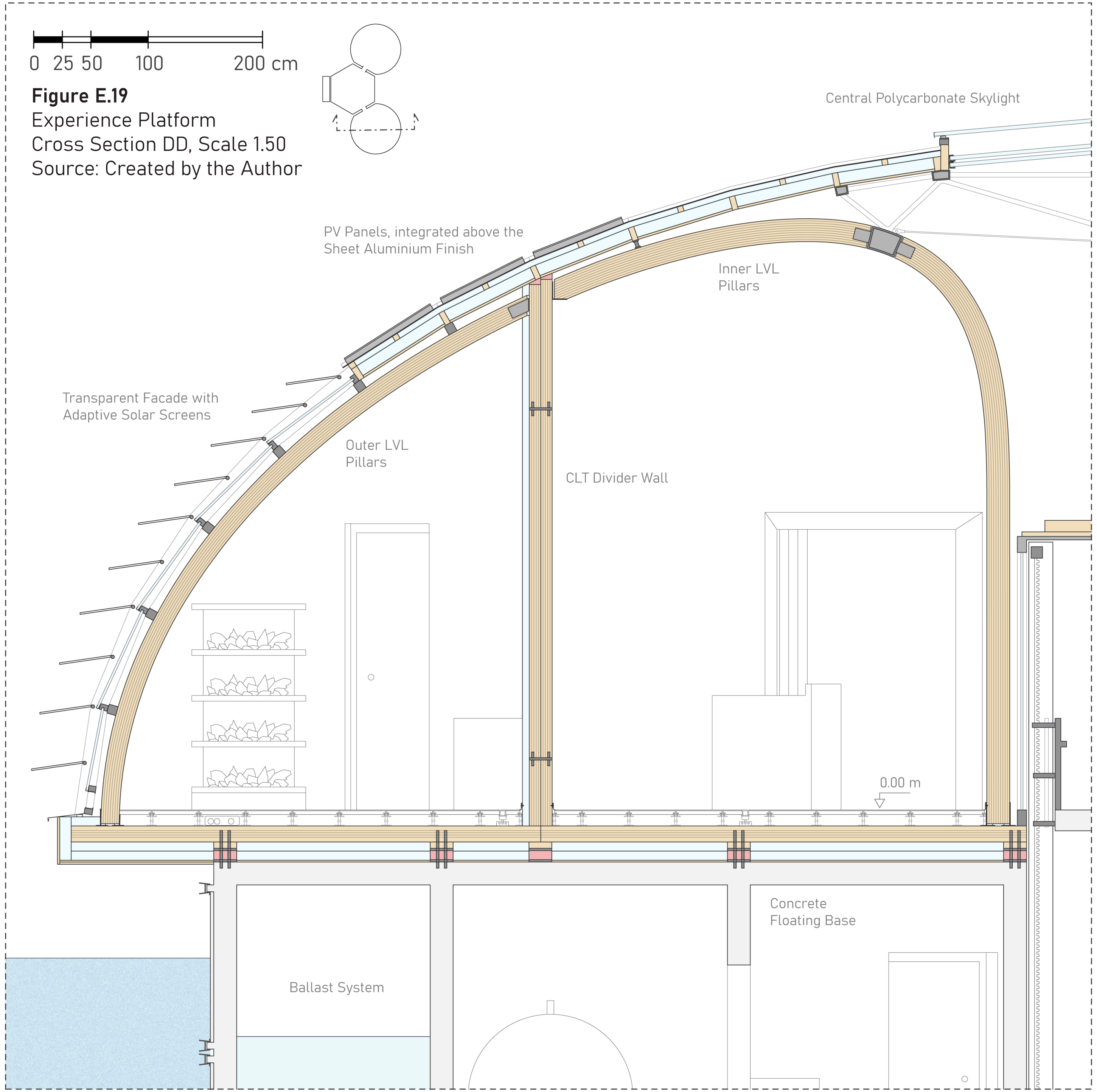


Figure E.19
Experience Platform
Cross Section DD, Scale 1.50
Source: Created by the Author

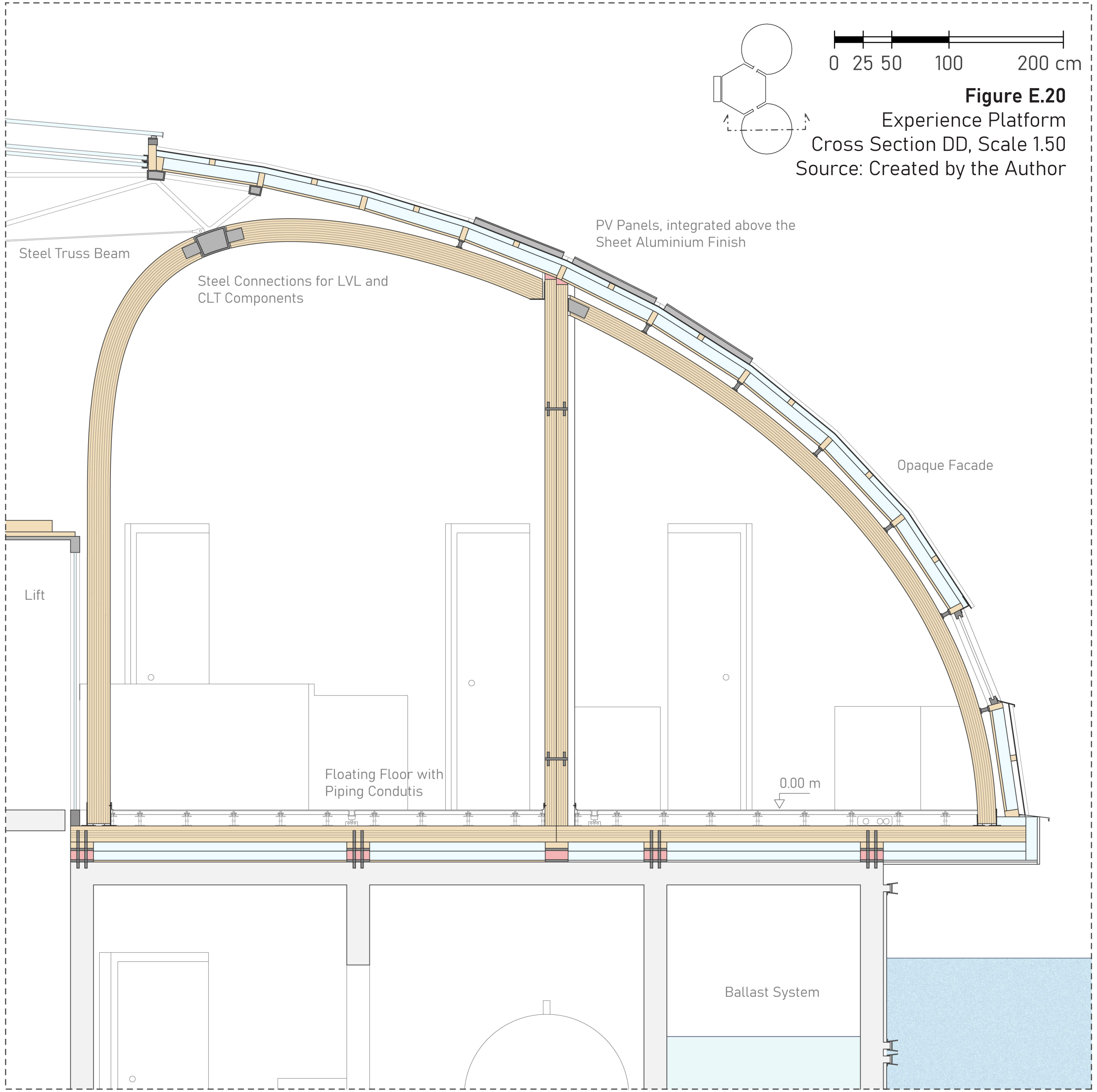


Figure E.20
Experience Platform
Cross Section DD, Scale 1.50
Source: Created by the Author

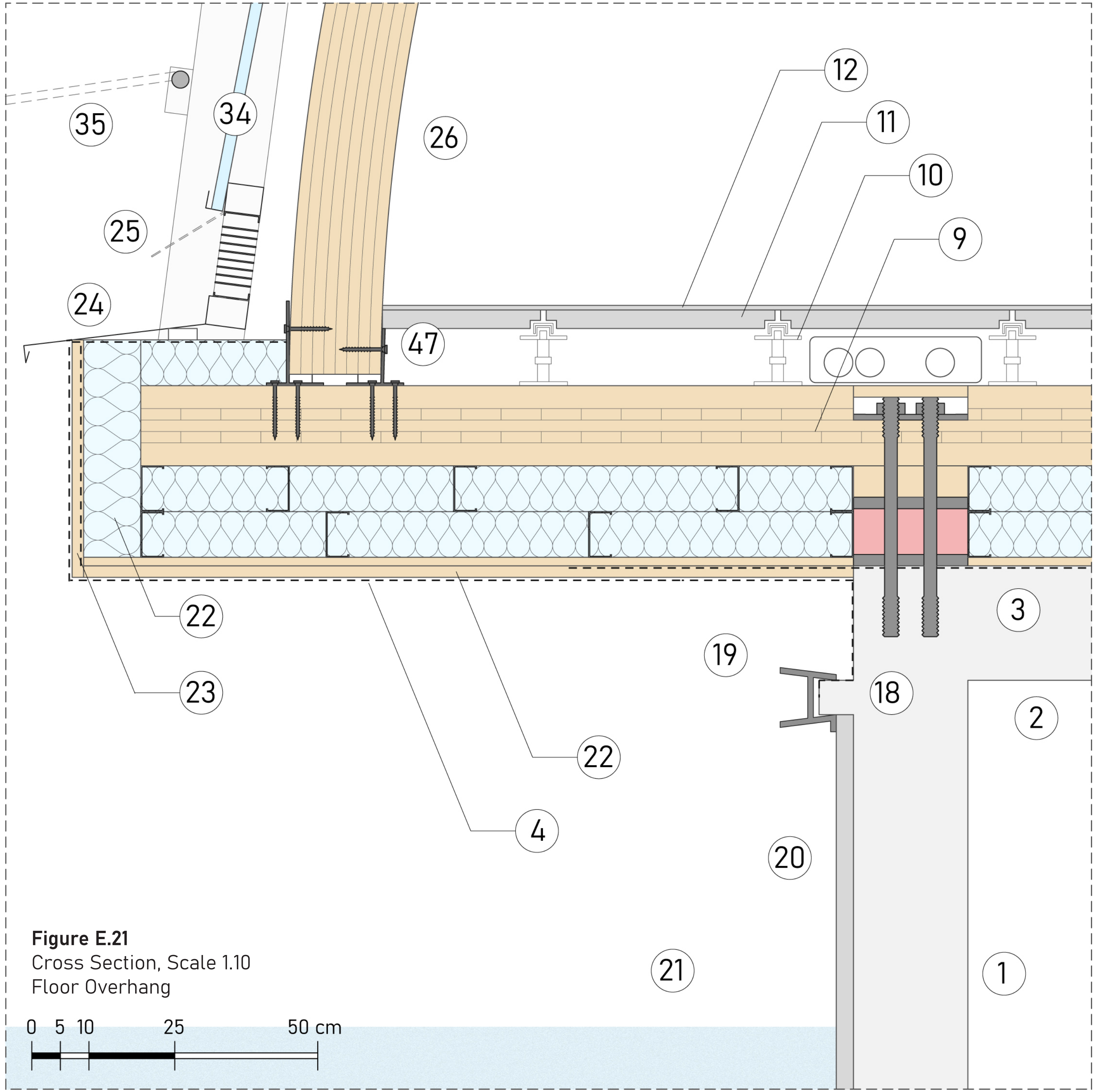


Figure E.21
Cross Section, Scale 1.10
Floor Overhang

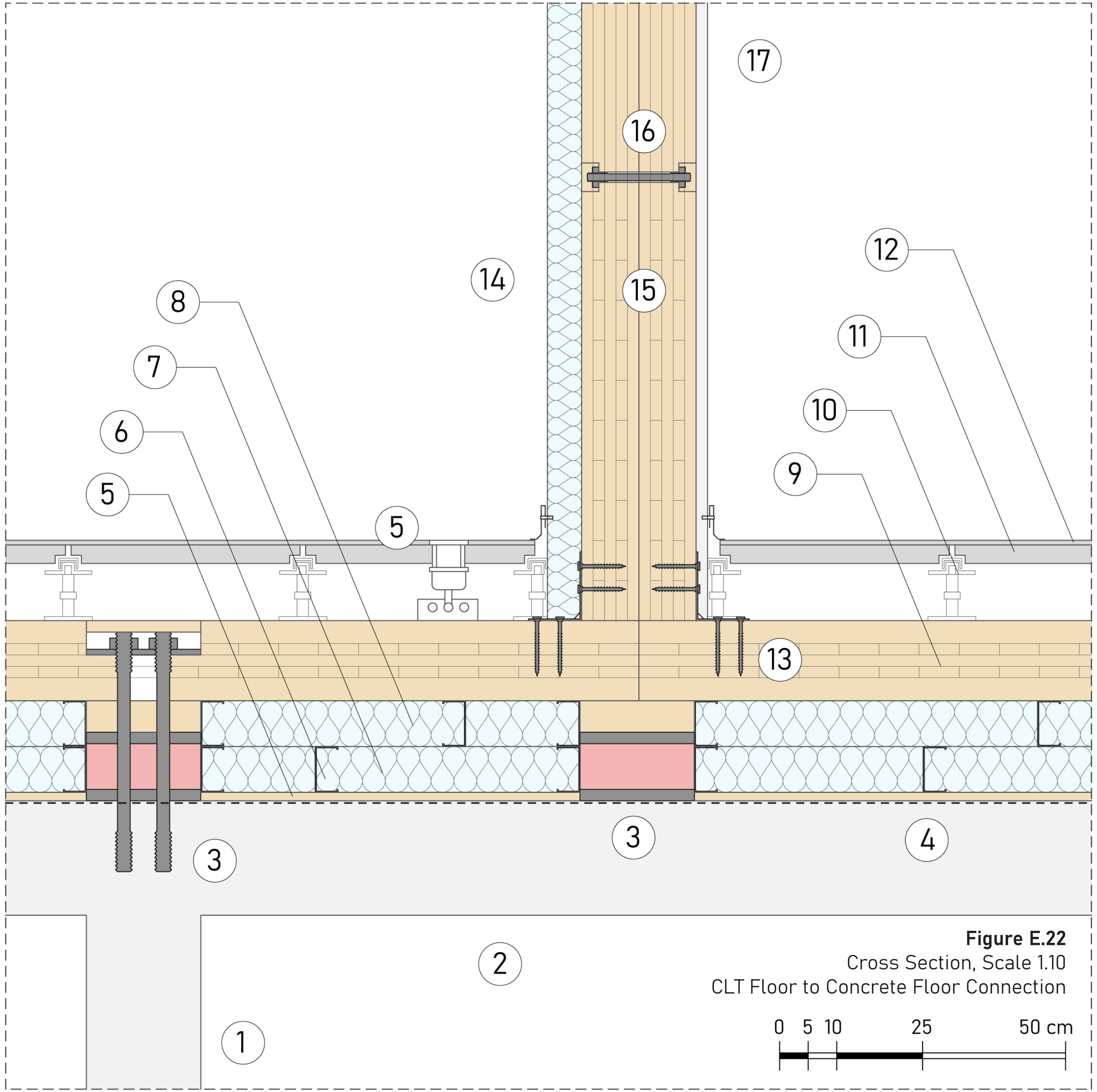


Figure E.22
Cross Section, Scale 1.10
CLT Floor to Concrete Floor Connection

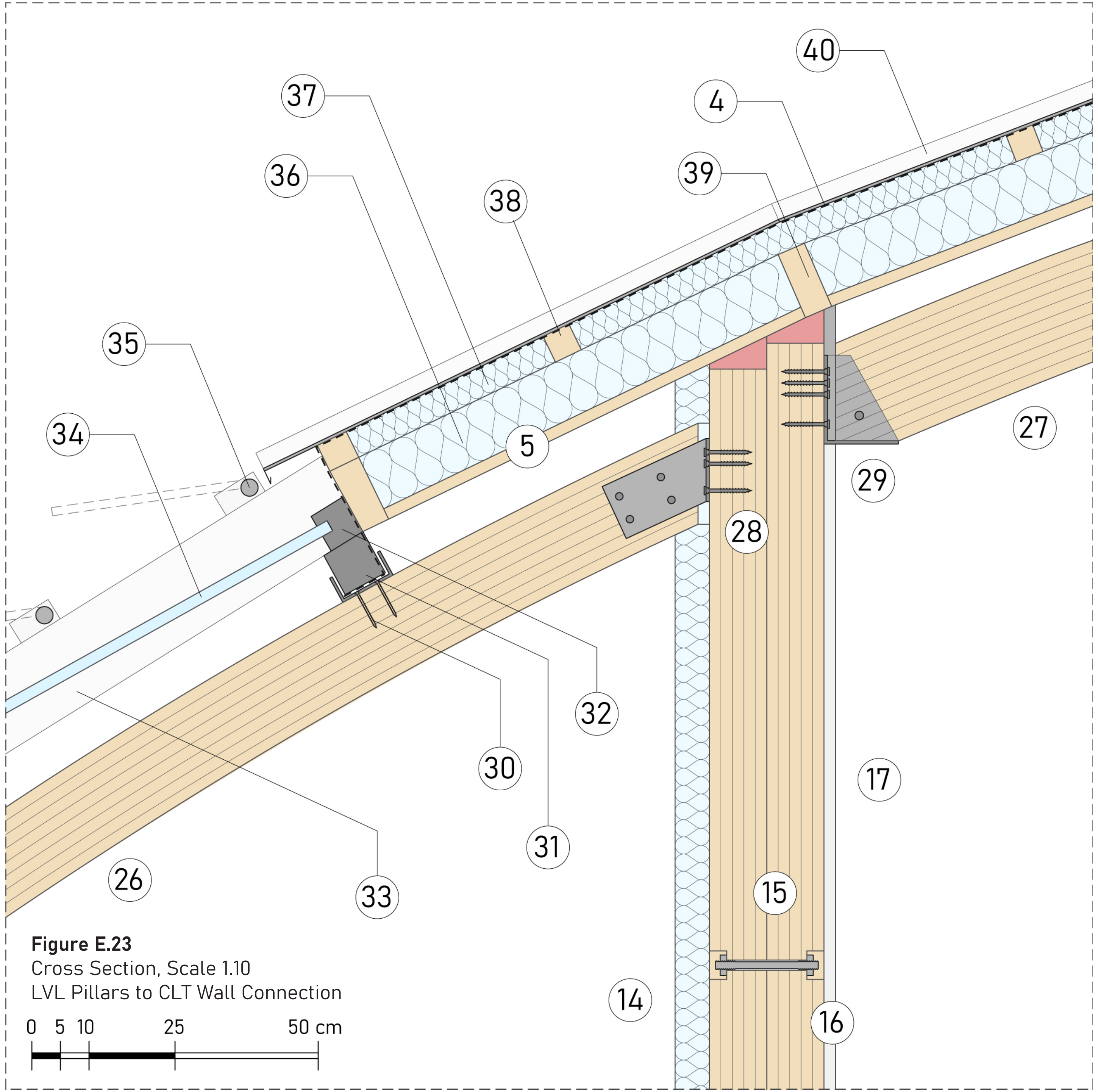


Figure E.23
Cross Section, Scale 1.10
LVL Pillars to CLT Wall Connection

0 5 10 25 50 cm

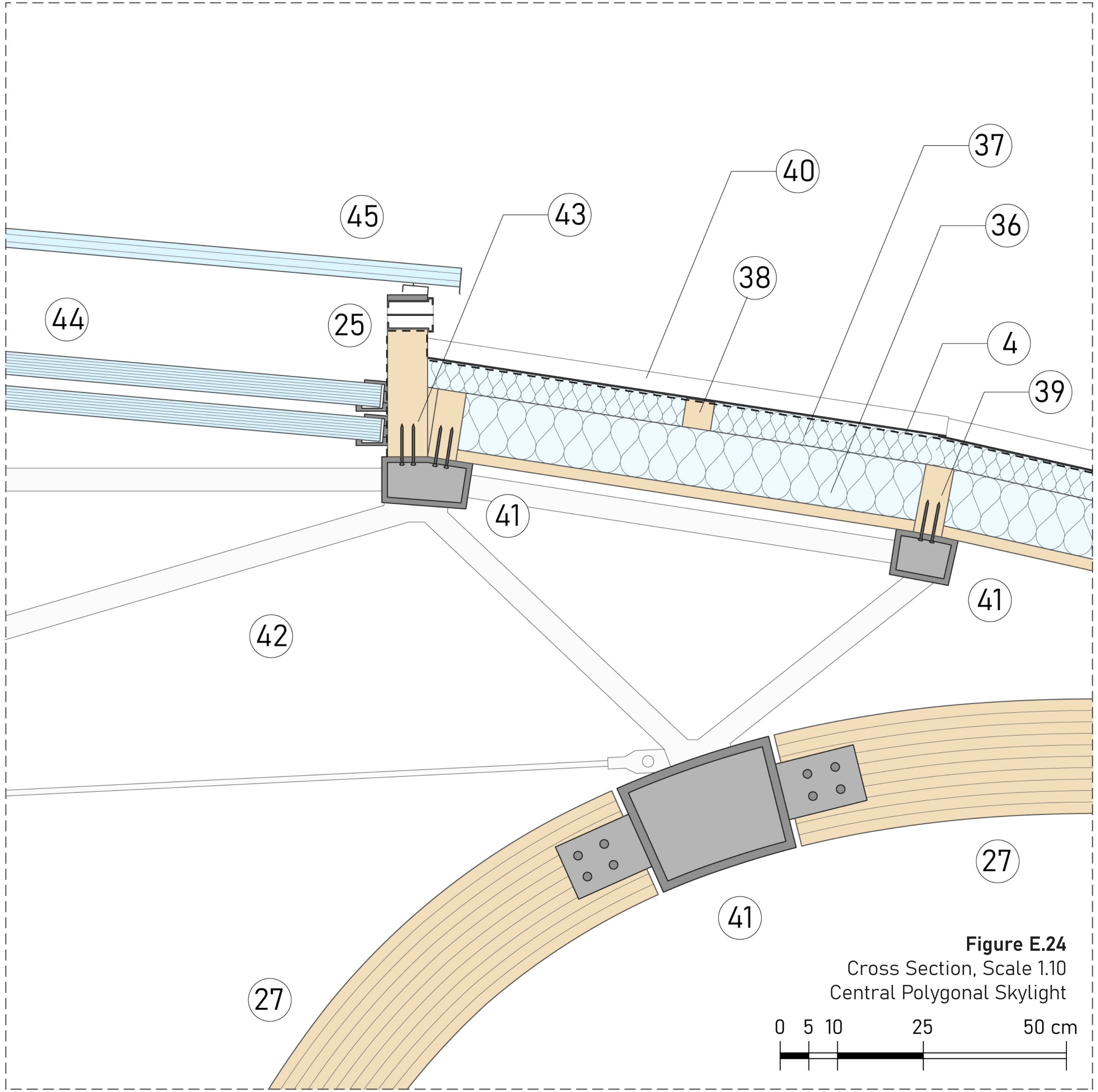


Figure E.24
Cross Section, Scale 1.10
Central Polygonal Skylight

0 5 10 25 50 cm

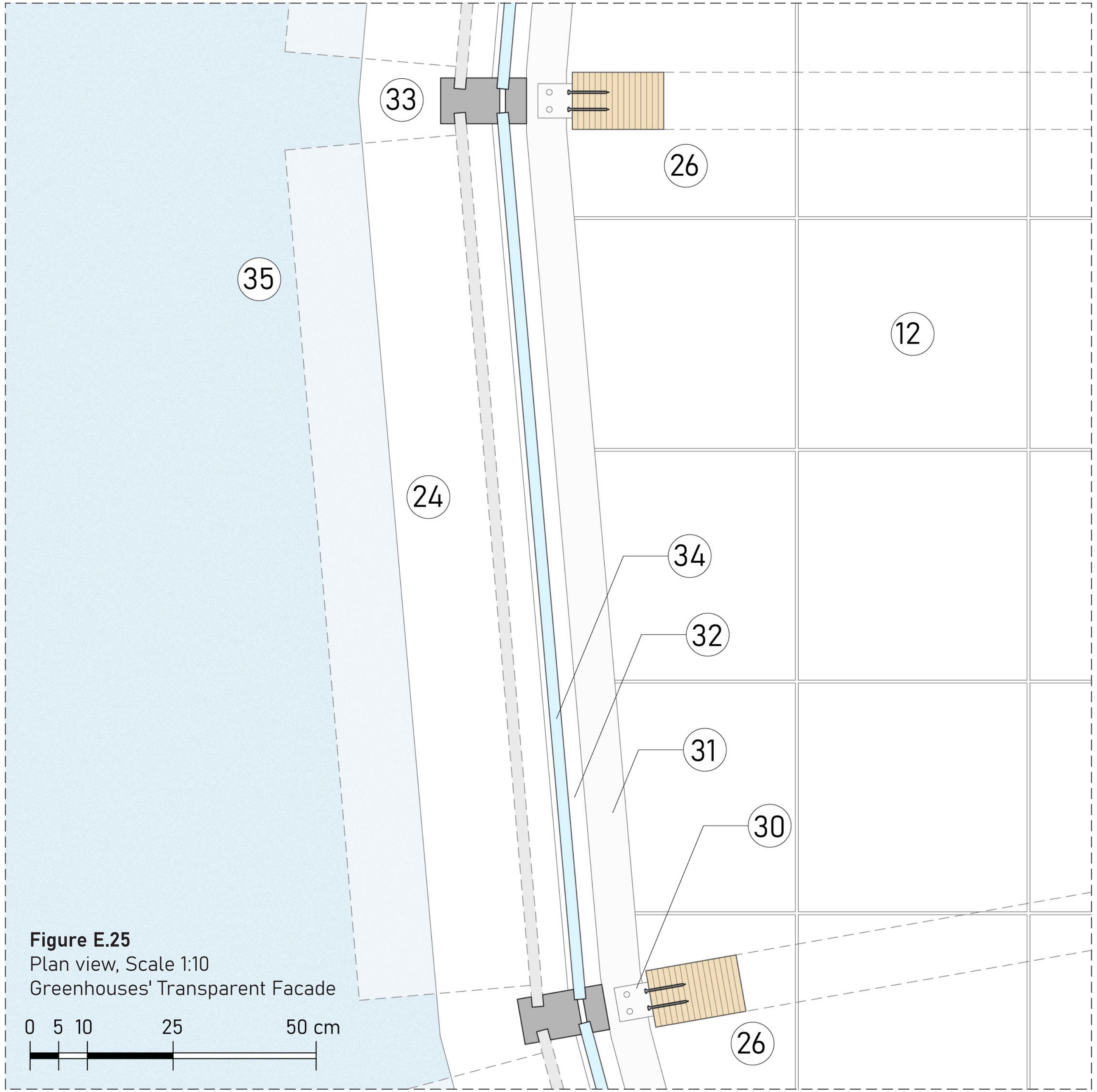


Figure E.25
Plan view, Scale 1:10
Greenhouses' Transparent Facade

Materials and Components Legend

1. Concrete Walls (20 cm)
2. Concrete Floor (20 cm)
3. Thermal-Break Connections Egcobox
4. Waterproofing Sheath
5. OBS Panel (2 cm)
6. Steel Dry-Wall Supports
7. Wood Fiber Insulation (8 cm)
8. Wood Fiber Insulation (8 cm)
9. CLT Floor, 5 layers (14 cm, 4+2+2+2+4 cm)
10. Floating Floor Steel Props
11. Floating Floor with Inspectable Cavity
12. Self-Laying Floor Finish, Marmoleum
13. Steel Connection Plates Rothoblass TITAN N
14. Recycled Cork Insulation (6 cm)
15. CLT Wall, 5 layers (2x10 cm, 2+2+2+2+2 cm)
16. Threaded Steel Rod Connection
17. Plaster and Protective Paint Finish
18. Concrete Moulding (6x6 cm)
19. PVC Connection Clip
20. Protective Concrete Panel for Biofouling (3 cm)
21. Lagoon Water
22. Protective OSB Panel (2 cm)
23. Steel Nail for External Insulation
24. Aluminum Profile for Water Drainage
25. Authomated Ventilation Metal Gratings
26. LVL Curved Beams (10x16 cm)
27. Coupled LVL Curved Beams (10x20 cm)
28. Steel Connection Plates Rothoblaas F70
29. Steel Connection Plates with Foothold
30. C Steel Plates for Dovetail Connection
31. Horizontal Steel Supports, Transparent Facade
32. Second Level: Aluminium Frames with Thermal B.
33. First Level: Aluminium Frames with Thermal B.
34. Double Glazing, Low-Emission Surface Treatment
35. Authomated Horizontal Solar Screens
36. Wood Fiber Insulation (5 cm)
37. Wood Fiber Insulation (10 cm)
38. Second Level: Wooden Joists (5x5 cm)
39. First Level: Wooden Joists (6x12 cm)
40. Hoxidized Seamed Aluminium Sheet
41. Truss Beam Steel Nodes (custom made)
42. Steel Truss Beam (tridimensional)
43. LVL beam (7x22 cm, polygonal)
44. Double Layer Polycarbonate Transparent Floor (Dr. Gallina), high thermic performance (4+4 cm)
45. Polyedric Skylight System, GeoRoof KALWALL System, for external finish.
46. PVC Channels for Systems' Ducts and Cables
47. Steel Cup Connection for Pillars, Rothoblaas

05.2.5 Internal Spaces & Finishes

Although the structural components are produced in engineered wood, the internal finishes do not necessarily display the same material. Most of the outer rooms, indeed, present complex conditions of temperature and humidity, which could significantly stress the naked structural components.

First of all, the internal surface of the opaque façade is, in the entire building, protected by a vapour barrier and a painted plaster finish. The waterproof coating is also added in every room where the surfaces could be regularly wet.

The greenhouses, the tech rooms, and the kitchen require internal finishes which can withstand high levels of humidity and at the same time strong temperature changes. The floors are, therefore, completed with resistant industrial linoleum flooring, which would better respond to frequent cleaning, aggressive products, and mechanical stresses. For the same reason, the bathrooms are provided with a stone finish, which can better behave given the room's function.

The curved LVL beams of the outer set are covered with a protective paint, which would reduce their recyclability but is considered necessary, to avoid material degradation.

Finally, most of the outer rooms require specific and autonomous climatic conditions, different from the ones of the central hall, to ensure the comfort of both people and plants. This requires some degree of thermal insulation in the divider wall, to be able to maintain different temperatures and humidity levels. For this reason, the CLT walls are provided with a layer of cork-based insulation, which other than providing a better thermal performance than the CLT alone, is

also extremely impermeable and resistant to humidity, acting as a waterproof layer as well.

The central hall, instead, presents much more forgiving conditions. Neither extreme temperature changes (as the free heat gains should be limited), nor high humidity levels are expected. This gives much more freedom in the choice of the internal finishes. The choice, in this case, is to directly show the structural materials, given the extremely sentimental and communicative charge of the wood as a material, also referring to the traditional extensive use of wood as a building material for the aquatic structures of the lagoon (docks, mooring, water signs, pillars, ...).
Therefore, both the CLT walls and the LVL beams are left visible, with some degree of protective coating. Wood is also used for flooring, with a simple decking used in the entire hall.
This choice links all the rooms with the metaphor of the central tree, with the intention of creating a strongly poetic and moving image.

05.2.6 Loads Compliance

The simulations and modeling conducted by SEAform's engineers provided data regarding the total weight that can be sustained by each of the concrete floating platforms.

Establishing certain characteristics of shape and dimensions for the floating platforms determines specific results concerning the weight these can hold without sinking. Given a certain footprint, increasing the platform height increases the floating capacity as well. Similarly, lowering the thickness of concrete walls and floors frees up more available weight.
The structural scheme proposed by SEAform is just one of the possible configurations, which could produce equally functional designs

with different wall configurations or with different thicknesses of the components. Further attention would be required to verify the structural performance of the concrete components, to ensure a satisfying response to both the exercise and exceptional loads and stresses. However, for the thesis' development, this configuration is accepted as a basic axiom, with the hypothesis that everything is stable and functioning.

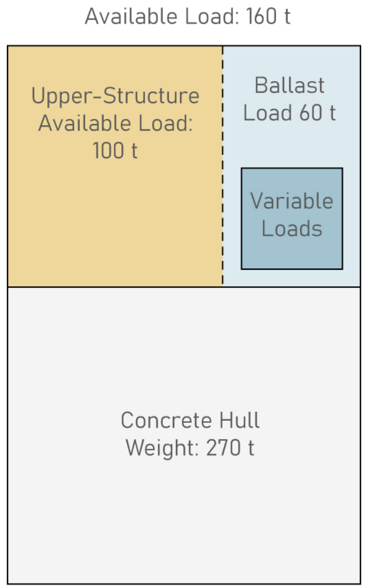
The reference values provided as design restrictions are reported in Table E.26 and visualized in Figure E.26B. A large part of the floating potential of the platforms is dedicated to sustaining the weight of the concrete platform itself. Additionally, important percentages are as well reserved for the weight of the ballast system, the action of variable loads (snow, wind, users, ...), the systems, and finally, the upper-structure itself.

Bottom Left: Table E.26
Reference values for the available loads provided as design restrictions.
Source: Created by the author.

VARIABLE LOADS		
Occupants Maximum Load	3,7	ton
Snow Maximum Load	19,4	ton
Water and Wastewater Maximum Load	24,0	ton
Water and Wastewater Minimum Load	10,0	ton
Total Maximum Variable Loads	47,1	ton

REFERENCE VALUES		
Submerged Volume of the Platform	430,0	m^3
Total Floating Potential	430,0	ton
Hull Weight (Under-Structure)	270,0	ton
Total Available Weight (Upper-Structure, Ballast, ...)	160,0	ton
Minimum Ballast Weight	46,5	ton
Defined Ballast Weight	60,0	ton
Available Upper-Structure Weight	100,0	ton

Below: Figure E.26B
Visualization of the available loads.
Source: Created by the author.



The ballast system, designed to hold up to 60 tons of water, as soon as the variable stresses start to encumber the structure, will empty itself, to compensate for the additional load, ensuring a consistent value for the draft of the platforms. This means that the variable loads will be completely compensated by the ballast system and will not be considered as part of the upper-structure weight.

The following paragraphs start with an evaluation of the variable loads, which provides a first indication of the minimum volume of water that the ballast system has to contain in a standard situation. Later, is produced a first evaluation of the permanent loads of the upper-structure and the tech equipment.

Variable Loads

Through the application of the normative, were pre-sized the variable loads produced by the snow and the visitors, which are here considered exceptional, as well as the additional load required by the water and waste tanks contained in the under-structure. The values are reported below:

- Occupants' load: 3720 kg (3,7 tons).

Although, on rare occasions, the total number of users inside the pavilion could approach 100 people (for example during occasional larger events), not every person would stand in the same room, but visitors and staff would be shared between the three platforms. Furthermore, as the arrival and departure from the pavilion are strictly controlled and managed, there is no standard situation where the total number of occupants would be higher than 60.

The value of 3,72 tons is calculated with the hypothesis that the maximum expected users, corresponding to 60 people, were, exceptionally concentrated on the same platform. The average weight was approximated to 62 kg, corresponding to the average weight of adult humans across the world. This choice goes in favor of safety, as such a scenario should never happen, nor in emergencies.

- Snow load: 19387 kg (19,4 tons).
This corresponds to the maximum expected snow load, given the location, shape, and dimensions of the building. The value is based on the 2018 NTC, concerning the sizing of the actions and loads produced on buildings.

The standard provides a formula to determine the load produced by the snow which deposits above the building. Variables used in the formula are dependent on the chosen location, altitude above the sea, the shape of the roof, the thermal performance of the external skin, and wind patterns of the area.
This value is exceptional and should be extremely rarely surpassed during the pavilion activity.

- Water and Waste Tanks' load: 24000 kg (24 tons).
This value represents the maximum weight of all the water and wastewater tanks combined. Although the total volume of the tanks is 24000 litres, these tanks will never be full at the same time. The black and gray wastewater tanks are, indeed, filled through sinks and toilets, which are directly supplied respectively by the freshwater and rainwater tanks. Therefore, the total volume of water contained in the platform, will rarely be larger than 15 tons, provided the unloading of the waste tanks happens before the loading of freshwater.

Other variable actions could have an impact on the pavilion and result in some dose of additional vertical load, further stressing the floating base. Examples are wind action and seismic action, both of

which could produce a vertical component. Properly assessing the scale of these actions, however, would exceed the available time for the thesis.
In any case, the actual scale of these components should be limited. Wind action, for example, mostly translates into horizontal stresses and deformations. Additionally, the load produced by the snow and the occupants of the building should be of a larger scale, rendering secondary most of the other variable loads. Finally, the probability that these exceptional variable loads act simultaneously on the structure is extremely low and should be negligible.

In the worst possible scenario, with 60 users on the same platform at the same time, completely full water tanks (due to logistic mistakes), and intense snow precipitations (an extremely unlikely scenario), the total additional (variable) load would be 47,2 tons. Considering an additional 20-25% weight, which would maintain a lower position of the centre of gravity (also acting as a safety margin), the ballast system should contain, as the starting value, 60 tons of water.

Permanent Loads

The 60 tons of water reduce the available load for the upper-structure from 160 tons to 100 tons. This paragraph is dedicated to ensuring that the upper-structure, the tech equipment, and the furniture of the pavilion have a total weight equal to or smaller than 106 tons.

The total weight of the upper-structure is close to 95 tons, barely lower than the maximum value. This, once more, highlights how the choice of a mixed wooden structure for the pavilion was practically forced by this limit, as most other structural technologies would have resulted in higher loads, not bearable by the current configuration.

Table E.27 reports the sum of the weight of each component of the building: structural and non-structural. For each list item, the weight is calculated by multiplying the total volume (or frontal area) of that component by its density (or frontal mass). More specific analyses were required to provide this same data for the furniture and the tech equipment, but are not reported in this text for space reasons, since would represent a deviation from the key path

Bottom Left: Table E.27
Weight of each building component and total weight of the upper-structure.
Source: Created by the author.

LOAD COMPLIANCE	A [m^2]	V [m^3]	$m_{surface}$ [kg/m^2]	m_{volume} [kg/m^3]	m [kg]
Available Upper-Structure Weight					100'000
STRUCTURAL PERMANENT LOADS					
LVL Curved Beams		7		480	3360
Steel Beams and Connectors					3523
CLT Floors		36		480	17472
CLT Walls		30		480	14400
Total Structural Loads					38755
NON STRUCTURAL PERMANENT LOADS					
Transparent Facade (Aluminium Structure)	130		60		7800
Opaque Facade (Wooden Structure)	270		64		17280
Polycarbonate Skylight	9		20		180
Wall Finishes	300		20		6000
Flooring	260		35		9100
Prefabricated Divider Walls	59		56		3326
Furniture					9000
Mechanical and Electrical Systems					3500
Total Non Structural Loads					56186
TOTAL PERMANENT LOADS					94942

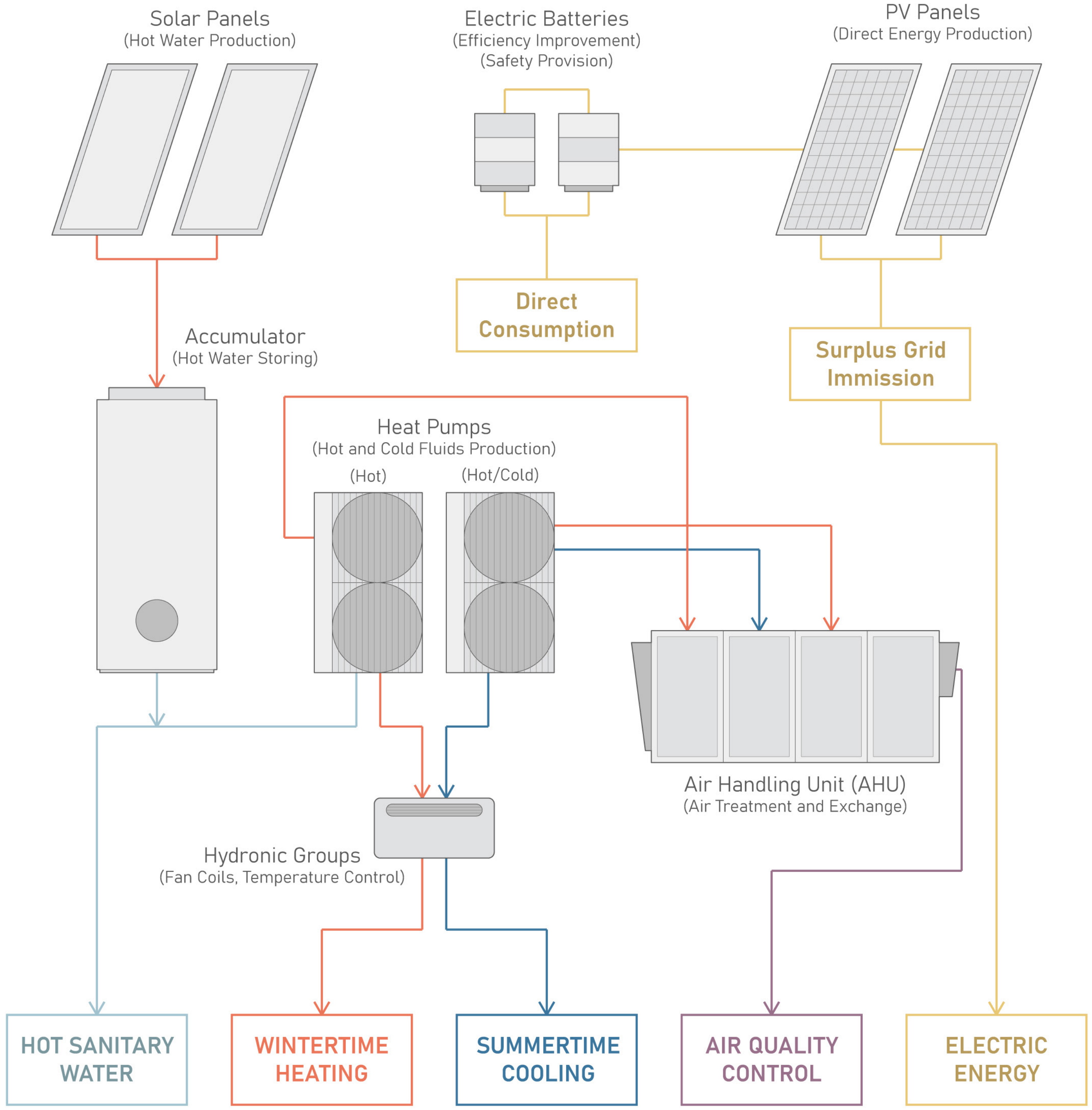
05.2.7 Mechanical & Electrical Systems Reasoning

Defining the size of the systems and services of such a building is particularly complex. The unusual shape and characteristics of the project render it difficult to compare to other structures or to categorize.
The degree of detail reached in the thesis would potentially allow for more precise evaluations concerning the heating and cooling energy demand, the necessity of ventilation or many other considerations. However, proper system sizing and design would require a very large amount of time, not available in the thesis path.

Nevertheless, intense effort was put into identifying all the necessary systems to properly operate the building and into providing the first indicative dimensions for the components, necessary to individuate a suitable position inside the building, as well as for the total load control.

Because of the remote location of the platforms, the pavilion, as previously explained, cannot be connected to most of the standard service grids of Venice. Notably, the gas grid is unreachable, and traditional natural gas-based heating is not an option.
Both heating and cooling of the pavilion, therefore, are provided by a mixed system, powered by two heat pumps, which produce hot and cold fluids for both hydronic groups (capable of controlling room air temperature) and an Air Treatment Unit (devoted to directly control air quality and indirectly capable of regulating temperature as well).

Figure E.18 represents the system organization of the floating pavilion, explaining the organization and functional choices and the motivations behind them.



Left: Figure E.28
Mechanical and Elcetrical Systems organization of the floating pavilion.
Source: Created by the author.

Air Handling Unit and Hydronic Groups

A building of this size and characterized by such an intense concentration of occupants cannot rely on natural ventilation alone to ensure sufficient internal air quality, but requires the presence of an Air Treatment Unity, to ensure sufficient air exchange and effectively control the ignition conditions, to preserve user comfort.

Controlling the temperature and humidity of the air, the AHU is also capable of regulating the same variables for the entire building, effectively covering a significant part of the required heating and cooling demand. This system, however, needs to be integrated by hydronic groups, devoted to increasing or lowering the temperature in every room, compensating for what cant be achieved by the AHU alone, particularly on extremely hot or cold days.

Both the AHU and the hydronic groups require hot and cold fluids (water), which in the first case are used to control and change the external air conditions before the introduction in the structure, while for the second case are used to heat or cool down the air of each room. The best solution to produce both hot and cold water, without the use of natural gas, are heat pumps.

To properly size the AHU, extremely detailed data about the users, the climate, the geometry, and the components' performance would need to be collected and analyzed. This procedure, however, was substituted by a more simplistic one and the AHU was dimensioned by analogy with other similar systems designed by the authors in previous academic experiences. Based on a proportional ratio (comparing the plan surface of the pavilion with that of the reference project) was established an indicative sizing, comprising a minimal volume of air which the system must be capable of processing.

- Required treated volume of air of the AHU: 560 m3/h
- Estimated dimensions: 1,8 x 1,1 x 0,35 (h) m

Specific air ducts connect each room to a main air channel, powered directly by the AHU, providing treated air to the whole pavilion. Identical correspondent ducts extract the air from the rooms and carry it to the exterior. Another main air duct withdraws air from the exterior, and, before providing it to the AHU, transports it through a water-based preheater (or precooler, depending on the season) inside one of the ballast tanks.

Heat and Cold Production and Sanitary Water

Heat pumps are extremely versatile and efficient heat and cold production systems. They only require electric energy and access to an external heat reservoir (air or water). Most heat pumps are capable of producing both hot and cold fluids but are limited to one of those at a time.

Inside the pavilion, the requirement for hot and cold fluids is significant and variegated. The AHU needs both hot and cold water (to fuel the heating and cooling batteries that compose it), hydronic groups require hot water during wintertime and cold water in the summer months, and hot sanitary water is required in both the kitchen and the restrooms. Furthermore, during summertime, both heat and cold are required simultaneously.
These requirements forced us to opt for two heat pumps, instead of a single larger one. One of them produces only hot water and aliments the hydronic groups, one of the hot batteries of the AHU and provides hot sanitary water. The second one, instead, provides hot water in the winter and cold in the summer, providing it to the remaining AHU batteries and the hydronic groups.

Similarly, to what was done for the AHU, the heat pumps were sized with reference to previous academic projects, defining the following characteristics:

- Total required heating power (Heat Pump 1): 27,5 kW
- Estimated dimensions (Heat Pump 1): 1,2 x 0,8 x 1,7 (h) m

- Total required heating power (Heat Pump 2): 19,5 kW
- Total required cooling power (Heat Pump 2): 12,5 kW
- Estimated dimensions (Heat Pump 2): 0,95 x 0,75 x 1,7 (h) m

Photovoltaic and Electric Batteries

To provide green and low-cost energy for the pavilion, which is however connected to the urban grid, one of the best options is the introduction of a photovoltaic system, architecturally integrated into the building (explained in more detail in Paragraph 5.3.4).

Any PV system, however, experiences peaks of production, alternated to low yield periods, both during the year (summer months are linked with better performances) and every day (production is null at night). Furthermore, during peak hours the production might exceed the demand, lowering the effective energy self-consumption of the building.

To increase efficiency and self-consumption are introduced storage batteries, capable of storing additional produced energy, to be consumed when the yield does not cover the demand.
Identical batteries are provided to respond to unexpected energy shortages caused by blackouts or extreme events that could damage the electricity grid. These batteries are devoted to allowing the correct and secure operation of the building in case of emergency.

Again, these components are sized with rules of thumb, lacking sufficient data for a proper system design. The approximate characteristics are:

- Efficiency batteries required energy capacity: 10,4 kWh
- Estimated dimensions: 0,44 x 0,44 x 0,65h m

- Emergency batteries required energy capacity: 10,4 kWh
- Estimated dimensions: 0,44 x 0,44 x 0,65h m

Solar Panels and Heat Accumulation

Given the extremely large suitable area of façade, the introduction of solar panels, to cover part of the energy demand for hot sanitary water production, could be an efficient choice. Additionally to the solar panels, similar to what was described for the efficiency PV batteries, is provided a heat reservoir, capable of storing hot water during the peak production hours, to be used later in the day.
This could significantly reduce the energy consumption of the heat pumps, effectively covering it with renewable sources.

The sizing is, once, based on reference projects, where similar systems were designed, obtaining the following specifications:

- Annual required production of the solar panels: 3000 kWh/y
- Volume of the required heat reservoir: 472 liters
- Heat reserve temperature: 50 °C
- Estimated dimensions: 0,5 (radius) x 1,6 (h) m

The solar panel would, however, be positioned in a single platform (most likely the vision platform), to optimize the costs and facilitate maintenance. Dimensions of the panels strongly depend on the

single chosen product and further analyses would be required to define a viable and economically sustainable solution. The value of 3000 kWh per year can be the starting point for future more detailed developments.

Hydronic Groups

To actively control the temperature inside the pavilion, one or more hydronic groups (fan coils) are positioned in each room, fueled by hot and cold fluids, produced by one of the heat pumps. The size of these components, however, cannot be determined with sufficient precision, given the current state of knowledge about the thermal performance of the building. Indeed, to properly size the fan coils, would be required a specific thermal model of each room.

Here the author, however, reports the necessity of these components, which would always be positioned close to the main hexagonal divider wall. This choice would provide a central position for the fan coils, also avoiding the more complex interaction with the curved façade and ensuring an easy path for the pipe.

Systems Rooms and Transport Ducts

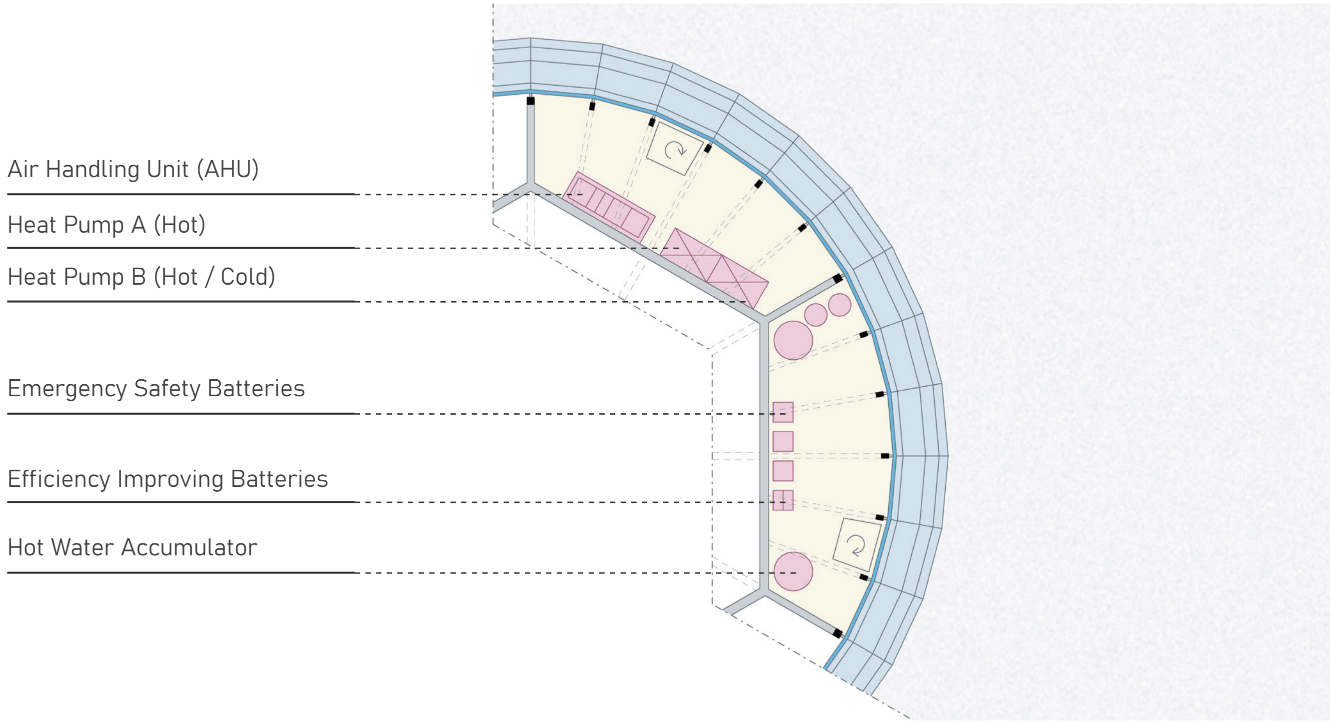
Defining a specific area for the placement of all the centralized systems could significantly simplify the design process (freeing up space in most of the other rooms), reduce costs, and favor any maintenance activity, as all the main components would be close together and easy to access.

The chosen spaces should be first of all sufficiently large to host all the required elements, at the same time allowing movement and ease of intervention. They should provide quick contact with the exterior, for both easy access and safety reasons. They should be insulated (acoustically and thermally) from both the exterior and the interior and be provided with a high fire resistance degree.

For what concerns the water and wastewater tanks, the dedicated rooms are on the underwater floor, inside the concrete platform. This was the only area where no intense activity was foreseen and the only room where such large objects could be positioned without impeding the movement. Furthermore, such large volumes of water can significantly alter the centre of gravity of the platforms. Positioning the tanks (with a symmetrical arrangement) in the lower part of the structure, moves the centre of gravity downward, producing a better response of the building to external forces.
Finally, the bottom concrete floor is the best location for large weights, as it directly sits on the water and can directly transmit the loads, as opposed to the upper floors, which would require larger thicknesses and generally more resistant structures.

All the other centralized systems are located in two service rooms, located above the bathrooms and the kitchen modules. Here, the available volume of the upper-structure is divided into two superimposed floors by an CLT floor, which is connected to the external and divider CLT walls.
This rooms, with a surface of 35,2 m2 are large enough to contain the AHU, heat pumps, electric batteries, and heat accumulation tank (for the solar panels). To sustain the weight of these systems, the CLT panel of the divider floor is 14 cm thick and transmits the loads to the main walls, but also to two secondary divider walls, which offer a central foothold and define a central hallway in the floor below.

Figure E.29 represents the location of the system room above the eastern and north-eastern sectors.



Top Right: Figure E.29
System room location. Pipes and ducts path inside the structure. Source: Created by the author.

From these spaces, therefore, originate all the pipes and ducts which feed the decentralized systems and services of the platform and move fluids through the pavilion.
Water and wastewater pipes (both for sanitary use and for heating/cooling) move through the gap below the floating floor. System walls allow for vertical movement of the ducts, allowing them to reach all the required locations and the system room itself. Specific holes in both the concrete and CLT floors allow them to move between the upper-structure and under-structure.
Air ducts are instead simply hung up and suspended above the rooms, going to the ceiling to reach every room. Again, special holes allow for the passage of these ducts as well, so they can reach the underwater floor as well.

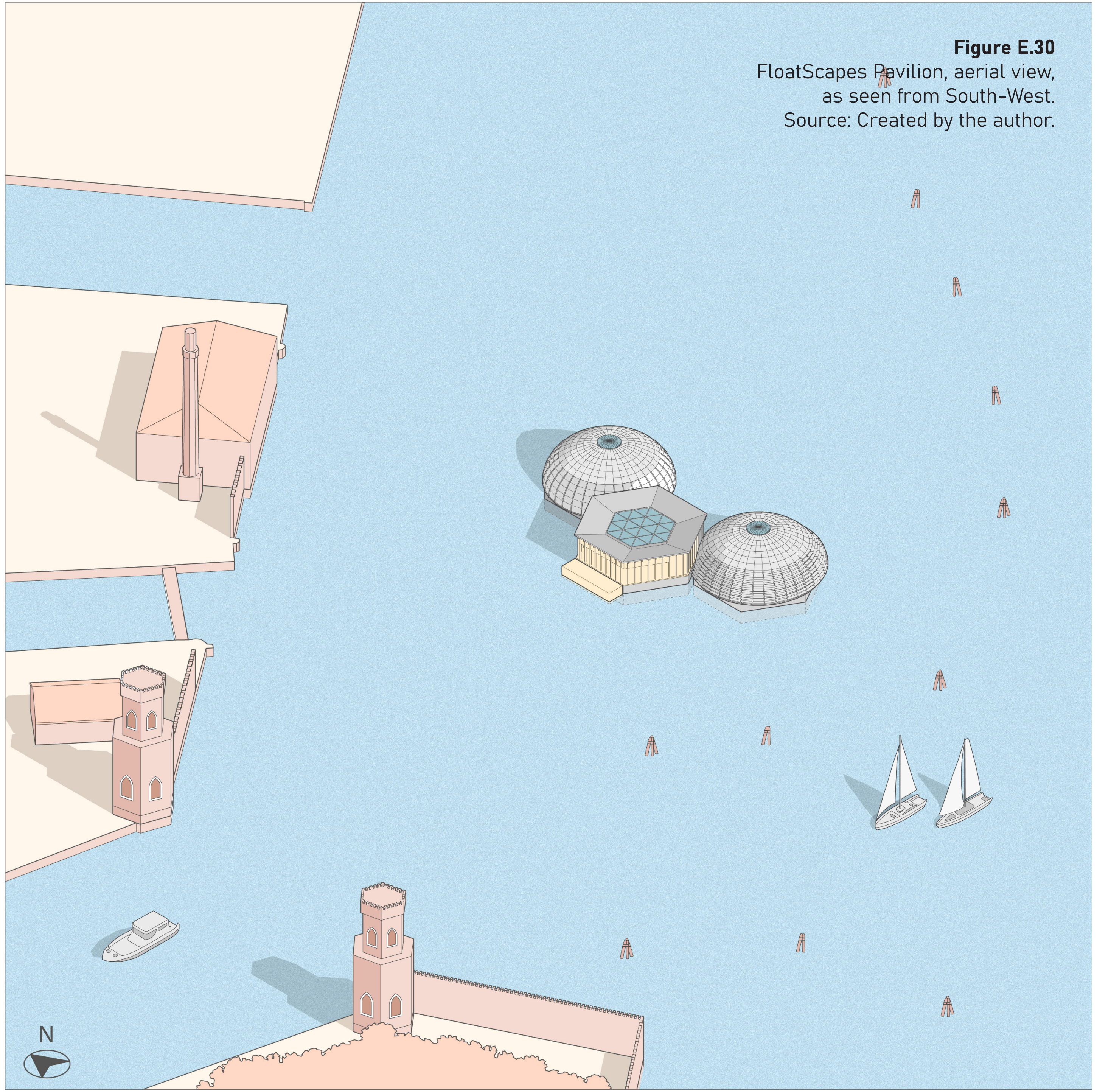


Figure E.30
FloatScapes Pavilion, aerial view, as seen from South-West.
Source: Created by the author.

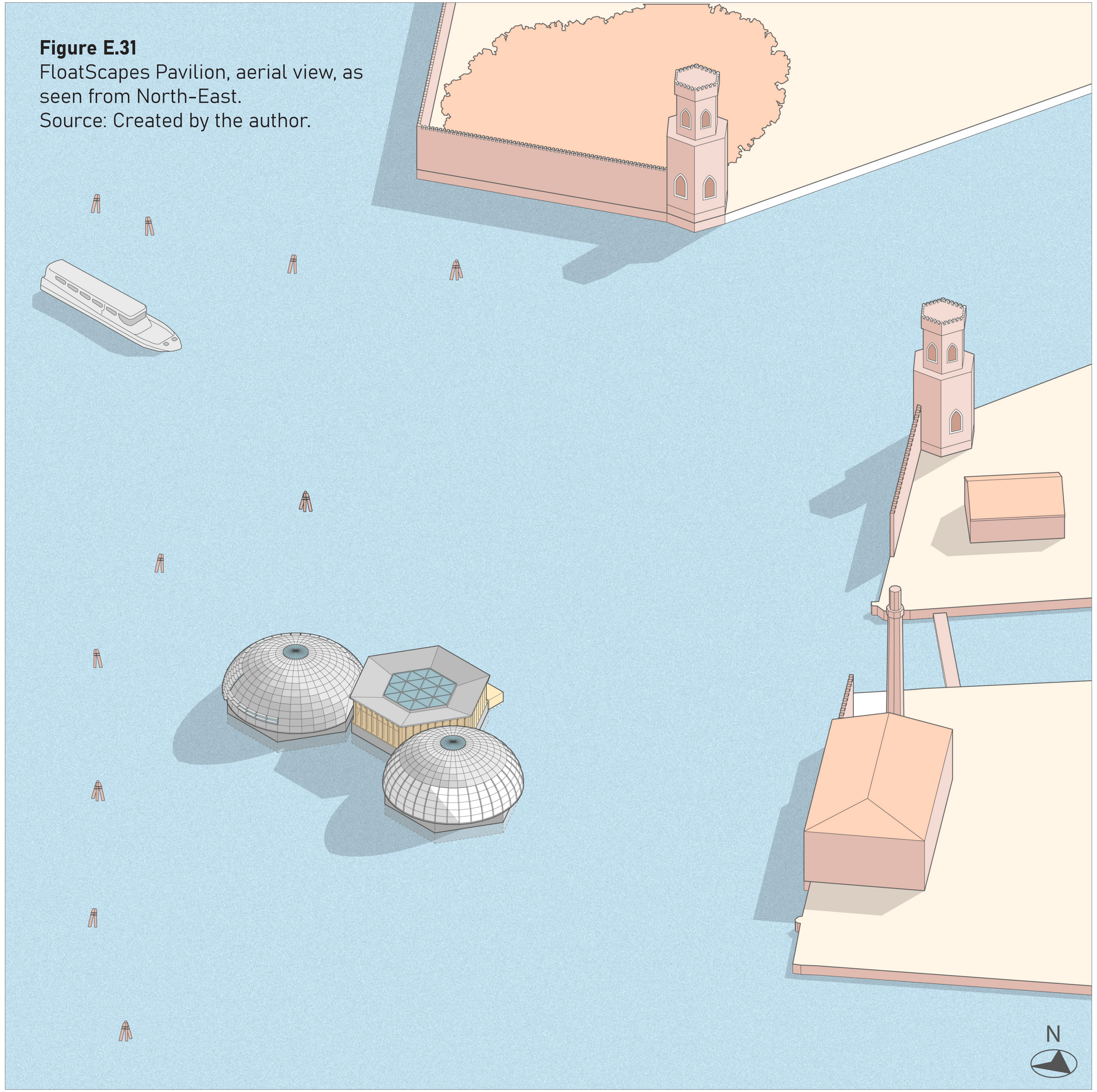


Figure E.31
FloatScapes Pavilion, aerial view, as seen from North-East.
Source: Created by the author.

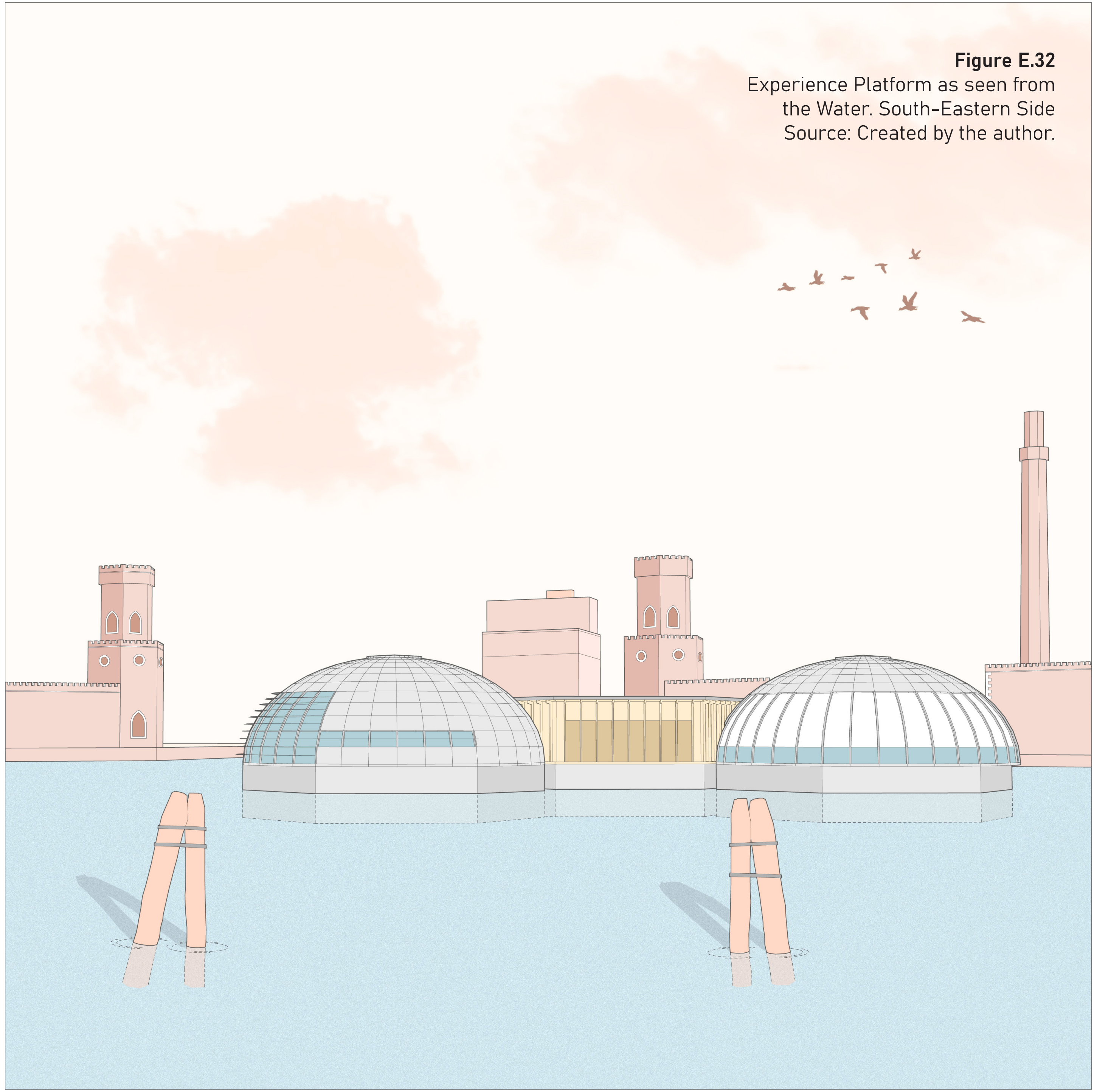


Figure E.32
Experience Platform as seen from the Water. South-Eastern Side
Source: Created by the author.

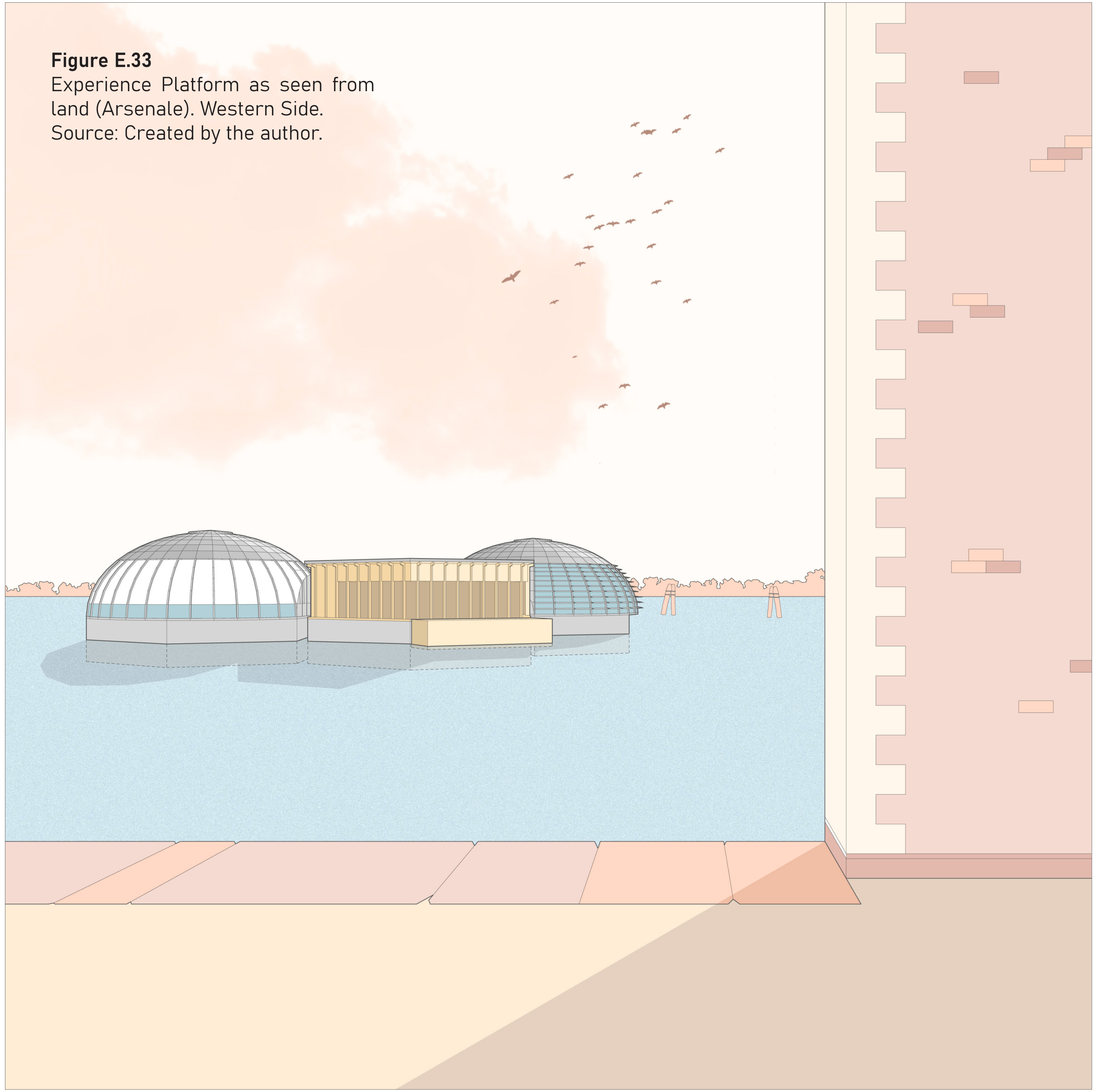


Figure E.33
Experience Platform as seen from land (Arsenale). Western Side.
Source: Created by the author.

Figure E.34
Experience Platform as seen from Inside. Central Hall
Source: Created by the author.

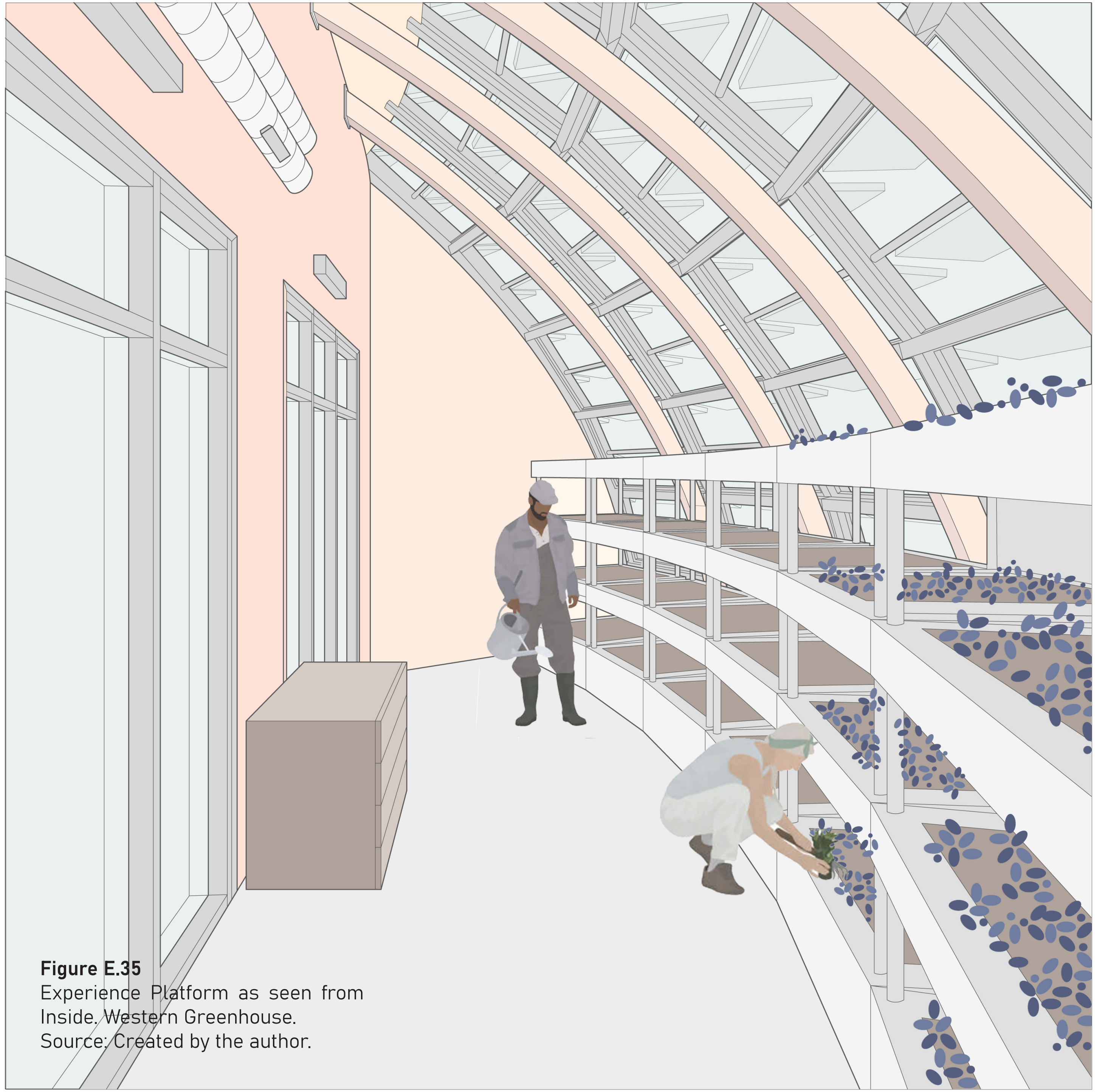


Figure E.35
Experience Platform as seen from Inside. Western Greenhouse.
Source: Created by the author.

05.3 BIOCLIMATIC DESIGN

- *Natural Ventilation*
- *Passive Heat Gain & Adaptive Facade*
- *Photovoltaic System*
- *Water Pre-Cooling & Pre-Heating Systems*
- *Other Renewable Energy Sources*
- *Water Management*
- *Waste Treatment & Management*

As said, one of the key potential advantages of floating architecture, compared to traditional buildings, is its sustainability potential. Provided that, from a sustainable point of view, the best building is one that isn't built, designers should always strive to achieve as virtuous of a building as possible.

In our case, openly declaring the design choices that push toward a reduction in energy consumption, the production and use of renewable energy, or conscious water management, becomes a fundamental step in the definition of the project, helping to create a strong character for it. Therefore, when possible, "green" choices are openly displayed and are frequently one of the main objects of interest of the pavilion itself.

This paragraph aims to briefly report some of the main specific designs, technologies, and systems deployed in the pavilion, with the end goal of lowering the environmental footprint of the building and its exercise. It starts with an analysis of the renewable energy systems integrated into the platforms, proceeds with an analysis of the key aspects that can help reduce energy requirements, and ends with a report on how water and waste are properly managed.

Figures E.36A and E.36B (next pages) contain a representation of the main bioclimatic strategies adopted for the design of the structure, both for the summer and winter months.

05.3.1 Natural Ventilation

As previously explained, the structural elements of the building can be greatly damaged by external air and water, as the marine environment is particularly complex and challenging for building materials. This however does not imply that natural ventilation has

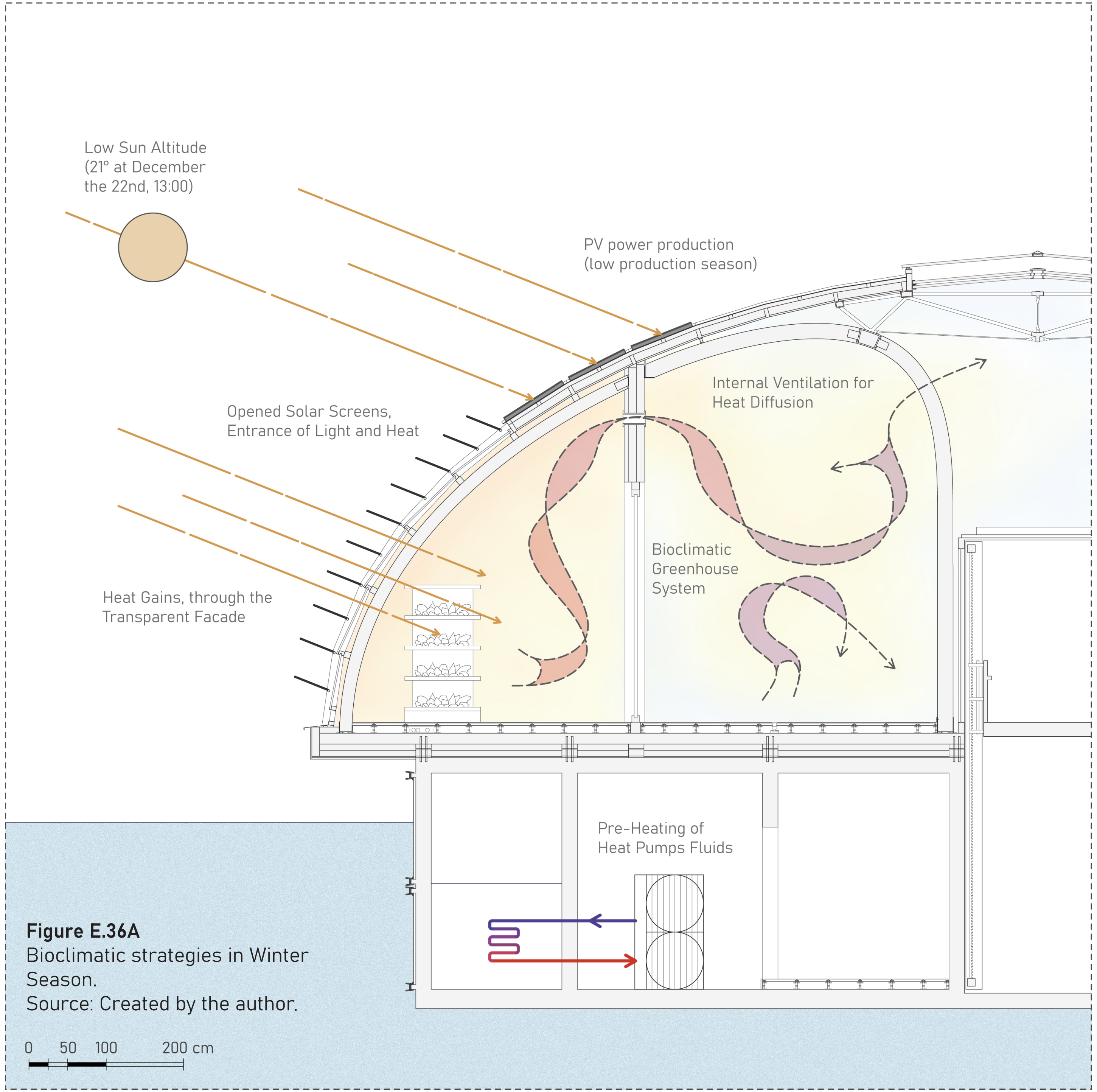


Figure E.36A
Bioclimatic strategies in Winter Season.
Source: Created by the author.

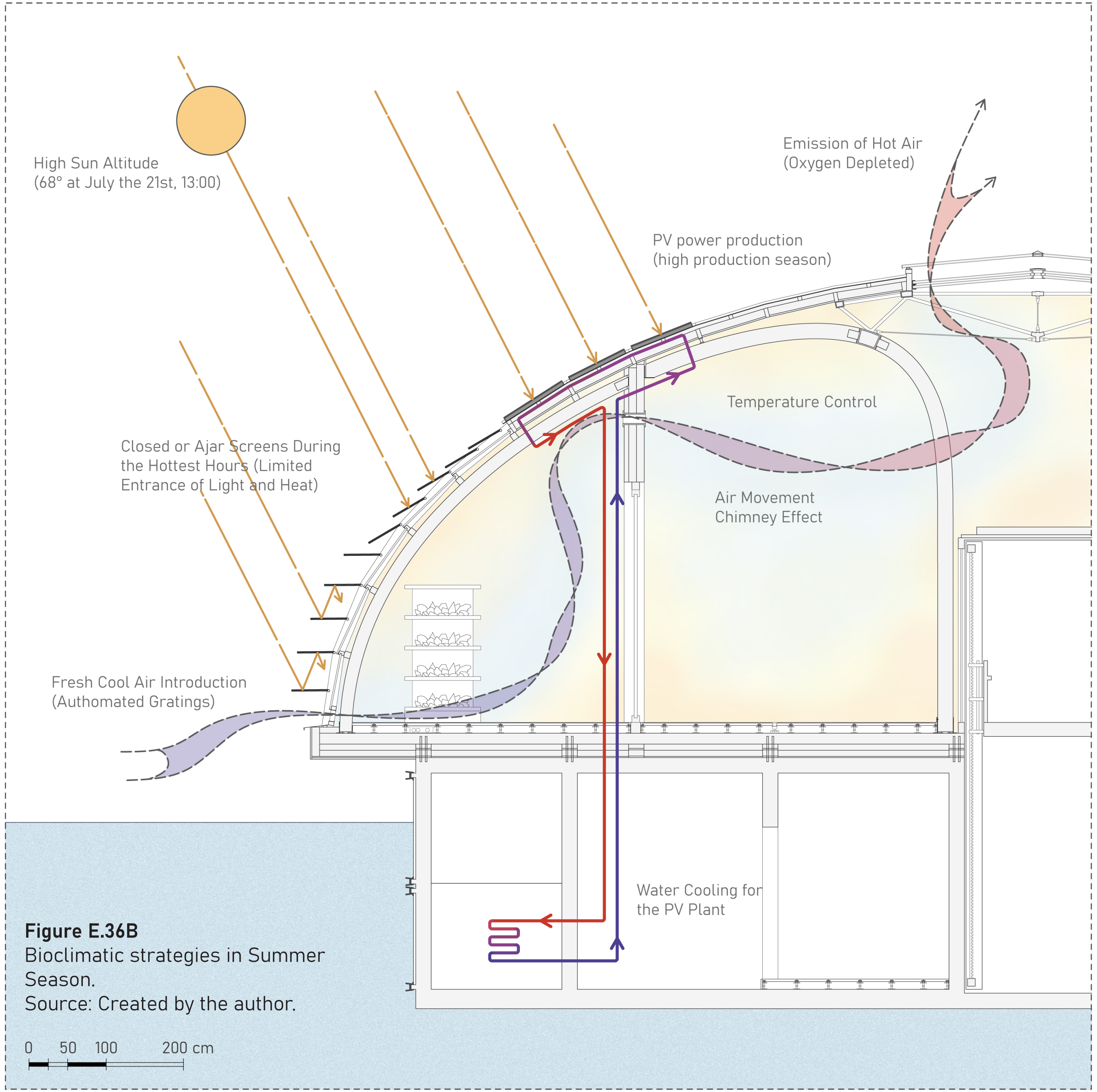


Figure E.36B
Bioclimatic strategies in Summer Season.
Source: Created by the author.

to be banned from the building. Indeed, attentive, and calculated air movement inside the building can be greatly beneficial for the comfort of the users, as it ensures higher air quality and can mitigate excessive heat and humidity. Periodical air changes can also be useful to reduce the risk of fungi growth, moulding, and rotting phenomena, particularly important in our case, where these are concrete risks posed to the wooden structure.

Therefore, two natural ventilation systems are provided to the platforms, one for the external spaces and one for the central main hall.
Given the water location of the project, it wasn't feasible to introduce traditional openable windows, as the glass panes must prevent any user from falling into the water. Furthermore, the complex shape of the glass surfaces would have rendered the introduction of "vasistas" windows or other similar technologies very problematic and expensive.

For the outer rooms, two out of the six bottom window components are divided into two sections: the top one hosts a standard glass pane, similar to the rest of the façade, while the bottom one is composed of an openable metallic grating. The same is done for two of the top transparent components of the same sectors. These gratings can be occasionally opened, creating a chimney effect, which pulls in external air from the bottom and expels depleted internal air from the top.
By automating this system and connecting it to the same control unit that opens and closes the solar screens, it is possible to respond to internal temperature changes and exploit the contribution of natural ventilation as well.

This system could be particularly useful for the greenhouses and the

kitchen, as these rooms are likely to generate high levels of humidity, as well as condensation phenomena.

The central space, instead, has no direct contact with the exterior, except for the top skylight. Therefore, the same system cannot be deployed here. However, during wintertime, the three greenhouses receive large amounts of solar radiation, which increases internal temperature, thanks to the passive heat gain. These spaces have higher temperatures than the rest of the building and can be used as a bioclimatic greenhouse. Here the air is both heated and enriched in oxygen, thanks to the presence of the cultivated plants, and is subsequently introduced in the central hall, effectively preheating it and improving its air quality.

To allow for this air movement, metallic openable gratings are inserted in the hexagonal divider wall, with the possibility to open and close them according to the specific necessity (during summertime, the temperature in the greenhouses might indeed be excessive and would be counterproductive to introduce it into the rest of the pavilion). Finally, to allow for air extraction, the central aluminium elements of the polygonal skylight, are equipped with additional gratings, again automated, and remotely controlled, producing a second chimney effect.

05.3.2 Passive Heat Gains & Adaptive Facade

The high percentage of transparent skin of the greenhouses goes in the direction of maximizing access the free natural light. The vertical farming system devised for the pavilion, provides artificial lighting for the night and for cloudy days, to ensure continuity of the plants' growth and, therefore, better reliability of the production.

The large transparent surface also has a second effect: it allows large quantities of solar radiation into the greenhouse modules. This can have both a positive and a negative role for the internal comfort of the building. In wintertime, the free solar gains, go in a favourable direction, as they help the heating system to increase the temperature of the building, effectively reducing the energy demand. On the contrary, during summertime, or any hot day with intense incident solar radiation, the entering energy increases the temperature of a building that is already being cooled down by the conditioning system, requiring a more intense activity of these machines.
These aspects highlight the necessity of providing some form of control, capable of limiting the entering solar radiation when required.

Solar Shading

To limit the entering radiation, during the hottest hours, each one of the transparent panels of the façade is provided with two horizontal solar screens, covering respectively the top and bottom half of the window.

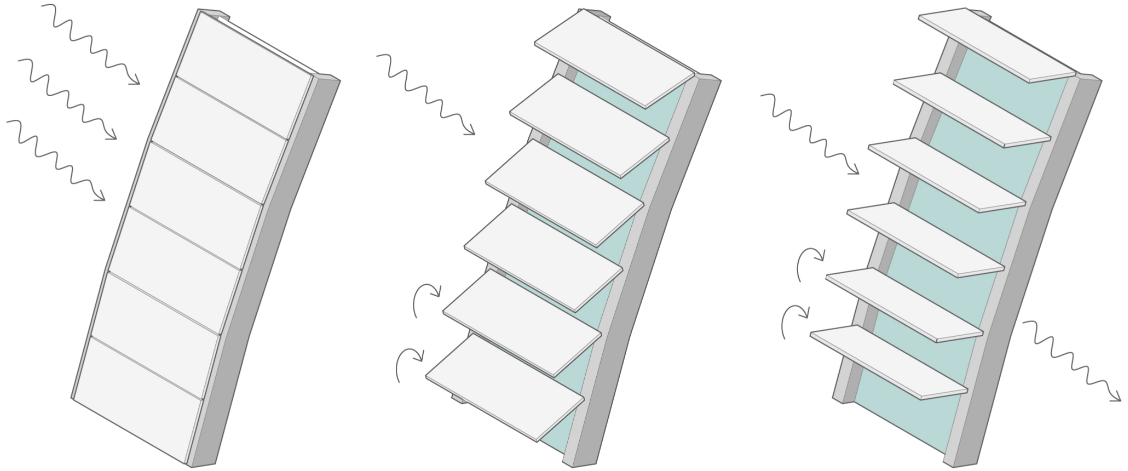
These screens are connected to the main vertical supports of the transparent curtain wall, which are specifically oversized to be able to provide anchorage for both the solar screens (on the outer edge) and the glass panes (on the interior part). Each of the screens rotates, becoming capable of changing its inclination angle. Once open, these let direct and indirect solar radiation inside the greenhouses and can be closed, instead, to prevent light and heat from entering the building. The inclination of the screens can, anyway, also be set between these two “open” and “closed” states, for example blocking direct solar radiation, while allowing the entrance of indirect light.

Bottom Right: Figure E.37
Adaptive facade functioning.
Source: Created by the author.

The selection of the material for these screens is again complex. First of all, these components have to be light, since the available weight for the upper-structure is limited, and since they need to be movable. They have to be resistant to water and, in general, adapt for outdoor use. They must be opaque, light in colour and not reflective, to ensure low energy absorption (which would lower their effectiveness as solar screens), without directly reflecting the light, to avoid disturbance to the surrounding water traffic and buildings.

Figure E.37 represents the functioning of the adaptive solar screens (and, indirectly of the athomated ventilation components), to actively control the internal environmental conditions.

These criteria, oriented toward the choice of metallic screens, produced in aluminium. This allows for extremely light and high-mechanical-performance components, also suitable for movable



solutions. Aluminium is particularly viable for use in aquatic and marine environments, since, once oxidised or protected with specific coatings, it is substantially inert, and doesn't easily react with water, saltiness, or industrial pollutants. The chosen finish for these components is an untreated oxidised surface, which links the solar screens with the sheet aluminium finish of the opaque façade. Together, these aluminium elements, create a light grey oxidized dome, which is intended as a contemporary reinterpretation of the traditional Venetian church domes.
The choice of horizontal screens is particularly suitable for the SW and SE greenhouses, since in these areas the sun radiation meets the façade at a high angle, during the whole year. It is, instead, less suitable for the western greenhouse, where, during sunset hours, the light rays are much more likely to cause glare to the users (given the low height of the sun, which corresponds to more horizontal radiation). This problem, however, would be significant in the case of fixed screens and can be easily avoided with movable elements. This allows to provide a single solution for all the greenhouses, and also for the individual windows of the other sectors, with a more uniform and cleaner image for the façade.

Adaptive & Responsive Control

Each of the transparent components of the curtain wall has a different orientation and a different inclination. This means that each one of them behaves differently during the day, as the sun follows its natural path, projecting radiation which meets the external skin with a multitude of different incidence angles. The solar screen system, therefore, has to be able to respond to this enormous variety of conditions, providing the opportunity to allow the entrance of solar radiation in some areas of the façade, while partially or completely blocking it in others.

The proposed design is for an automated adaptive skin, controlled by an automation unit. A multitude of sensors, placed in key locations of the building, collect large amounts of data, detecting (among other information) internal and external air temperature, humidity, the surface temperature of the glass, and weather forecast information. Analyzing this data, the central unit is capable of controlling each one of the screens, changing its inclination, and effectively opening or closing it (or positioning it in an intermediate position).

The façade, therefore, is capable of altering its shape, to actively respond to the environmental changes, produced by the daily sun path, but also by the seasonal changes, and by the weather.
The possible configurations are potentially infinite, each one of them suitable for a specific scenario. This system could also be capable of acting preventively, anticipating the expected changes and, for example, avoiding any excessive temperature increase, instead of responding to them.
To avoid a continuous movement of the screens, the system could be set up to activate them once every 15-30 minutes.
Similarly, also the ventilation gratings (described in paragraph 5.3.1) could be automated with the same system, leaving to the control unit the task of opening and closing them, improving the thermal performance of the building.

05.3.3 Photovoltaic System

The open-water location of the pavilion offers easy access to solar radiation. The pavilion receives continuous radiation during the entire day, as the closest buildings are more than 50 meters away and cannot project any shadow on the floating platforms. The only possible shadows, except for those produced by clouds and fogs, are cast by extremely distant elements (mountains and buildings) and

only affect the very first and last minutes of daylight.
Furthermore, the presence of water all around the building, results in albedo phenomena, where the lagoon reflects a certain percentage of the incident radiation, partially redirecting it to the pavilion façade, increasing the total mean incident radiation.

These elements render the location particularly suitable for the installation of a photovoltaic plant, integrated into the pavilion. This provides the building with an autonomous renewable energy source, which can be integrated with the public energy grid.

Many would be the possibilities and variations of PV systems that could be suitable for this project, and the final choice would depend on many complex variables. This paragraph reports the solution adopted by the authors for this project stage, highlighting some of the other possible choices.

PV Plant Sizing

The first sizing of the PV plant is here carried on with direct reference to the minimum requirements established by the Italian Legislation. Particularly, Legislative Decree 28/2011 defines a minimum peak power for the PV plant which must be integrated into the building. For a platform of 260 square meters, whose realization began after 2017 (as would be true for our project), the minimal required peak power is 5,2 kW. This value would most likely not be sufficient to cover a major component of the building energy demand and could probably represent a useful integration.

A larger plant could obviously be designed for the building, however, such a choice has to be motivated by specific calculations and scenarios, as it would be useful only if economically and

environmentally sustainable for the pavilion. The value established by the legislation is instead mandatory and has to be respected in any new building.

Defined a guideline for the system's peak power, specific evaluations of how the system could be integrated into the building were carried out, and what could be a suitable portion of the structure.

Guidelines

The possible locations for the integration of the PV plant of the building were numerous. However, some efficiency rules were easy to provide:

- Integrate the PV elements on the building wedges that provide an efficient orientation, generally avoiding all the northern ones. This already excludes half of the available surface. It has to be cited that it could be feasible to integrate certain products even in the less efficient areas, but economic sustainability would be much harder to achieve.

- Integrate the PV elements on the façade panels that provide an efficient inclination. Assuming that the ideal inclination of PV panels for Venice would be 38°, the available façade panels for the integration are here taken into consideration if characterized by an inclination of 20° - 50°, adopting a certain tolerance in both directions. This again strongly limits the viable locations.
The ideal inclination of 38° was provided by the Photovoltaic Geographical Information System, through the use of the Pvgis interactive tool. This inclination is specific to Venice and indicates the ideal inclination that a south-oriented PV panel should have, to maximize efficiency

– Avoid integration in the transparent façade. The presence of automated solar screens means that the glass panels would always be at least partially shaded, particularly during the peak production hours since those are also the hottest hours of the day (and the solar screens would be closed to limit the entering radiation). An alternative would be to integrate the PV system into the solar screens, but their ever-changing character renders them unsuitable for this use. For efficiency reasons, integration into the transparent curtain wall is not really a viable path.

Integrated PV Plant

The viable area for the PV plant, therefore, is effectively limited in the experience platform. The areas where the integration would correspond to satisfying productions are even smaller.
The upper transparent panels of the greenhouses, for example, occupy the position with the best inclination, and, therefore, the highest expected production.

The most suitable area is the ring produced on the southern side, by the first 3 rows of opaque panels of the roof, just above the greenhouses' transparent façades. These three rows, with inclinations respectively of 29°, 26° and 21°, offer a not ideal position, which could, however, allow for decent production. The total available area is 43,4 m2 (16,2 + 14,7 + 12,5 m2).

The choice was to integrate the PV plant in the outer sheet aluminium skin and somewhat hide it, choosing a product with a similar colour and shape to the aluminium components. The solar panels, based on the same trapezoidal shape of the other skin components, substitute their corresponding aluminium sheet and are anchored to the same wooden structure of the opaque façade. To further mimic the

Top Right: Figure E.38
Integrated PV plant in the pavillion external skin.
Source: Created by the author.

The panels with the best inclinations and orientations are already dedicated to the greenhouses transparent walls and cannot easily host a PV plant (glass-to-glass would obscure the view). The chosen panels represent a compromise, exploiting the best ones out the available.

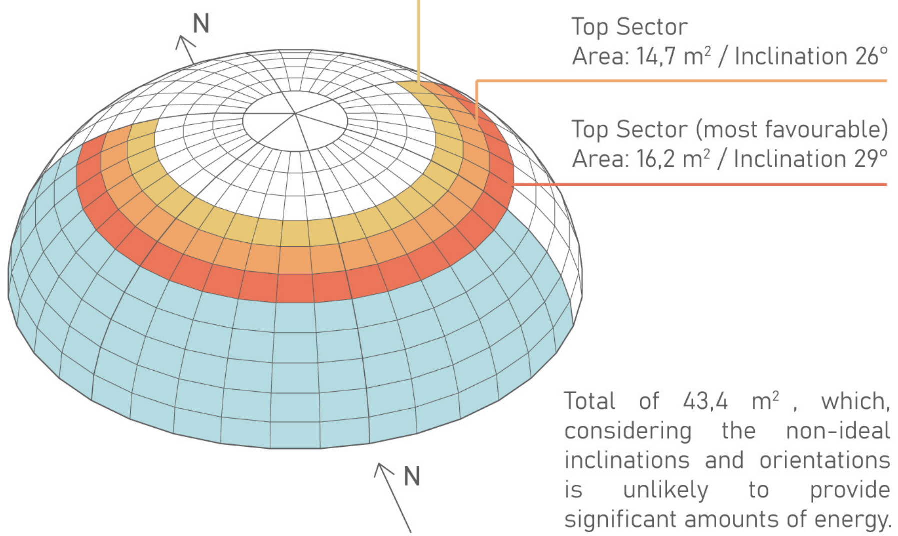


image of the dome, each of the panels overlaps with the one below, referencing the image of both the opaque roof and the greenhouses' glass windows.

Figure E.38 represents the location of the integrated PV panels in the external skin of the building, highlighting the chosen panels. In addition a small scheme indicates the relative positioning of the PV panels.

The chosen technology is based on a PV coating above monocrystalline cells (silica-based product), with a glass base. This is a technology available in various sizes, shapes, and colours, which could, therefore, adapt to the complex shape of the façade elements.

The expected peak power of such a product, given a light grey colour (to mimic the aluminium) is around 0,155 kW/m2. Projecting this value over the available 43,4 m2, the peak power of the installed plant would be 6,73 kW. This data largely satisfies the legislation requirements (5,2 kW).
Considering the extremely variable orientations of the components and their non-optimal inclination, as well as the expected efficiency loss after some years of exercise, a slightly oversized plant should help respond to these inefficiencies over a longer period of time.

The effective choice of product is left open, as it strongly depends on financial availability. Furthermore, the possibilities are endless. Less integrated products could achieve larger production, as more expensive products would do. A larger plant could easily be installed, and the design of the pavilion could change to better host it.

05.3.4 Water Pre-Cooling/Pre-Heating Systems

Lagoon water (as happens in all water bodies) is characterized by a much higher specific heat than its surroundings (water and land) and tends to experience much smaller temperature changes, both daily and during the year. This means that the water tends to be hotter than its surrounding during winter months and colder during summer.

As the pavilion sits in open water, the structure has easy and immediate access to the almost endless heat (and cold) reservoir represented by the lagoon. This can be easily exploited for both the cooling of photovoltaic systems and for preheating and precooling of the air used in the air conditioning system.

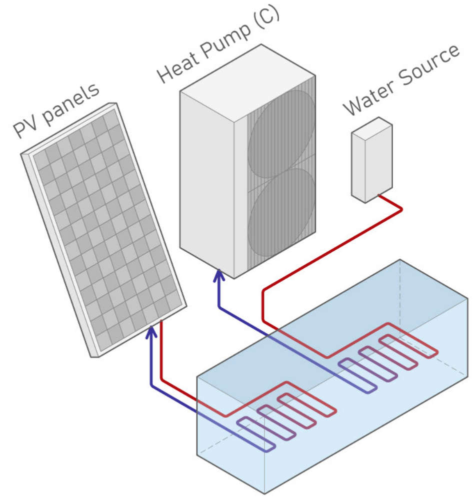
High temperatures are one of the main reasons for productivity reduction for PV systems, effectively limiting the efficiency of the products. Therefore, a cooling fluid is provided, which partially lowers the temperature of the components. This fluid, however, has a limited cooling potential and, during peak hours, struggles to keep up with temperature growth.
Cooling fluid pipes are therefore here deviated to the underwater floor, where they are placed inside lagoon water, allowing for heat exchange and, therefore, lowering the temperature of the fluid, which can be sent back to the PV system. The cooling water can be then poured back into the lagoon, as it has had no contact with dangerous substances. This procedure actively raises total energy production, maintaining temperatures in a more efficient range.

The possibility to preheat or precool the fluids (water and air) used by the air conditioning systems and by the Air Treatment Unity (ATU) in particular, can help to significantly reduce the energy demand of the building.
During wintertime, the fluids can be preheated by contact with lagoon water, which is usually at a higher temperature than external air. This allows starting with hotter external air, requiring a smaller temperature increase, before the immission in the rooms. During summertime, instead, fluids can be precooled, again thanks to lagoon water, which, in these months, is colder than outside air. Again requiring a smaller temperature change to reach the required conditions.
For this reason, the air ducts for external air intake, before reaching the AHU, make their way inside one of the ballast system's tanks, where, depending on the season, the transported air is preheated or precooled. The air duct is immersed in water and folded multiple times, ensuring tens of meters of underwater movement. This produced a very high contact surface between water and the duct

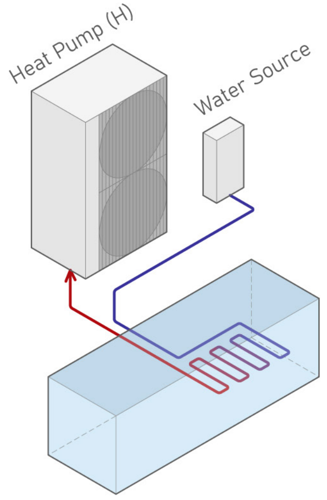
(and indirectly with the air), allowing for intense heat exchange in a contained volume.
The same procedure is foreseen as well for the fluids (water) used to operate the hot and cold batteries of the AHU. These fluids are treated by the heat pumps to reach the required temperature (and function as a vector fluid, to transport heat to the air) and can be preheated (or precooled) in the same way, again lowering energy demand.

Figure E.39 represents the pre-cooling/pre-heating system in one of the ballast system tanks, water/oil ducts that immerse into the lagoon water for heat exchange.

The large size of the lagoon compared to the building would ensure that no significant water temperature alteration should be expected due to the insertion of these technologies, thanks to the active water mixing of this water body.



Summertime: pre-cooling of source water before cold fluid production and PV cooling liquid (water / oil).



Wintertime: pre-heating of source water before hot fluid production, also sanitary water.

Bottom Left: Figure E.39
Water pre-heating and pre-cooling system inside the ballast system.
Source: Created by the author.

05.3.5 Other Renewable Energy Sources

The use of renewable energy sources, other than solar radiation with PV systems, is in our case far more complex. The wind regime is far too unreliable, with too few windy days during the year and an average speed (even only looking at windy days) which would result in negligible production.
The lagoon water, being enclosed and separated from the sea, is characterized by waves and currents of a completely different scale, compared to the open sea. The average depth of the water location, while sufficient for the correct operation of the building, is far too small to produce significant temperature gradients.

Any attempt to use waves, currents, winds, or water temperature gradients, to produce energy and actively cover a meaningful part of the building demand, would probably result in a failure. The efficiency of any system based on these sources would be economically unsustainable, given the scale of the project (much larger designs could for example better amortize the realization of a floating wind power plant). Furthermore, any solution to try and exploit these resources would be almost impossible to integrate into the design.
Therefore, the energy production of the pavilion is completely entrusted to the PV system (described in the previous paragraph), relying on the urban power grid to cover any additional demand.

However, given the character of this project, the platforms could represent the perfect opportunity to test small-scale academic and professional prototypes for renewable energy production. Active interaction with potential partners of the project could result in the introduction of testing prototypes, particularly for wind and wave energy production. In particular, the open external skin of the Technology platform offers a large space, potentially usable for the installation of small wind turbines, while almost the whole east side of the pavilion could host systems in contact with the water. This would have primarily an academic and research character and the building would not rely on these systems to cover any of its energy demand.

05.3.6 Water Management

Given the importance of water for FloatScapes and floating architecture in general, conscious and sustainable use of water on the pavilion becomes fundamental, and propedeutic for conveying the key message of the project.

Given the extreme complexity of the location, as previously explained, the pavilion cannot be directly linked with Venice freshwater systems, nor to the public sewage. This means that the project needs a different way of providing water to the users. The choice falls on a system based on water storage tanks, capable of holding enough fresh water and wastewater to completely cover the building's demand for at least two days.

Four large tanks and two smaller ones are installed inside the floating base, on the underwater floor. The tanks are deputed to contain respectively:

Large tanks, 5000 litres each in volume:

- Freshwater, for sanitary use in the kitchen, the restrooms, and the greenhouses.
- Rainwater, collected to be used for the discharge of toilets (which usually represents a significant portion of the entire water demand and does not need to be fresh drinkable water).

- Grey wastewater, coming from any sink in the building and from dishwashers and washing machines.
- Black wastewater, coming from restroom toilets.

Small tanks, 2000 litres each in volume:

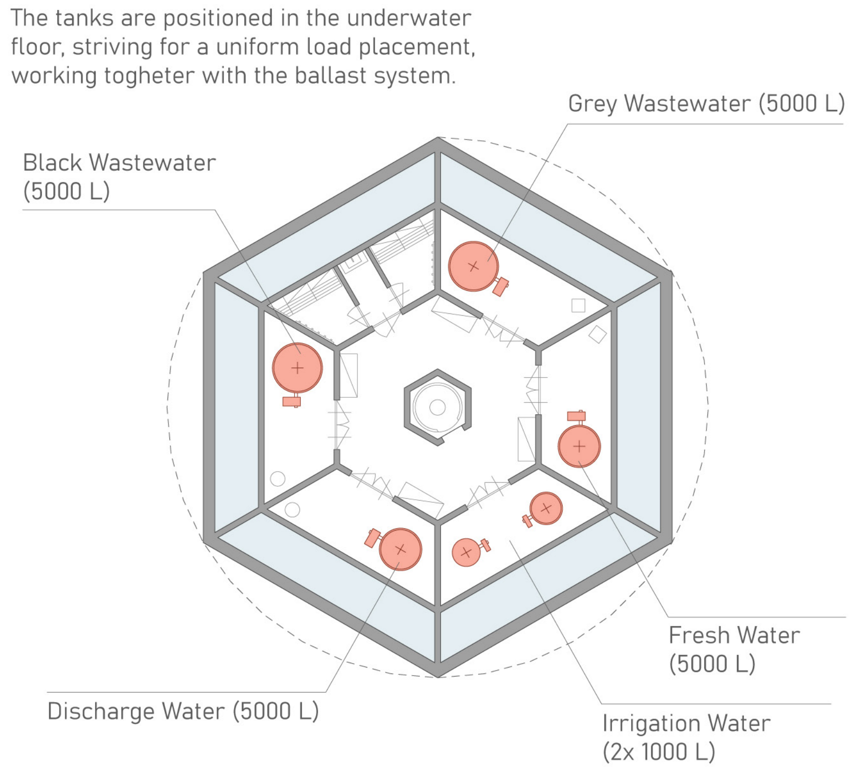
- Freshwater for agricultural use in the three greenhouses.
- Nutrient-enriched water, used for fertirrigation in the greenhouses.

All the tanks are contained in the inner rooms that surround the central hexagonal space of the floating base. All are directly accessible for maintenance, but are not replaceable, as they would not fit through the lift opening. These tanks, therefore, need to be installed before the construction of the upper concrete ceiling.

Water ducts reach the upper-structure through dedicated holes in the concrete base. Once they reach the upper volume, they move below the floating deck, reaching all the required locations. The same is true in the opposite way for the wastewater movement.

The tanks are finally also connected with a control unit, positioned in a small room on the northeastern side. Here, every two days, a service boat docks the pavilion, and with the help of an operator inside the building, it connects charge and discharge pipes, unloading the wastewater tanks and replenishing the freshwater one, ensuring proper functioning of the platform.

Rainwater is collected in all platforms through a deviation of the drainage system, up to the point of filling up the dedicated tank. Then, excess precipitation water is deviated back to a normal path, being filtered (as explained in Chapter 7) before being poured into the sea. Periods of intense precipitation would completely satisfy the demand



Top Left: Figure E.40
Underwater Floor plan view, with location of the water and wastewater tanks.
Source: Created by the author.

for discharge water. Instead, during the dryer months rainwater might not be sufficient and could be replaced by lagoon water, directly accessible from the pavilion.

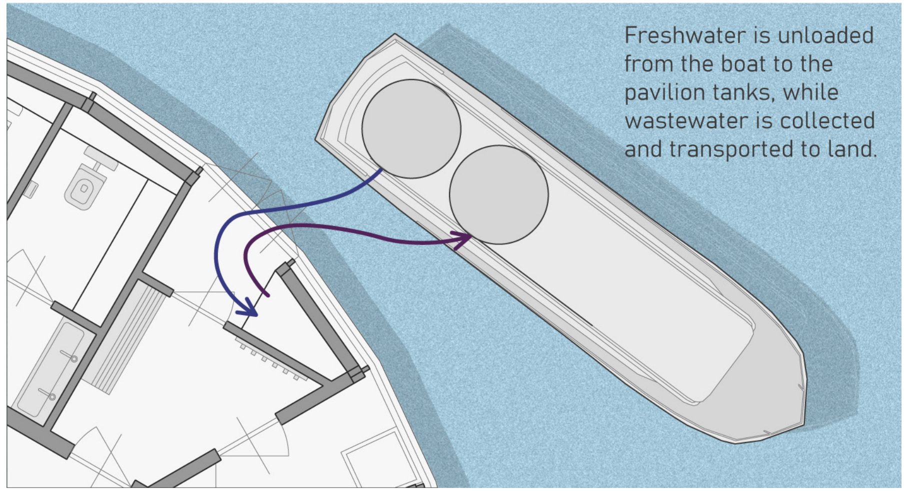
Figure E.40 represents the plan view of the underwater floor (inside the concrete floating base), where the water and wastewater tanks are installed. The tanks are placed around the central space, for a better and more uniform load distribution.

05.3.7 Waste Management

As described in the last paragraph, all wastewater produced on the platforms is completely collected, moved to land, and properly treated in the existing sewage system.

As interesting as it can be, proper treatment of any waste directly on the pavilion is not truly feasible, as the limited space and the absence of open areas would render it damaging for the comfort of the users. This forces us to foresee a proper waste collection and sorting method, referring to the specific Venice rules.
From a logistic point of view, waste disposal happens in the same manner as wastewater. The typical garbage collection boat of Venice would dock the platform, again in the small control room, where, with the help of the pavilion staff would unload the produced garbage and bring it to land, to be properly processed.

Figure E.41 contains the indication of the service room for loading and unloading of the tanks and for the contact with the service boats.



Bottom Left: Figure E.41
Location of the service room inside the Experience Platform.
Source: Created by the author.

06

MODULAR DESIGN

“"While re-imagining the future of construction, we believe that prefabrication is not just a building method; it's a transformative approach that enhances efficiency, sustainability, and precision in creating architectural solutions."”

Stephen Kieran & James Timberlake

KieranTimberlake

The Modular Design chapter delivers a deeper vision of the FoatScapes project Lifecycle by going deeper in the different stages of the project that are influenced by the principles of Prefabricatrion, Design for Disassembly and Lifecycle Thinking to enhance the opportunities of floating architecture construction in a difficult context for construction, putting in evidence that architecture and its processes can also follow adaptation allowing us architects, to not only design building, but also to design the corresponding processes involved.

Cover: Elements, Components, Panels, and Modules at Sea
Created by the Author

06.1 LIFECYCLE APPROACH

- *Lifecycle Thinking & Prefabrication*
- *Timber & Environmental Impact*
- *Cradle-to-Cradle Processes*

06.1.1 Lifecycle Thinking & Prefabrication

Prefabricated and modular-designed buildings represent a particular opportunity when quantifying and qualifying the design priorities when designing a LCA-friendly building according to Aitchinson (2018). As buildings are responsible for significant energy consumption and greenhouse gas emissions, it is important to reduce energy use and carbon footprint in buildings. Reducing the CO2 emissions and the energy demands attributed to buildings is very important for climate policy nowadays.

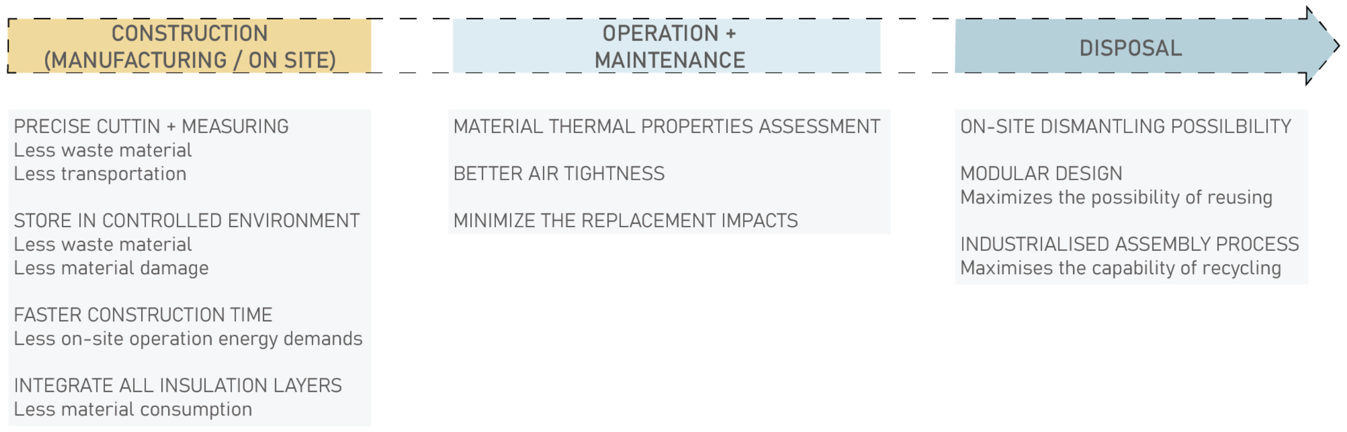
According to Aitchinson (2018), approximately 24% of global CO2 emissions stem from existing buildings, which also consume over 40% of the world's primary energy. In the attempt to reduce the carbon footprint and energy use in buildings, prefabrication has a unique opportunity to capture the benefits of Lifecycle Thinking.

The main methods developed since the mid-1980s involve the lifecycle phases of the buildings and even further analysis includes the products' life related to materials, including extraction, production, use, and waste. It could be said the LCA is considered a cradle-to-grave approach, but in this specific project and case scenario of the Experience Platform, we are focusing on a cradle-to-cradle scope. For this reason, and as seen in the previous section about Material Selection, choosing environmental-friendly materials from the early design phases is fundamental when reducing energy consumption and the carbon footprint, when evaluating the specifics of the project with their own specific requirements.

This development of building prefabrication is only achieved after a long pre-design process before the individual components and modules are manufactured and then transported for a final assembly.

And when developing the improvement of environmental impact, it is possible in every phase of the lifecycle, from manufacturing to the end of life with different strategies according to the phases, but in most of the successful cases reaching better results when the strategies were thought from the beginning carrying initial quality. In the case of prefabrication, the benefits reach several parts of the lifecycle with a positive impact as seen in Figure F.1.

Center: Figure F.1
Beneficial impacts on a building's lifecycle when prefabricated.
Source: Illustration created by the author based on the book Prefab Housing and the Future of Building: Product to Process. (2018).



06.1.2 Timber & Environmental Impact

As previously explained and illustrated in this chapter, the building itself is composed of several elements of different materials. Particularly, in the category of components, Metal Building Systems are mostly found. For these elements, in order to present a lower environmental impact a deeper understanding of the raw material sources and manufacturing, like recycled metals and forges approaches, would have been pertinent.

However, the following section focuses on Wood Building Systems, particularly in the category of Modules, as wood has the biggest use percentage in the building and therefore, the choice to elaborate further about it, represents a better understanding in terms of its relationship with environmental impact.

Timber as the Main Material

Timber is a particular material, and the inherent charisma that it has reveals its previous living state and condition. The different textures and appearance demonstrate its organic origin and past. In addition, it also has a historical background of tradition that goes centuries ago, which is still evident nowadays in many architectural examples around the globe like the great frames and roofs of the medieval period and earlier.

Timber is appealing to designers thanks to its visual and tactile qualities, its material properties, and its environmental properties. As it has an organic origin, Ross (2009) explains that its cellular composition, strongly directional, generates linear members that work in a strength-to-weight ratio making it appropriate for roof construction. Nowadays the dimensions restriction to log cuts has been solved by the development of adhesives that join individual laminates. The limitation nowadays is still the size of these products but constrained by transport dimensions.

Additionally, in terms of timber connections, it is known that this material has a discipline when designing joints, but also these design elements have evolved also from timber traditional interlocks to steel fasteners as a product of modern standardization where the visual satisfaction of assemblage is still present behind a logic construction.

On the other hand, there are some disadvantages that could be identified as timber is an organic material. Humidity and as a consequence, fungal decay, are the reality issues this material faces when becoming part of a building. Correct practices from design faces are the ones that protect this element in terms of durability; it is also important to mention that fire resistance is another specific topic that nowadays standards focus on when building with this material, and for what it relates to certified products, these are covered by a series of tests to ensure the requirements and specifications in the construction field.

Low Carbon Benefits of Timber

It is essential to ensure that the low-carbon benefits of timber materials products are realized when using them for construction. As a main benefit, timber offers the chance to reduce the embodied carbon footprint in buildings. According to LETI (2023), timber has a lower associated carbon emission when it is compared to concrete or steel; however, careful attention to the sourcing and its full lifecycle in terms of carbon sequestration must be held in order to avoid the existing risk of reaching a higher carbon emission in Lifecycle of a building, especially at Product Stage and at the End of Life Stage.

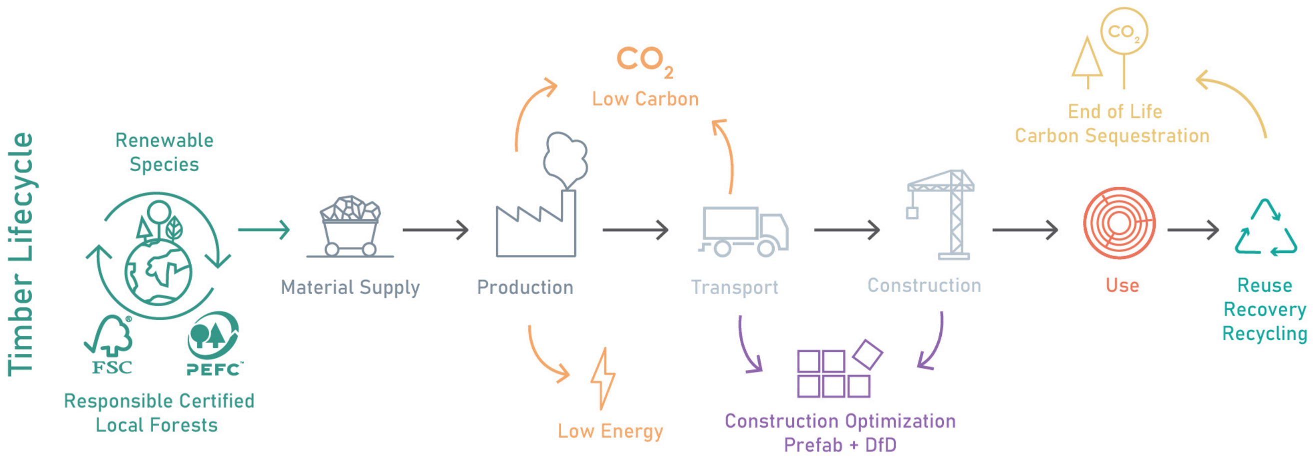
Some of the guidelines to ensure the low-carbon benefit is that timber must be sourced from sustainable forestry practices and also that at the End of Life Stage, re-use or re-purposed strategies ensure carbon sequestration. For an effective specification, timber should be sourced from sustainably managed forests under the certifications of FSC or PEFC, which certifies the source of the materials from sustainable sources and/or recycled materials (LETI, 2023).

Bottom: Figure F.2
Beneficial impacts on a building's Timber Lifecycle with Low-Impact vision.
Source: Illustration created by the author based on the information of LETI Low Embodied Carbon Specification and Procurement Guide (2023).

At the same time, it is recommended to use locally produced materials to support the local economy and reduce transport carbon emissions. As timber has low embodied carbon in the Production Stage (A1-A3), the transportation of this material from more distant sources is associated with a higher embodied carbon, and therefore more impactful in the accountability of this material.

On the other hand, timber-engineered products and their composition include adhesives and fire retardants that as known, are toxic, they cannot be in contact with waterways and when burned as fuel, they release carbon back into the atmosphere and also toxic chemicals from the composites. In this sense, the End of Life Stage of timber products could be accounted for carbon sequestration when the End of Life is directed towards recycling and re-use.

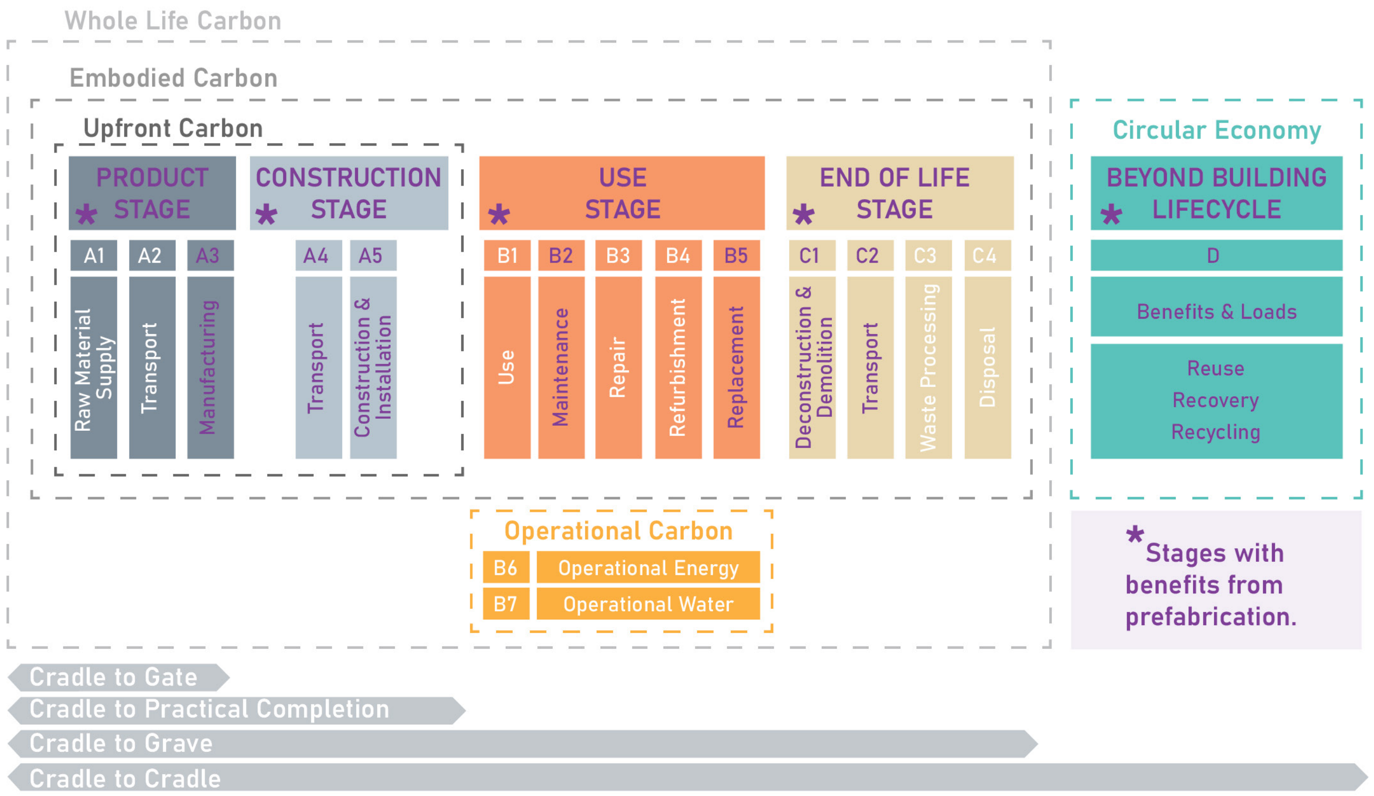
For this reason, the benefits of timber could be maintained if there is a strong narrative on end-of-life when thinking about the impacts of the materials.



06.1.3 Cradle-to-Cradle Processes

The understanding of the previous concepts and topics that were applied in the Modular Design process of FloatScapes as explained, puts in evidence the will of creating an LCA-friendly design through a lifecycle thinking approach where the use of engineered timber demonstrates that with its own requirements and practices, it could be possible to minimize the environmental impact from this point of view.

Bottom: Figure F.3
Building Lifecycle & Stages with Benefits from Prefabrication.
Source: Illustration created by the author based on the information of LETI Low Embodied Carbon Specification and Procurement Guide (2023).



The following section elaborates on the Cradle-to-Cradle processes of the Experience Platform, as a useful exercise to expand the perspective of the project development from the origin of the materials, the manufacturing suppliers, transportation, layovers, assembly, disassembly, and beyond the end of life.

Product Stage (A1 to A3)

In the Italian context, according to FAO (2020), forests represent 32% of the whole Italian territory, and in 2020, Italy presented a forest Growing Stock (million m³ over bark) of around 1424 million m³.

It is known that the central and northern parts of Italy mostly compose this percentage, for this reason, finding a local supplier of the engineered timber elements will positively influence the construction process, as Timber is the main construction material for the project.

By taking into account Venice as the location of the FloatScapes project, the Product Stage was envisioned according to the possibility of maintaining the low carbon benefits of the engineered timber products when transported as the main sustainable goal. Previously it was explained that transportation of distant sources represented a higher embodied carbon regarding wood materials.

In order to keep the embodied carbon lower, the following manufacturers of engineered wood construction products were chosen as possible suppliers based on the following factors that might have different weight in the decision-making process:

- Location: Explore the minimum possible distance between the source of the product/materials, the manufacturing, and the project site in the Italian territory to minimize the transport impact.

- Products Quality & Performance: Ensure that the manufacturing suppliers deliver the desired products selected for the project with the corresponding certifications.

- Sustainable Forest Certification: Promoting responsible and balanced forest management with tracking from the suppliers, supporting the well-being of the renewable ecosystems.

For the CLT panels:

A. X-lam Dolomiti:
Located in Trento, IT. PEFC Certification.
Local timber raw materials from the Val di Fiemme.
Products count with EPD.

B. Artuso Legnami S.R.L.
Located in Caselle, TV, in Veneto. PEFC Certification.
Timber raw materials from Austria and south of Germany.
Products count with EPD.

For the LVL beams:

A. Pollmeier:
Located in Aschaffenburg, Germany. PEFC Certification.
Timber raw materials from several forests of Germany.
Products count with EPD.

Figure F.4
Engineered Wood Suppliers & Transportation Map.
Source: Created by the author.

Construction Stage (A4 to A5)

In this stage, the actual construction of the building takes place, starting with the transportation of the different parts of the building to be ready for its assembly. As previously seen in this chapter, the study of the different elements, panels, and components of the Experience Platform, served not only for accountability of parts but also as a decomposition to understand the shipment limitations in terms of parts dimensions and transportation.

In the transportation realm, according to Smith (2010), the sub-assemblies must be protected during transit so that damage is mitigated. Nevertheless, we know already that one of the advantages of unit modules relies on their structural strength which makes them more difficult to receive damage.

The strategy taken to minimize any possible damage relies on the assembly concentration of the unit modules in the closest place possible before the final setting of the building, which in this cases is the port of the city of Mestre as the final destination of the Experience Platform is over the Venice Lagoon. For this reason, the steps of transportation, construction, and installation events with layovers for assembly are the following:

1. Elements Packaging & Loading: The finalized prefabricated elements off-site are packed, protected, and loaded onto the transport truck in reverse order of how they will be placed at the assembly port station. Variations could exist according to suppliers.

2. Transportation Planning: Transportation routes and the estimated time for execution, considering any restrictions and permits. Variations could exist according to the supplier's location.

3. Transportation to Assembly Port: The loaded prefabricated elements are transported in several trips from the different supplier's manufacturing sites.

4. Arrival, Unloading, and Unpackaging of Elements: Upon arrival to the port of Mestre, the elements are carefully unloaded with the appropriate equipment in the assigned warehouse for unpackaging.

5. Unit Modules Assembly: Assemblage of the elements according to the construction documents assembly schedule to create the different types of unit modules.

6. Arrival & Preparation of Floating Understructure: Upon the arrival of the prefabricated Floating Understructure at the port of Mestre, the platform is anchored, covered, and protected at the closest docking area to the preliminary assembly warehouse.

7. Unit Modules Fastening to the Floating Understructure: With the corresponding equipment and operators, the main crane and the supervision boat are set on the Floating Understructure dock. One by one, and in the order of internal to external unit modules, the modules are lifted to be immediately located, anchored, and stitched to the Floating Platform

8. Integration of Systems: Building systems integration such as electrical, mechanical, and plumbing are installed to be ready for functionality.

9. Finishing & Detailing: After unit modules fastening completion, the finishing works involves the fastening of curtain walls, waterproofing sealing joints, windows, doors, furniture setting, building external skin, and installment of the photovoltaic panels

10. Quality Control Inspections: With the supervision boat, quality control and internal inspections are executed to ensure that the assembly has been done correctly and meets the quality standards.

11. Towing Planning: Towing route and the estimated time for execution, considering any restrictions and permits from the "Capitaneria del Porto di Venezia" are taken into account. A medium cargo towing boat is contracted for this procedure.

12. Towing to Floating Site: The assembled Experience Platform is towed from the port of Mestre to its final location in front of the Venice Arsenale.

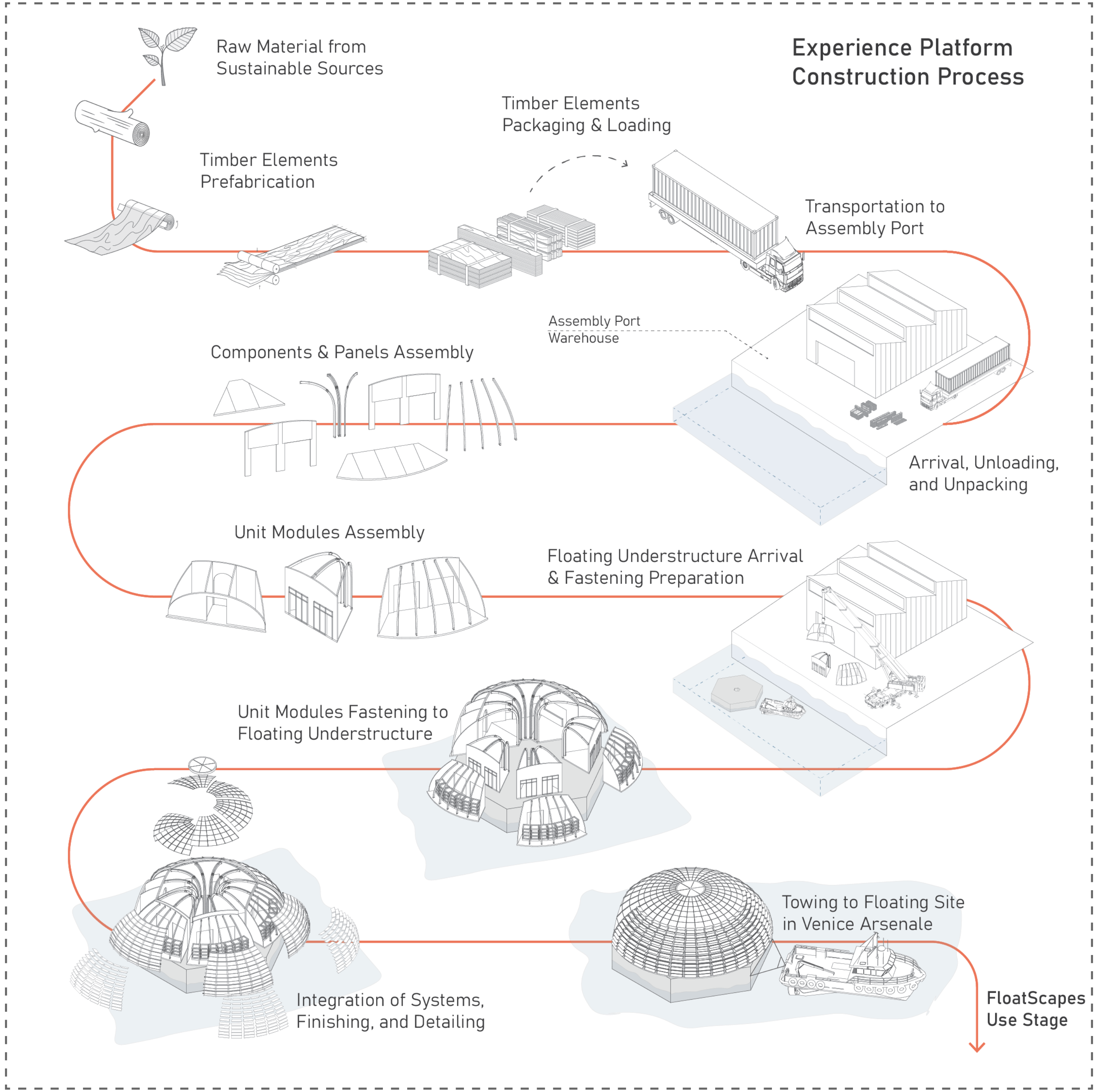
13. Experience Platform Arrival & Anchorage: Upon arrival, immediate anchoring takes place to avoid any undesired drifting of the building.

14. Final Inspections & Testing: A final inspection and test of the systems takes place to verify that the assembled and towed building works with normality.

15. Occupancy Readiness & Handover: The Experience Platform is prepared for occupancy with the final touches regarding the presentation, marketing elements, and proper cleaning to be handed to the operators and administrators of the Use Stage.

Regarding the Use Stage, where prefabrication also presents efficient benefits but in a minor portion, it could be inferred that, within the short life of the project, the benefits will only apply if any of the Experience Platform parts are damaged during its use. In this way, the benefited stages will be the Maintenance and Replacement ones, if the case demands it, but also in the Energy Performance realm.

Right: Figure F.5
Experience Platform Construction Process Diagram.
Source: Created by the author.



End of Life Stage (C1 to C2) & Beyond Building Lifecycle (D)

In the Cradle-to-Cradle cycle proposed for the Experience Platform, as previously explained, the main strategy to keep the benefits of prefabrication and minimize the environmental impact in the final stages of the building is Design for Disassembly. This represents the structured and organized lifecycle thinking behind the project that is aligned with the circular economy principles, which as Smith (2010) states, delivers a better way to realize buildings with principles of reuse, recovery, and recycling.

For the End of Life stage, the reasoning of evaluating the materials, systems, and modules of the building, defined a selective dismantling that could minimize any possible damage and facilitate the foresight of the different alternatives of the building with the right deconstruction techniques. For this reason, and due to the building macro composition of the building, the two main prefabricated bodies were defined for this stage:

- Dry Assembled Upper Structure (Off-site wooden modular building in which visitors and operators interact with each other)
- Floating Understructure (Off-site concrete building that floats thanks to its ballast system developed by SEAform)

The solution alternatives for both bodies of the building share the common denominator of Re-use. Their separation at the End of Life stage allows the unique opportunity of delivering two new buildings after the corresponding process of disassembly, and transportation of both bodies to the corresponding destinations In simple terms, the Experience Platform beyond its End of Life, will divide into two new buildings, complying with the circular economy principles.

In the case of the Dry Assembled Upper Structure, due to its peculiar characteristic of food production, the potential to be re-used in the same field food production field was highly considered to define a possible orientation towards an urban garden that offers the same food production experience to raise awareness on land. Architecturally speaking, thanks to the circular floor plan, the building delivers the advantage of easy orientation for solar radiation independently of the location. For this reason, a possible location for thi scenario could be an urban space that is benefited with the flow of people in a city context like a square or even a park.

Alternatively, in the case of the Floating Understructure, the SEAform research group and the MORElab, have shown an early interest in the End of Life stage as their ballast mechanism differentiates the prefabricated concrete building from any other common concrete building as it floats.

Within their future plans is to test the understructure as the floating base of a possible renewable energy island station in the central part of the Venice Lagoon, next to the small island of Fisolo. In this case, the solution is simple but will require further construction processes, considering the technology adaptation to the understructure that will be executed by the MORElab and SEAform respective teams to adequate the understructure into an energy-producing platform.

Taking into consideration the future possible scenarios of both buildings, the following steps for deconstruction, transportation, and re-construction for re-use are the following:

1. Re-use Execution Planning: Logistics organization for the possible scenarios, schedule of events, needed permits, and procedures.

2. Towing Planning: Towing route and the estimated time for execution, considering any restrictions and permits from the "Capitaneria del Porto di Venezia" are taken into account. A medium cargo towing boat is contracted for this procedure.

3. Towing to Disassembly Port: The Experience Platform is towed to from the Venice Arsenale to the port of Mestre.

4. Experience Platform Arrival & Anchorage: Upon the arrival of the Experience Platform at the port of Mestre, the platform is anchored and secured at the closest docking area to the disassembly warehouse.

5. Disassembly Preparations: The disassembly warehouse is prepared with the corresponding equipment and operators for the disassembly execution.

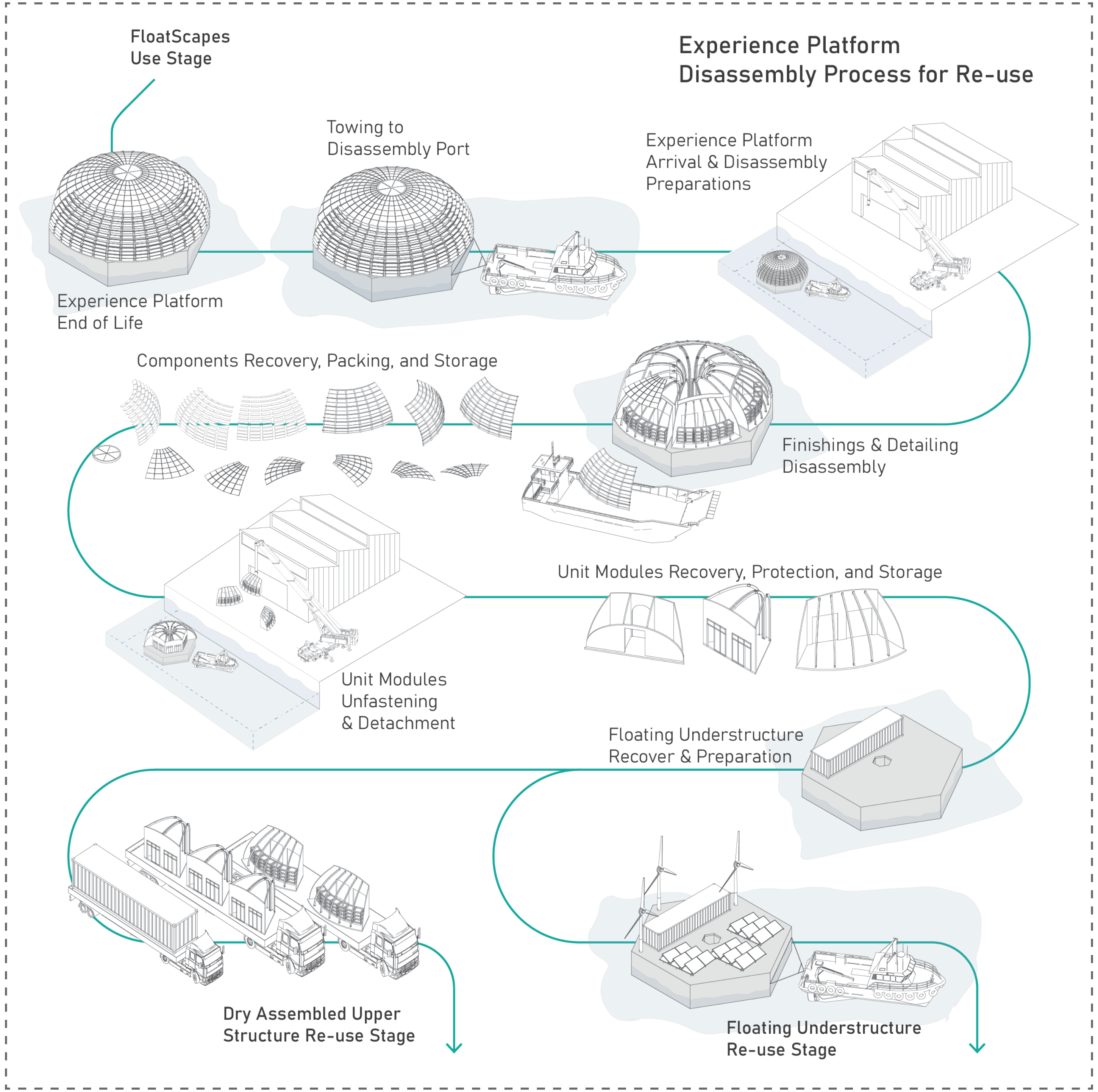
6. Finishings & Detailing Disassembly: The corresponding components of photovoltaic panels, external skin of the building, furniture, windows/doors, and Adaptive Façade curtain walls are disassembled from exterior to interior parts.

7. Components Recovery, Packing, and Storage: Components are carefully inspected for possible recovery due to the disassembling process to later be protected, packed, and stored.

8. Unit Modules Unfastening & Detachment: With the corresponding equipment and operators, the main crane and supervision boat is set in the docking area. One by one, the unit modules are unfastened, and in the order of external to internal unit modules, the modules are lifted and located on a hauler car on the dock to be transported to the warehouse.

9. Unit Modules Recovery, Protection, and Storage: Unit modules are carefully inspected for possible recovery due to the unfastening process to later be protected and stored.

10. Floating Understructure Protection & Preparation: Once all unit modules are off the Floating Understructure, operators inspect the building to later properly clean it and protect it from external conditions.



Left: Figure F.6
Experience Platform Disassembly Process for Re-use Diagram.
Source: Created by the author.

For the **Dry Assembled Upper Structure**, the final steps are:

11. Transportation Planning: Transportation routes, number of trips, and estimated time of execution considering any restrictions and permits.

12. Components & Unit Modules Loading: The components and unit modules are loaded onto different trucks, depending on their transportation limitations as modules with bigger dimensions are going to be transported.

13. Components & Unit Modules Transportation: The components and unit modules are transported to their final destination following a schedule for re-assembly.

14. Arrival, Re-assembly, & Re-integration Processes: Upon logistical arrival, the assembly sequence follows the initial construction steps for the re-used building. Finishes, detailing, and integration of systems are included in this process.

15. Final Inspection & Testing: A final inspection and test of the systems takes place to verify that the re-assembled building works with normality.

17. Re-use Readiness & Handover: The new food production building is prepared for occupancy by finishing any final touches and new image of the second life. Proper cleaning is executed to be handed to the new owners and administrators of the building.

For the **Floating Understructure**, the final steps are:

11. Floating Understructure Technical Adequations: Operators with the corresponding equipment build the required adequations for the future energy systems addition.

12. Systems Extensions Fastening: Energy systems are loaded and fastened to the Floating Understructure.

13. Towing Planning: Towing route and the estimated time for execution, considering any restrictions and permits from the “Capitaneria del Porto di Venezia” are taken into account. A medium cargo towing boat is contracted for this procedure.

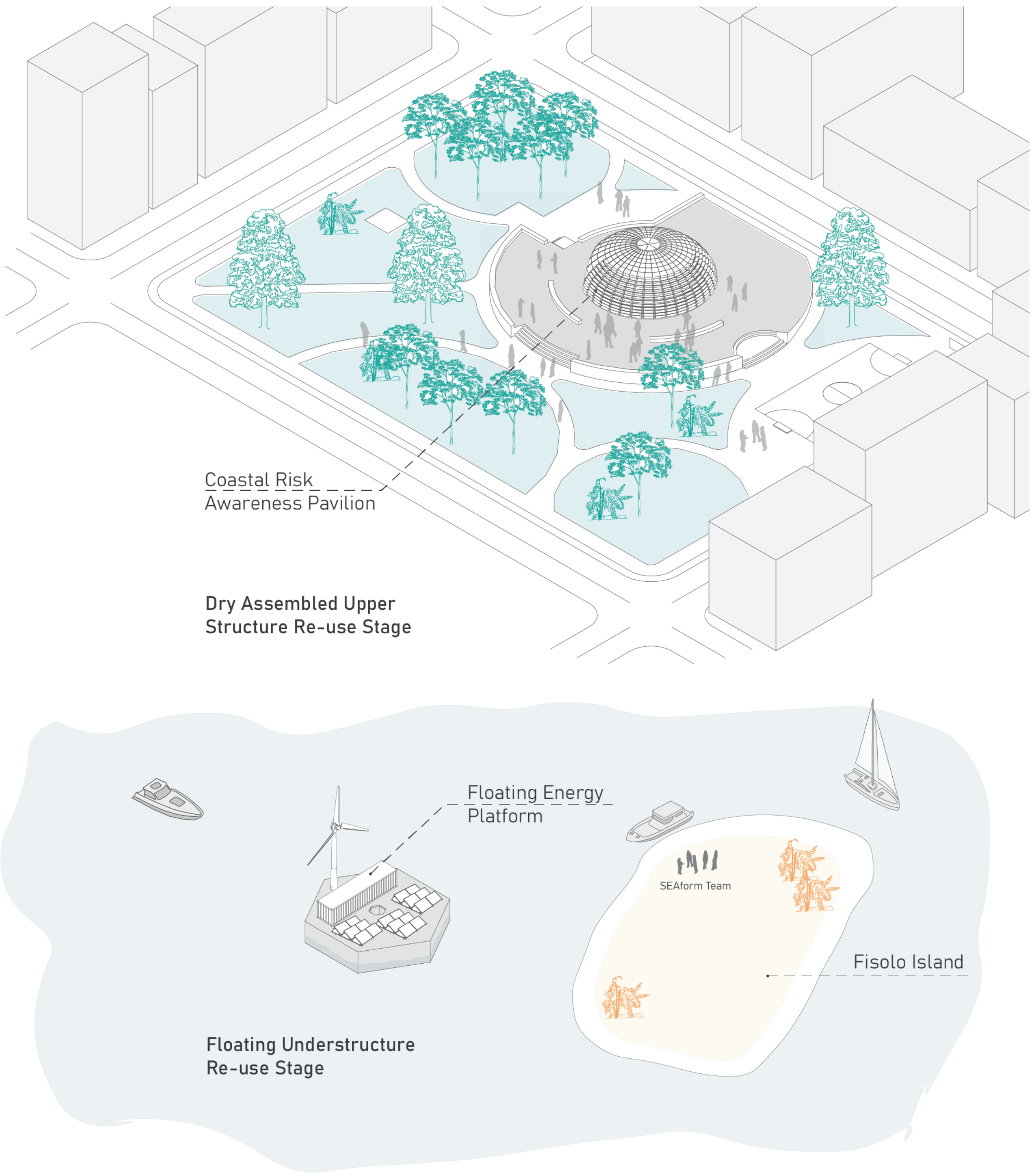
14. Towing to Fisolo Island: The new Energy Platform is towed from the port of Mestre to the island of Fisolo in the Venice Lagoon.

15. Integration of Systems: A small group of engineers and operators, that will be in charge of the monitoring station, integrate the energy systems. Finishing, detailing, and installments are included in this process.

16. Final Inspection & Testing: A final inspection and test of the energy systems takes place to verify that everything works with normality.

18. Re-use Readiness & Handover: The new Energy Platform is ready to be left near the Fisolo island to collect renewable energy from the lagoon.

Right: Figure F.7
Circular Economy Scenarios for the Dry Assembled Upper Structure and the Floating Understructure.
Source: Created by the author.



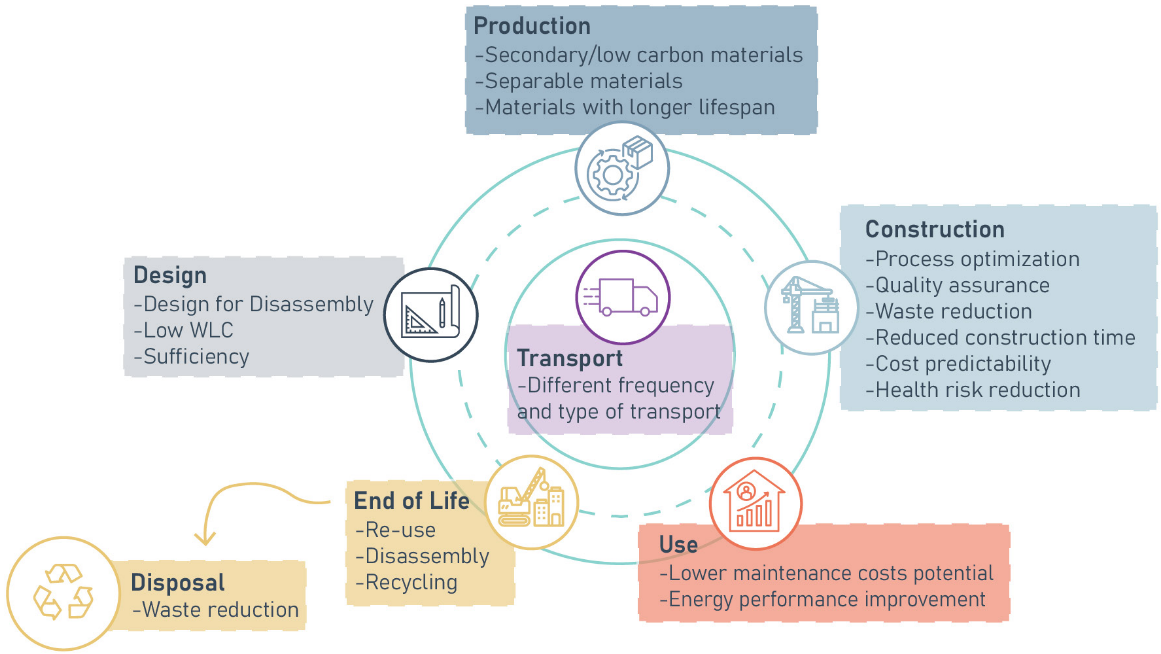
06.2 EXPERIENCE PLATFORM PREFABRICATION BRIEF

As introduced in Chapter 4, the building procedure of the pavilion is based on standardized prefabricated modules, which are manufactured and assembled off-site in a nearby production plant, transported to the final location, and connected to the concrete floating platform. This section elaborates a further development in the same direction of prefabrication but within the scope of the Experience Platform Development Design presented in Chapter 5.

Compared to full on-site construction, this choice became an indispensable approach for floating architecture, where more accurate design is needed for the maritime context to meet the different project requirements, climate targets, and synergy with whole-life carbon. To clarify the prefabrication background, according to BPIE (2021), industrial prefabrication in the AEC industry responds to integrated solutions for building systems to mainly reduce construction time on-site. Parallel to its development in buildings, it brings several benefits, process improvements, resource efficiency, cost savings, and quality control. For this reason and the limitations that include building over water, the vision of the pavilion's construction aims for less environmental impact.

06.2.1 Prefabrication Advantages

Considering that buildings, beyond representing a great percentage of total emissions, are also the biggest energy consumers (40% of total energy and 70% of electrical usage) (Kaufmann, 2009). Using nowadays materials and systems, like Off-Site Manufacturing (OSM), that reduce these impacts in their construction process and in-service performance is imperative as it is a great opportunity to integrate a reduction in the Whole-Life Carbon (WLC) impact by minimizing the CO2 emissions if we want to reach implement a zero-emission contribution in the following decades.



As seen previously in Figure. X, advantages are present in several topics and stages of a prefabricated building. A beneficial vision of modular design could be understood better according to Lawson et al. (2014) by the following topics.

Materials: In relationship to materials we can associate immediately to use efficiency. This efficiency could be later translated into less waste and less environmental impact. By accounting for the measures and sizes of the building materials more control over the resources could be achieved.

Waste: On-site construction wastes are originated from over-ordering materials, any type of damages or losses on-site, and reworks due to errors. Off-site construction counters all of these waste origins.

Top: Figure F.8
Socio-economic advantages of Prefabrication.
Source: Illustration created by the author based on BPIE (Buildings Performance Institute Europe) Whole-life carbon and industrial renovation report (2022).

Materials Waste Reduction: Construction waste, which is approximately a 1/3 of landfills is considerably reduced as precision cutting in the manufacturing saves around 50% to 75% of materials waste compared to on-site construction. The remaining elements from the manufacturing process usually are stored for reuse or recycling. Reducing the amount of materials and resources that go into the construction means not only less cost but less space to heat or cool in the cold and warm seasons according to Kaufmann (2009).

Management: Regarding site management, improvements include in-time deliveries of materials and minimal on-site storage as schedules could be very effective according to the construction advancement. Part of this effective management is due also to the Design Phase, where tools like BIM are key when developing the detailed construction documents that all members of the construction have access to (Lawson et al., 2014). Architects nowadays use BIM to develop a digital model of the building, including material inventories, which they can use to calculate the environmental impact of materials (BPIE, 2021).

Time-Saving: Considering skilled operators and thanks to standardized design and construction, modular construction is 30% quicker than conventional on-site construction (Kaufmann, 2009).

Water: Thanks to Dry Assemblage construction when manufacturing the products and at the off-site assemblage, the use of water is significantly reduced when compared to the use of water when traditional concrete manufacture occurs.

Pollution: On-site setting, after the off-site assemblage of the parts of the building, results in much less noise, dust, and noxious gas generation when using modular construction of any type. According to Lawson et al. (2014), highly prefabricated construction systems have a 70% reduction in materials transportation when comparing brick or blockwork construction, meaning less traffic pollution. This is affected directly by materials efficiency.

Performance Improvements: Modular units present improvements in the resistance to damage as they become strong and robust after being assembled. At the same time, the layering of the modular units could achieve higher performance levels with the more careful setting of acoustic and thermal insulation; thanks to better quality products with longer lifespans, airtightness is also achieved (Lawson et al., 2014).

Quality Control: The controlled atmosphere in which the materials are produced represents a higher quality of products, particularly due to not exposing materials to the exterior when assembled. When applied long-lasting materials, longevity is the result where low maintenance of the building is possible. In addition, shrinkage on-site is significantly reduced by building in quality-controlled factory conditions; errors and callbacks are practically eliminated by checking the model units before delivery (Lawson et al., 2014).

Adaptability: At the End of Life Stage, modular buildings if designed correctly, could be disassembled and reused. Re-using construction modules generates less than 10% of the embodied carbon and uses less than 3% of the energy during construction according to Lawson et al. (2014). Later in this chapter, we will go deeper into this topic as the main strategy.

Social Responsibility: In terms of modular construction, module manufacturing, and installation process require professionals with high levels of skills and training in their practice. This high standard of workforce achieves, according to Lawson et al. (2014), a 5x times safer and clean construction environment in comparison with on-site construction, taking into account the risk of accidents. Modular construction also minimizes noise and disruption in neighborhoods.

06.2.3 Design for Disassembly

The existence of buildings that could be built apart comes from the beginning of human existence, if we think about nomadic tents that were transported and settled in different places, these were designed to be dismantled. Nevertheless, change and development in construction history for sedentary settlements built the need for building with materials with a longer lifespan. The arrival of industrial manufacturing changed the construction industry even more with Prefabrication.

Design for Disassembly (DfD) has become familiar in terms of environmental strategies for construction and sustainable design. It represents a broader strategy of reuse and recycling by involving a whole-life approach to materials and buildings, especially in the prefab industry where the possibilities include easy dismantling for maintenance, refurbishment meaning changing/removing pieces or simply reusing (Aitchinson, 2018).

In terms of negative environmental consequences, this approach tackles consumerism and scarcity of natural materials as the process gets more circularity.

In the European context, the Circular Economy Package from 2016, included measures that cover the lifecycle from production, consumption, waste management, and raw materials.

Aitchinson (2018) explains that DfD helps with the management of cyclic phases of the resources in order to reduce harmful substances in the environment and at the same time reduce the consumption of newly harvested raw materials and to harvest embodied energy.

The following actions are key for DfD:

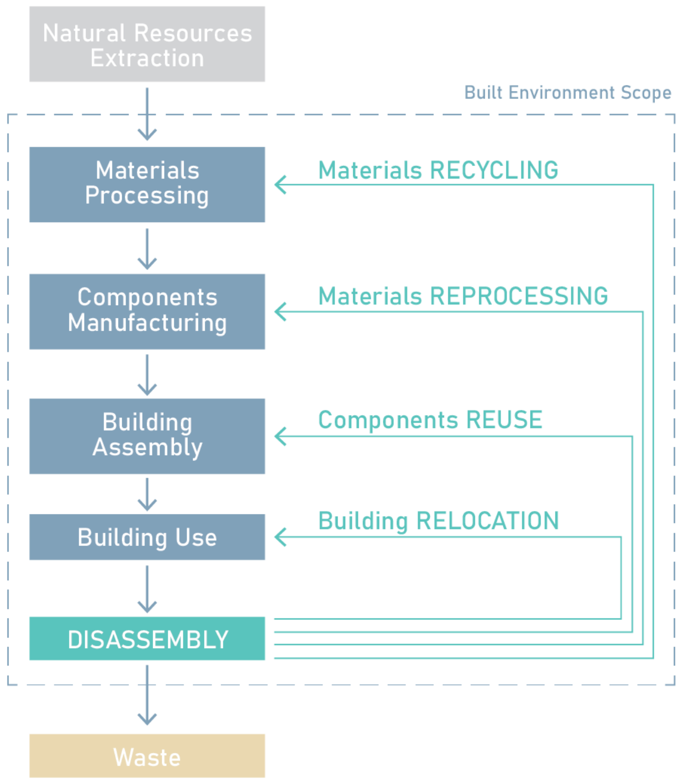
To Minimize: In terms of quantities of materials and resources, reduce the number of parts, and types of joints, and identify environmentally problematic materials.

To Categorize: Use unpolluted recycled materials over polluted materials, and understand the lifespan of the materials to aim for the longevity of the building elements.

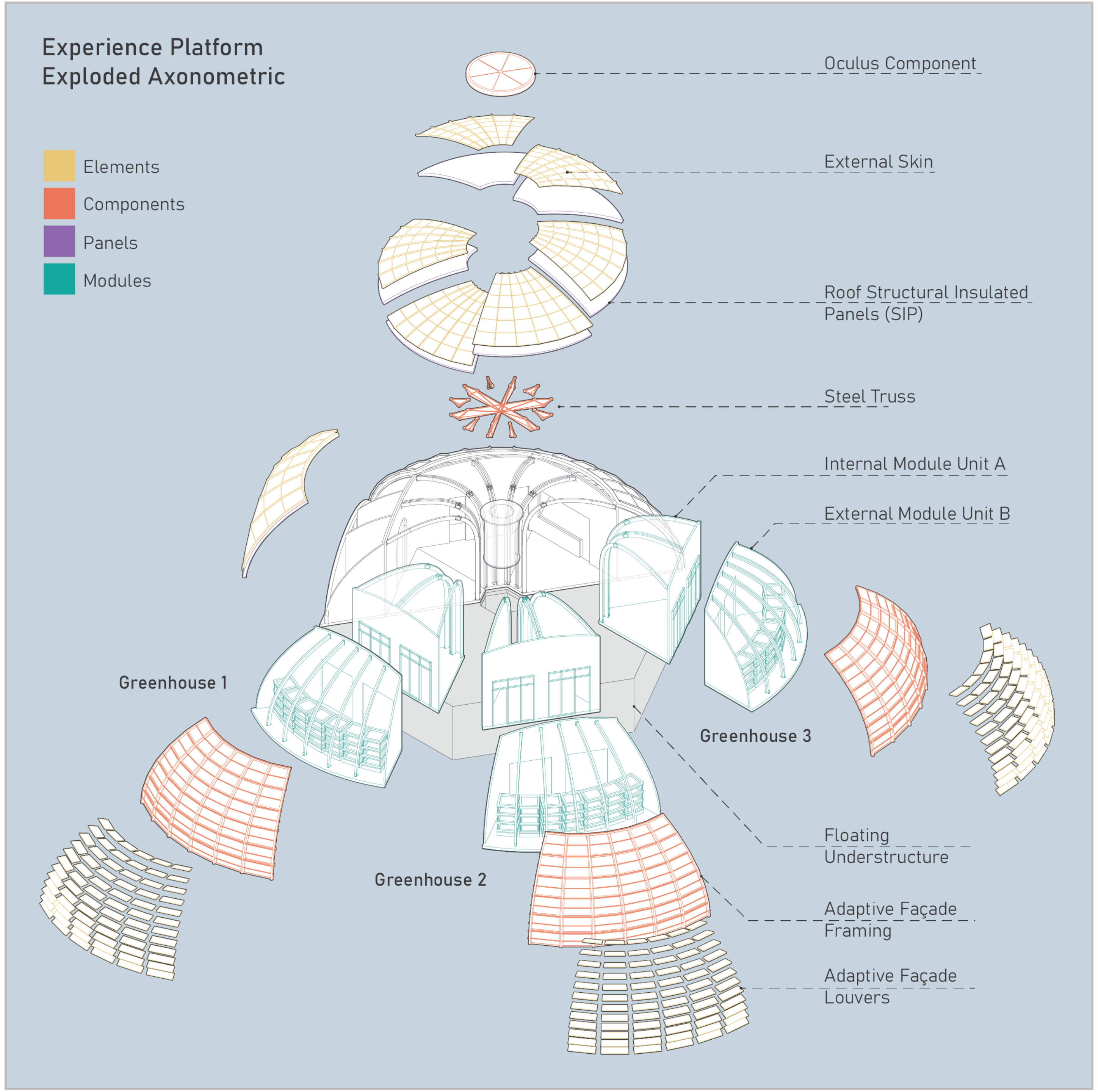
To Systemize: Avoid unique parts for interchangeable applications, create criteria for assembly and disassembly, and at the same time identify the disassembly points to avoid confusion.

To Standardize: The use of modular design and generic components for manufacturing and easy compatibility, the identification of components as the principle of the building information for the construction process.

Right: Figure F.9
Opportunities after Disassembly.
Source: Illustration created by the author based on the book Prefab Housing and the Future of Building: Product to Process. (2018).



When talking about systems for DfD, mainly we speak about the efficient modes of construction that could render a fast and easy assemblage of individual parts with the possibility of being renewed in any damage scenario, at the same time the parts should be considered as valuable resources that could be kept and reused in the future. When considering the topic of the future of a building there are some possibilities that could be considered.



Left: Figure F.10
Experience Platform Exploded Axonometric.
Source: Created by the author.

In this occasion, it is worth differentiating within the scope of DfD, that reuse strategies are a preference over recycling strategies, mainly because elements with a material value could be maintained intact and keep the same service and aesthetic purposes with reduced modifications. Design for Recycling (DfR) on the other hand, involves destructive disassembly processes that degrade the value of the elements and materials, not to mention the increment of pollution levels (Aitchinson, 2018).

In addition, the preference and hierarchy of elements and materials conservation will not always align with the economic and feasible efficiency, so in terms of DfD, separating the layers of the assemblage of the building enables changes with minimal use of resources and costs, adding even more reasons why DfD takes more time than traditional design.

This main strategy, in the case of the Experience Platform, is considered the right approach in terms of Floating Architecture as the "pavilion" character means a limited Use Stage, that considers the global detailing of actions in the lifecycle of a building and the quality of the materials proposed in the design development, makes the pavilion more than suitable to be re-used in another context that will be explained further in this chapter.

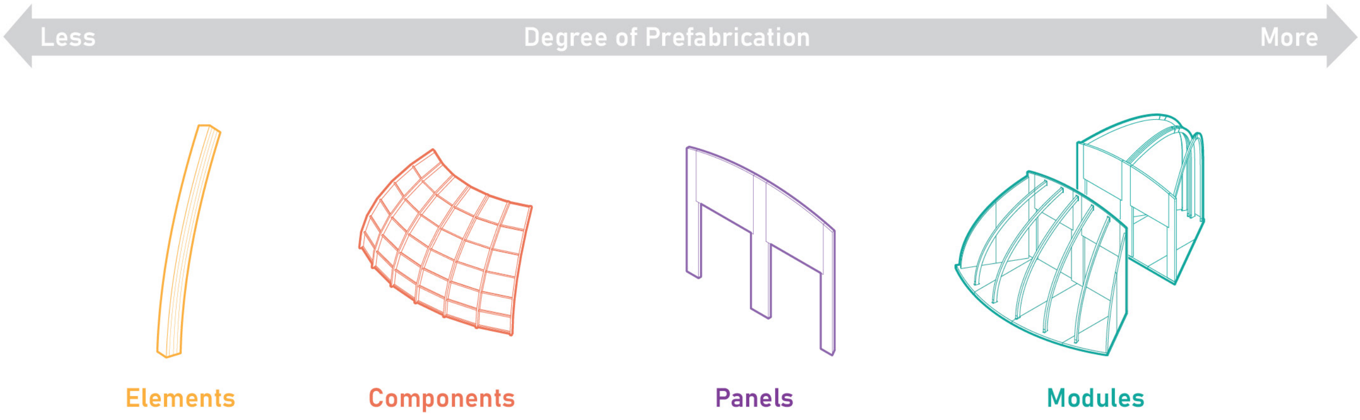
06.3 ELEMENTS OF PREFABRICATION

- *Components*
- *Panels*
- *Modules*

As seen previously, Prefabrication is associated with the concepts of assembly and off-site. To enter into the concepts composition of this innovative system of building production, according to Smith (2010), it is key to understand that prefabrication involves not only degrees but also categories in which it could be clearly identified the kind of organization that this process has behind as a theory of construction.

The following categorization of Components, Panels, and Modules is an effective method to describe the different prefabricated elements, in this specific case with the Experience Platform, where the elements arrive on-site more or less finished. The posture of this construction system comes from the desire of exploring efficiency in the construction process by reaching different solutions in which many of the obstacles resolving, involve moving the manufactured components panels, and modules that, if well developed towards a high prefabrication degree, could be erected faster on-site.

According to Smith (2010), prefabrication of Components, Panels, and Modules, are a combination of elements that complies with the aesthetics and the function goals of a project. To have an idea of the prefabrication degrees that we could expect, we can take as an example that Panels reach levels of finish at around 60%, while Modular Systems are finished at around 85%. However, fully finished Modules could reach up to 95% leaving the remaining 5% for anchorage/foundation work and setting hookups, putting in evidence that prefabricating module units are more efficient. For this reason, the whole pavilion explored modular units for the sake of efficiency when building over water.



06.3.1 Components

In this category of prefabrication, componentized elements could include customization and flexibility from the design and execution phases. A good definition of the different parts of a component is needed to ensure the correct functionality of the proposed systems, components could be projected for structure or enclosure, where joints and connection reasoning could resolve misalignments and air/water infiltrations.

To illustrate better what is understood as components, we can think about framing systems with several materials for different objectives. These systems are efficiently fabricated and assembled thanks to the aid of CNC manufacturing machines, as they offer versatility, precision, and speed (Smith, 2010).

Top: Figure F.11
Degree of Prefabrication Elements.
Source: Illustration created by the author based on the book Prefab architecture: a guide to modular design and construction (2010).

In the case of the Experience Platform, components were used as solutions for the different types of enclosures of the building. The design for components in this section includes the following Wood and Metal Building Systems:

LVL Structure & Fasteners

Laminated Veneer Lumber elements were used for the internal and external structure thanks to their flexibility and easy adaptation to curved shapes as presented in Chapter 5. These elements are projected to form a structural grid of components, which are designed to be anchored to the different slabs and walls of massive timber with Carbon Steel connectors and fasteners:

A. Metal Hangers with internal plates. (Wall/Beam Connection)
B. Angle Brackets with perforations for Carpentry Screws. (Slab/Post Connection)
C. Composed Fixed Fastener with internal plate and external hook. (Beam/Post Connection)

Adaptive Façade Framing

Glass facades, sometimes referred to as curtain walls, are exterior non-load-bearing transparent or translucent enclosures. The system for the adaptive façade is primarily fabricated of glass and recycled aluminum prefabricated pieces in the factory. The system responds to a plug-and-play anchoring system that attaches it to one of the modules presented further in this chapter. The system approaches accommodation when plugged in to allow tolerance in the dimensions.

Oculus Structure

As a skylight assembly, the component is a translucent enclosure primarily fabricated by recycled steel pieces, polycarbonate custom panels, and recycled aluminum frames. Following the previous example, this component too responds to a plug-and-play anchoring system that is attached to the joints of the central main structure. Accommodation tolerance is also taken into account when assembled before fastening the component.

06.3.2 Panels

The following category of prefabrication involves planar elements used to build structural walls, floors, and roofs, load-bearing or non-load-bearing enclosures, and interior partitions (Smith, 2010).
Nowadays it is in modern timber construction where the 'basic element', as Deplazes (2001) elaborates, is the slab or a solid wood panel, no longer belonging to the linear wood category.

A solid wood panel belongs to timber systems prefabrication that nowadays is composed of three or more layers of laminated timber panels to provide lateral resistance and enclosure towards the exterior. According to Smith (2010), this type of product has an 80% increment in thermal performance. The companies that produce this type of engineered wood products, usually manufacture with CNC (Computer Numerical Control) machines that prepare the elements for pressing the different elements and cutting them with mm error tolerance in the desired dimensions. Furthermore, in this chapter, we will elaborate on the relationship between the material choice of the panels, which in the case of the whole pavilion is mostly Cross Laminated Timber (CLT), and the lifecycle of the building.

In the case of the Experience Platform, panels were used as solutions for the main structure of the building and as enclosures. The design for components in this section includes the following Wood Panel Systems:

CLT Walls & Slabs

Wood is an extremely versatile material, and with wise and prudent forestry practices, it could be an environmentally responsible material that could serve buildings for many years. The manufacturing of engineered wood as CLT brings customization thanks to the precision cutting; in this case, due to the geometry of the project, curved profiles could be achieved for all the CLT walls and slabs. This paneling prefabrication is the previous step for our modules composition, which will be explained later.

Structural Insulated Panels (SIP)

SIP panels, as its name includes insulation, come with quality and structural/thermal performance that cannot be compared with framing on-site methods. Its prefabrication in the factory ensures the quality of the panels and a longer lifespan (Smith, 2010). This type of panel is composed of several elements and following modularity reaches standardization. The SIP panels were used as structural enclosures in the Experience Platform, where only one type of panel is produced.

06.3.3 Modules

This last category of prefabrication includes modular units that use a high percentage of the same components and panels for their composition. This standardized unit of construction is mainly designed for ease of assembly (Smith, 2010). Nowadays steel and wood modules are common thanks to their lightweight, very much considered when transporting the units.

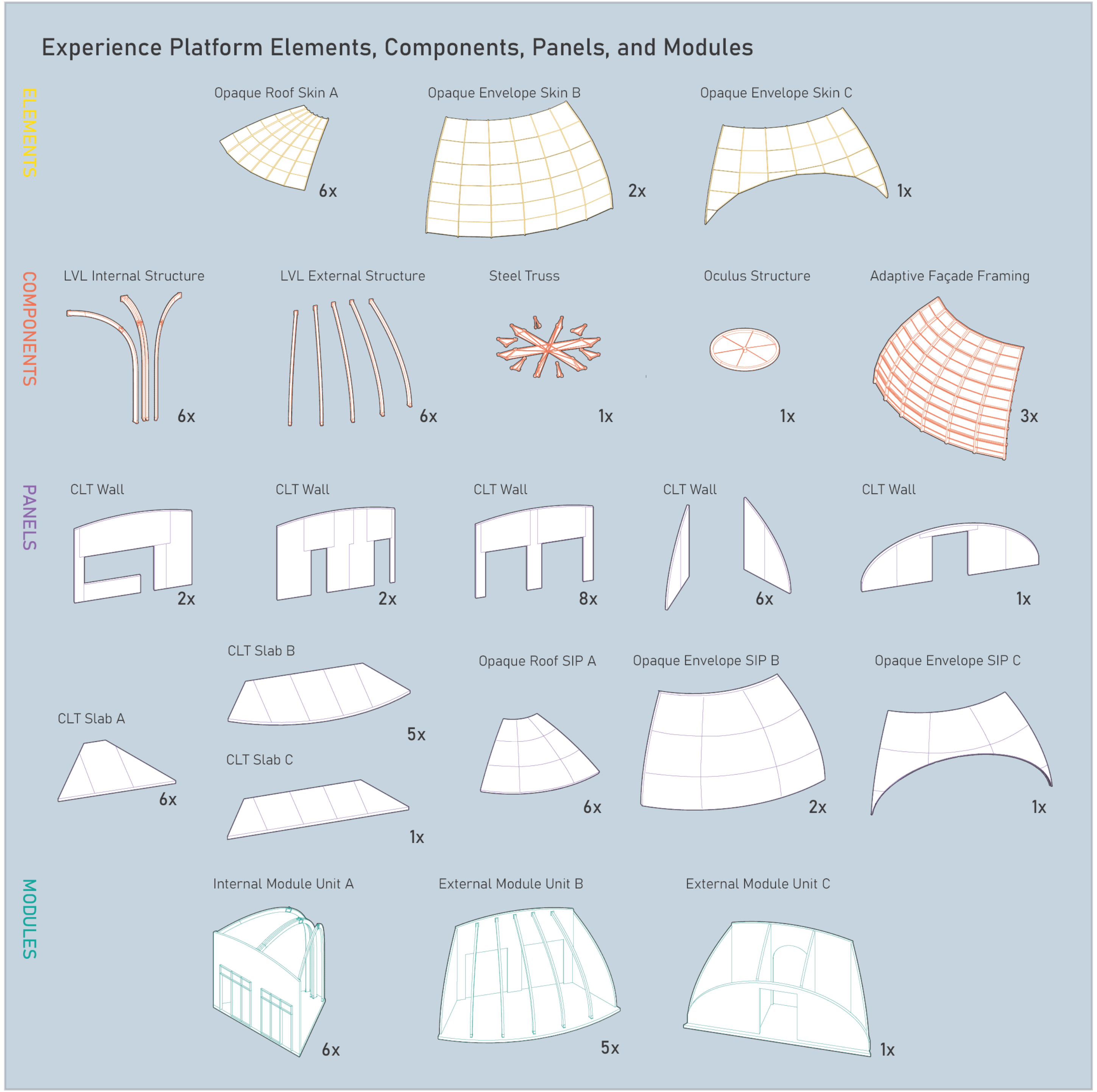
Modular units, depending on their dimensions, weight, and other specific design characteristics may present obstacles to transportation. Modular strategies for prefabrication and erection processes will define the construction sequence depending on the specific case scenario.

In the case of the Experience Platform, two types of Wood Modules with several variations according to the specific use of the spaces were used to mostly complete the building by delivering the structure and enclosure.

Wood Modules

As presented previously, the categories of Components and Panels include most of the elements that assemble the final units of the Experience Platform. However, due to the case scenario of building over water, the modular strategies for the erection and assembly present a sequence that will be presented later in this chapter with the construction process. Counting with the previous prefabrication categories, the wood modules are the last step before the anchoring and stitching activities on-site.

Right: Figure F.12
Experience Platform Elements, Components, Panels, and Modules Parts.
Source: Created by the author.



07
CLIMATE ANALYSIS

“To foresee is to provide. Forewarned is forearmed. By providing accurate forecasts, we save mariners from the risks of ignorance."

Robert FitzRoy
(British Naval Officer, Meteorologist, and Scientist)

As a technical continuation of the Modular Design study, the following chapter develops an experimental exercise in the direction of adaptation, but within the scope of building physics. The experiment presents a study of some of the Bio-climatic Strategies used for the Greenhouse spaces within the Experience Platform. The exercise outputs reveal the performance and possible limitations of the startegies analyzed.

From the beginning of the FloatScapes project, the word “adaptation” has been present as a principle that carries solutions for future conditions. In the same way, the experiment follows this principle thinking about the Beyond End of Life stage, where the possibility of re-using the Greenhouse spaces of the Experience Platform in future climate scenarios could still be contemplated for food production purposes.

Cover: Heat Map visualization of Piazetta San Marco.
Created by the author.

07.1 GREENHOUSE ANALYSIS BRIEF

- *Analysis Aim*
- *Analysis Periods*
- *Spatial Scope*
- *Analysis Passive Strategies*
- *Methods, Tools, and Standards*

07.1.1 Analysis Aim

The following analysis aims to test the Experience Platform greenhouse spaces, with some of the bio-climatic strategies previously proposed in Chapter 5, and the climate conditions of Venice-VE.

The analysis intention relies on showing the process, analysis, and conclusions of the thermal performance of the three Greenhouse spaces in the Experience Platform. By developing different simulations in the most extreme months of the year, with the passive strategies of Solar Shadings and Natural Ventilation, the analysis puts in evidence their individual and combined performance in the most extreme months of the year.

As previously explained in Chapter 5, regarding the platform's activities, the Experience Platform delivers a food experience to the visitors and therefore, has a crops production process behind that should be tested. For this reason, to evaluate if the needed conditions for crops to grow and operators to work in these building zones could be reached with these passive strategies, is the main goal of this analysis, as the entire FloatScapes project foresees a productive future over water even though the project is characterized as temporarily.

It is also imperative to mention that the future vision of the project also includes a set of simulations that regards the comparison with the future climate conditions that the climate in Venice might encounter in the year 2050. This is important for the project in terms of Climate Change understanding, Risk Management for future informed decision making, and Public Awareness that could lead to better support for climate action.

07.1.3 Analysis Periods

Regarding the analysis periods for the simulations, the months with the most critical temperatures were chosen from summer and winter seasons.

- Hottest Month: **July (7/01 to 7/31)**
- Coldest Month: **February (2/01 to 2/28)**

The simulations were developed with the climate data extracted from the Energy Plus Weather file (.epw) from the Venice Tessera station corresponding to the year 2021. According to Murano (2016), this data refers to the International Weather for Energy Calculation (IWEC), and the Italian Climate data collection "Gianni De Giorgio" (IGDG).

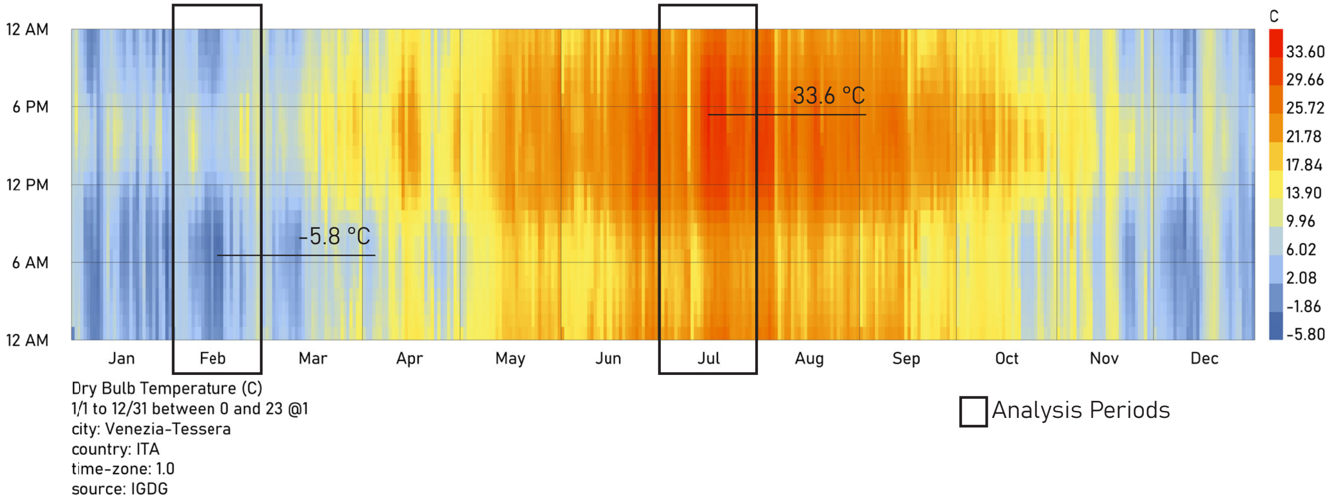
- ITA_Venezia-Tessera.161050_IGDG_EPW

In addition, as an exercise to understand the impacts of Climate Change, the simulations were also developed with the 2050 climate data projection within the RCP 8.5 scope of the same Venice Tessera .epw file.

This file was generated and extracted from the **Meteonorm Sofware**, a software which includes a global meteorological database of typical years and historical time series from worldwide weather stations that could be used for specific calculations.

The climate data from both years (2021 and 2050) correspond from the same meteorological station, and was used for academic purposes only. The use of the 2050 climate data in the worst RCP scenario doesn't affirm the future climate of Venice, but its use aimed to raise climate change awareness in this exercise.

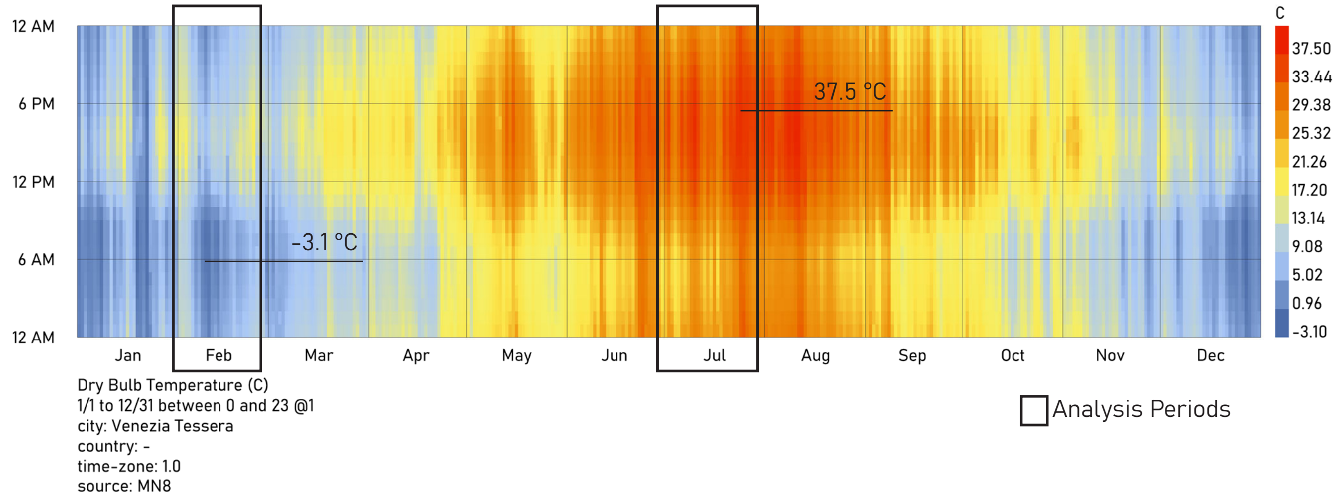
Top: Figure G.1
Meteonorm Logo.
Source: meteonorm.com



2021			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Dry Bulb Temperature*	TEMP	(°C)	2.00	3.00	7.00	12.00	17.00	20.00	23.00	22.00	19.00	13.00	8.00	3.00
Maximum Temperature	TMAX	(°C)	11.00	13.00	17.00	22.50	25.00	31.00	33.60	31.00	26.00	22.00	16.50	10.50
Minimum Temperature	TMIN	(°C)	-5.00	-5.80	-2.00	3.00	7.00	14.00	15.00	16.00	11.00	4.00	-1.00	-4.00
Dew Point Temperature*	TEMP	(°C)	0.00	1.00	3.00	7.00	14.00	16.00	16.00	17.00	15.00	11.00	5.00	1.00
Relative Humidity*	RHUM	% points	84.00	83.00	77.00	73.00	83.00	78.00	67.00	75.00	79.00	85.00	84.00	82.00
Wind Direction	WINDd	(°)	30.00	70.00	160.00	130.00	180.00	170.00	200.00	30.00	170.00	120.00	30.00	260.00
Wind Speed*	WINDs	%	1.00	1.00	1.00	3.00	2.00	2.00	2.00	2.00	1.00	0.00	2.00	1.00
Global Horizontal Radiation**	DSWF	Wh/m²	880.00	1150.00	2561.00	3709.00	5018.00	5472.00	5681.00	4677.00	3349.00	1955.00	911.00	729.00

*Average Monthly
**Averga Daily Total

Top to Bottom: Figure G.2
2021 Dry Bulb Temp. Graph.
2021 Weather Data Summary.
Source: Created by the author with Ladybug Tools.



2050			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Dry Bulb Temperature*	TEMP	(°C)	4.00	6.00	10.00	15.00	20.00	25.00	28.00	28.00	22.00	16.00	11.00	5.00
Maximum Temperature	TMAX	(°C)	14.50	16.00	20.20	25.00	31.00	34.00	37.50	37.30	32.50	26.00	22.00	15.50
Minimum Temperature	TMIN	(°C)	-3.00	-3.10	1.00	6.00	12.50	15.50	19.00	19.50	14.00	6.50	3.00	-3.50
Dew Point Temperature*	TEMP	(°C)	1.00	2.00	5.00	9.00	14.00	18.00	20.00	20.00	16.00	12.00	7.00	1.00
Relative Humidity*	RHUM	% points	78.00	75.00	72.00	72.00	70.00	69.00	65.00	66.00	72.00	75.00	79.00	76.00
Wind Direction	WINDd	(°)	30.00	40.00	30.00	210.00	220.00	240.00	290.00	340.00	120.00	60.00	60.00	20.00
Wind Speed*	WINDs	%	2.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	1.00	0.00	2.00	2.00
Global Horizontal Radiation**	DSWF	Wh/m²	1236.00	1992.00	3426.00	4555.00	5884.00	6611.00	6733.00	5711.00	3998.00	2451.00	1359.00	996.00

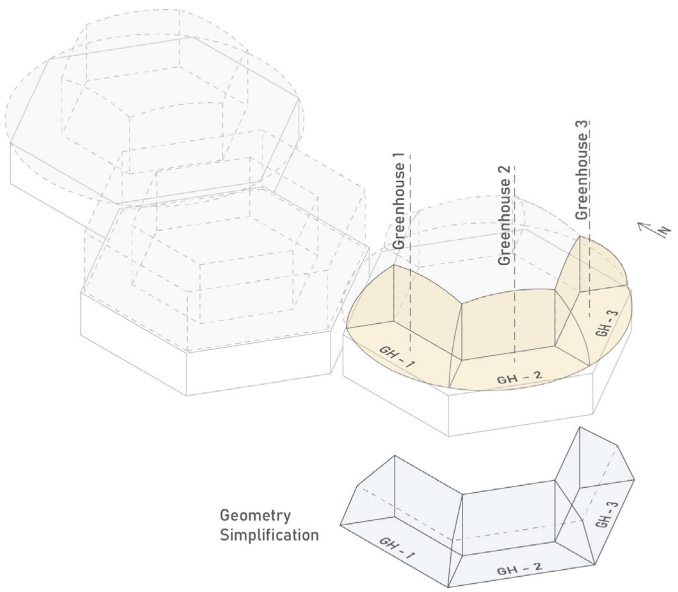
*Average Monthly
**Averga Daily Total

Top to Bottom: Figure G.3
2050 Dry Bulb Temp. Graph.
2050 Weather Data Summary.
Source: Created by the author with Ladybug Tools.

07.1.4 Spatial Scope

The simulations were developed for three rooms of the Experience Platform which corresponds to the greenhouse spaces facing south-west orientation. The following room names will be displayed further in the graphics for easy identification of the simulation outputs:

- Greenhouse 1 (GH-1)
- Greenhouse 2 (GH-2)
- Greenhouse 3 (GH-3)



Left: Figure G.4
Greenhouse Rooms 1, 2, and 3 with Geometry Simplification.
Source: Created by the author.

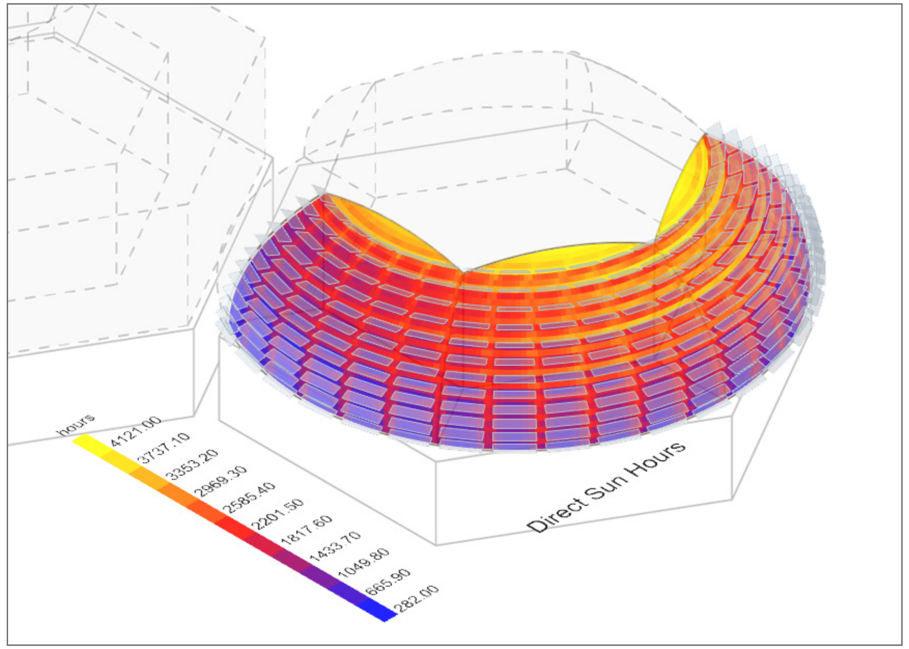
Given the complexity of the curved geometry of the Experience Platform, a planar simplification of the greenhouse spaces was made in order to obtain the data in a more efficient way during the simulations.

07.1.5 Analysis Passive Strategies

The following passive strategies of the Greenhouse rooms, are the main variables in the simulations according to the analysis periods:

- Solar Shading (Adaptive Façade Louvers)
- Natural Ventilation

For the Solar Shading strategy, a previous study of the solar incidence in the Greenhouse surface was developed for the proposal of the louver's angles for the corresponding hottest and coldest months. As seen in **Figure G.5** below, the presence of the Adaptive Façade Louvers puts in evidence even more clearly, the zones of the Greenhouse surface that will receive more radiation and therefore, be the most protected surface areas in the coldest months of the year.



Left: Figure G.5
Greenhouse Surface Annual Sun hours.
Source: Created by the author with Ladybug Tools.

Bottom Left to Right: Figure G.6
Coldest Month Strategies.
Hottest Month Strategies.
Source: Created by the author.

Coldest Month:

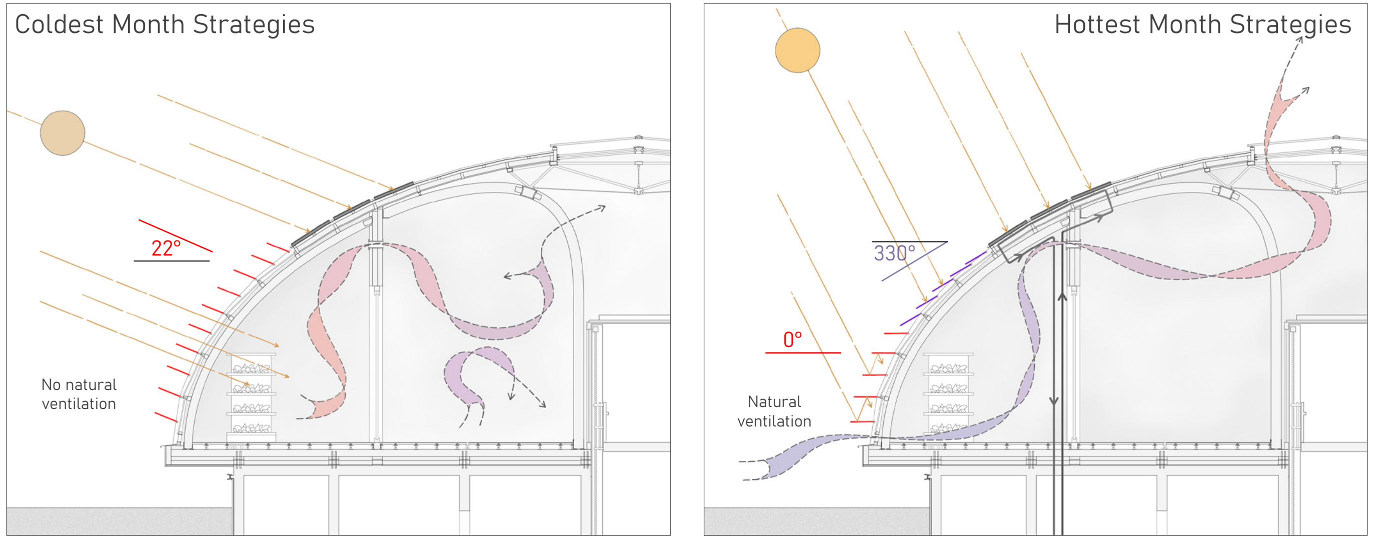
Louvers present a 22° degrees angle aperture to welcome incident solar radiation.

In this period windows are not operable, canceling any natural ventilation to avoid heat losses.

Hottest Month:

Louvers are divided according to the solar radiation incidence angles. The lower set presents 0° degrees while the upper set presents 330° degrees, blocking and allowing indirect solar radiation incidence.

In this period windows are operable allowing natural ventilation.



07.1.2 Methods, Tools, and Standards

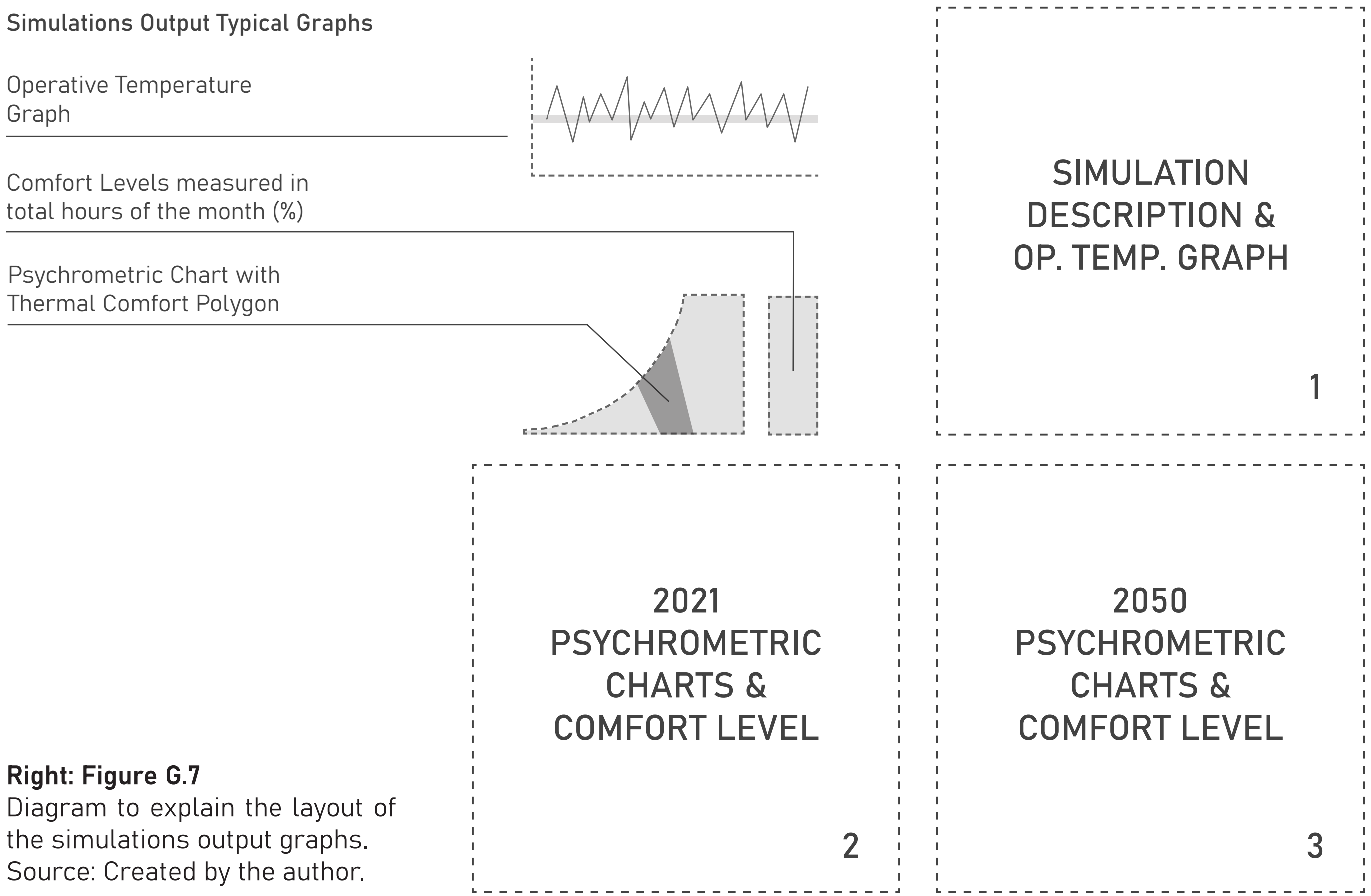
In order to evaluate the impact of the proposed passive strategies, the Experimental Research method was used where simulations were carried out as a process to extract data to later be measured and visualized as the outcomes of the different tests. The simulations presented a Base Case as a starting and comparison point, as the approach of cause-and-effect was applied to observe the affected results with the different manipulations of the variables, which in this case is the appliance of the passive strategies.

In terms of the tools used for this experiment, a VPL (Visual Programming Language) approach was taken for the development of the simulations, the exportation of the data, and the visualization of graphics. Rhino was used as the modelling software, while Grasshopper and Ladybug Tools were used as the simulation softwares. The chosen parametric interface allowed an easy exploration of the passive strategies with the correspondent climate data as the software uses Energy Plus engine parameters.

About the standards involved in the whole experiment, the simulations follow the **ANSI/ASHRAE Standard 55-2017** for the definition of the thermal comfort conditions for a generic office program with a human occupancy comfort range between **20 °C to 25 °C**, taking into account the low activities of the operators of the greenhouses in the Experience Platform. In addition, the crops growth comfort range between **20 °C to 30 °C** for the following warm season crops was added to evaluate similarly the growing conditions:

-Cherry Tomatoes (between 21°C to 29 °C, nighttime above 10°C)
-Basil (between 21°C to 32 °C, nighttime above 10°C)

To visualize the outputs of the different simulations in a coherent and homogeneous way, the following layout was defined. A first page where the simulation is described, included the main results and noteworthy observations, accompanied by the Operative Temperature graph to observe the 2021/2050 Greenhouse rooms data confronted with the previous presented comfort ranges for crops growth and human occupancy. The second and third pages include the Psychrometric Charts and Comfort Levels graphs of the 2021/2050 Greenhouse rooms data with a percentage comfort result (%).



Right: Figure G.7
Diagram to explain the layout of the simulations output graphs.
Source: Created by the author.

07.2 HOTTEST MONTH STRATEGIES SIMULATIONS

- *Base Case*
- *Adaptive Façade (Summer Angles)*
- *Natural Ventilation*
- *Combined*

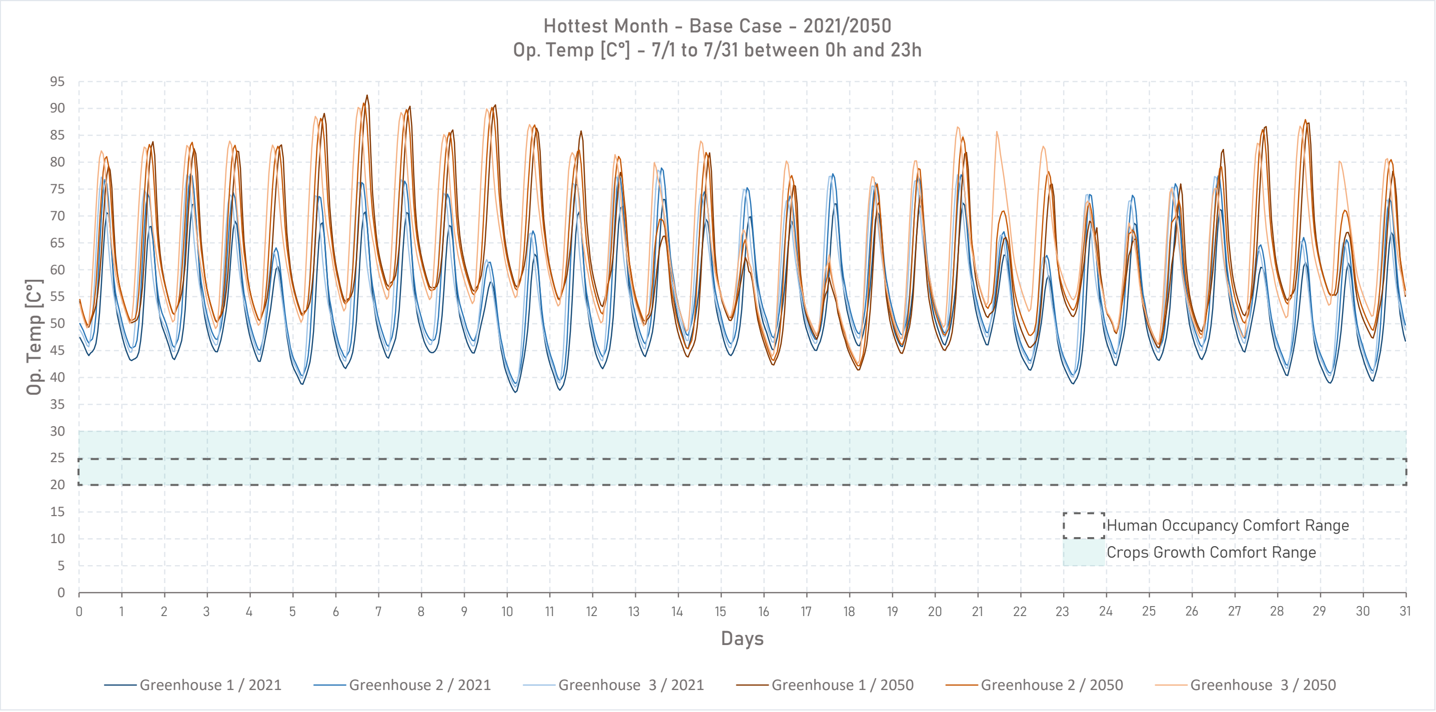
07.2.1 Base Case

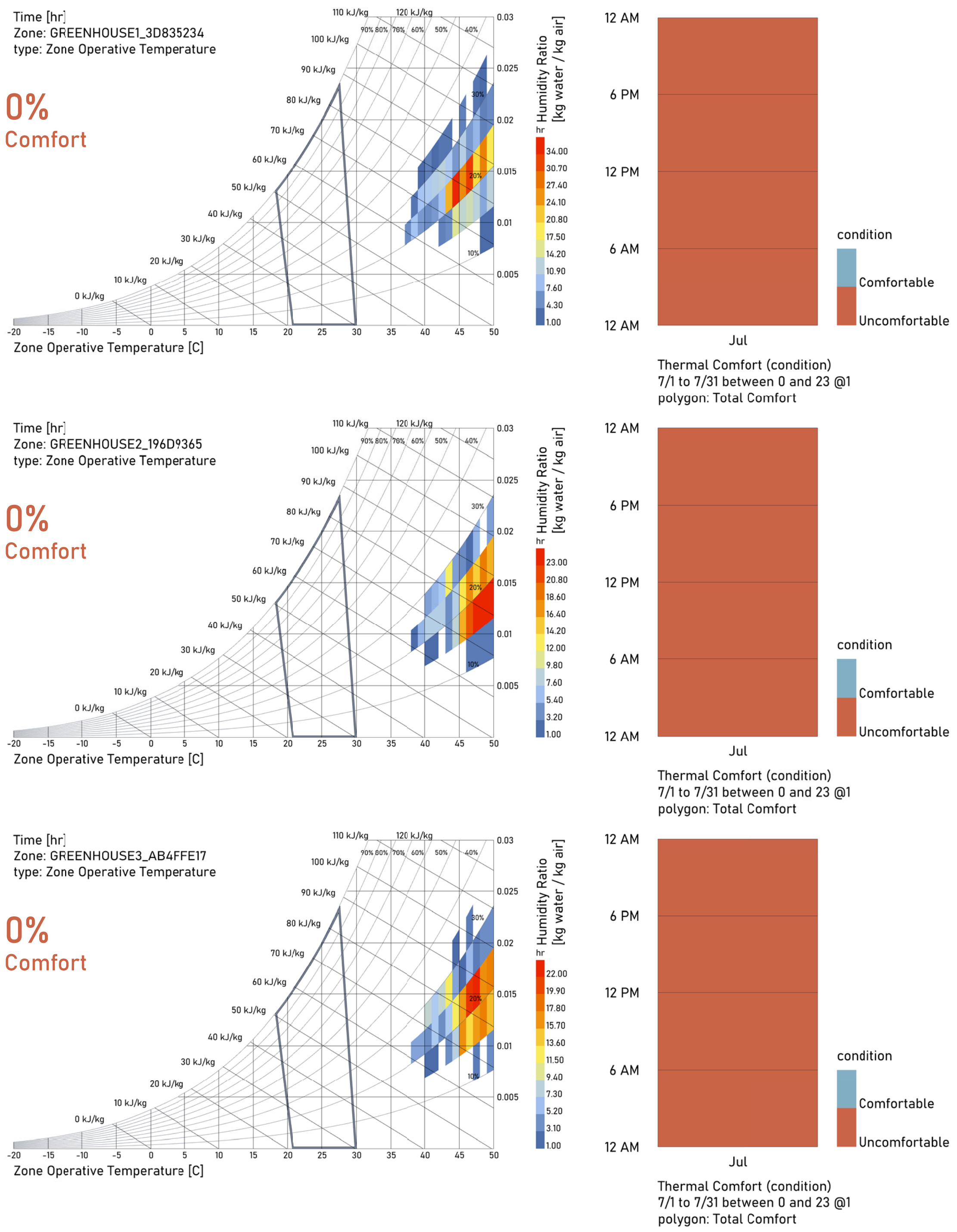
The base case was developed on purpose with none of the bio-climatic strategies as a base point presenting an high temperature unconceivable scenario to really visualize later the impact when applying the different strategies.

In the Operative Temperature graph it could be seen that both years data, 2021 and 2050, present extremely high temperatures being far from the crops growth comfort range .

Alternatively, it could be observed with the psychrometric charts, that both 2021 and 2050 Greenhouse spaces data is way displaced from the comfort polygon showing a 0% of thermal comfort.

Bottom: Figure G.8
Hottest Month Base Case 2021/2050.
Source: Created by the author.



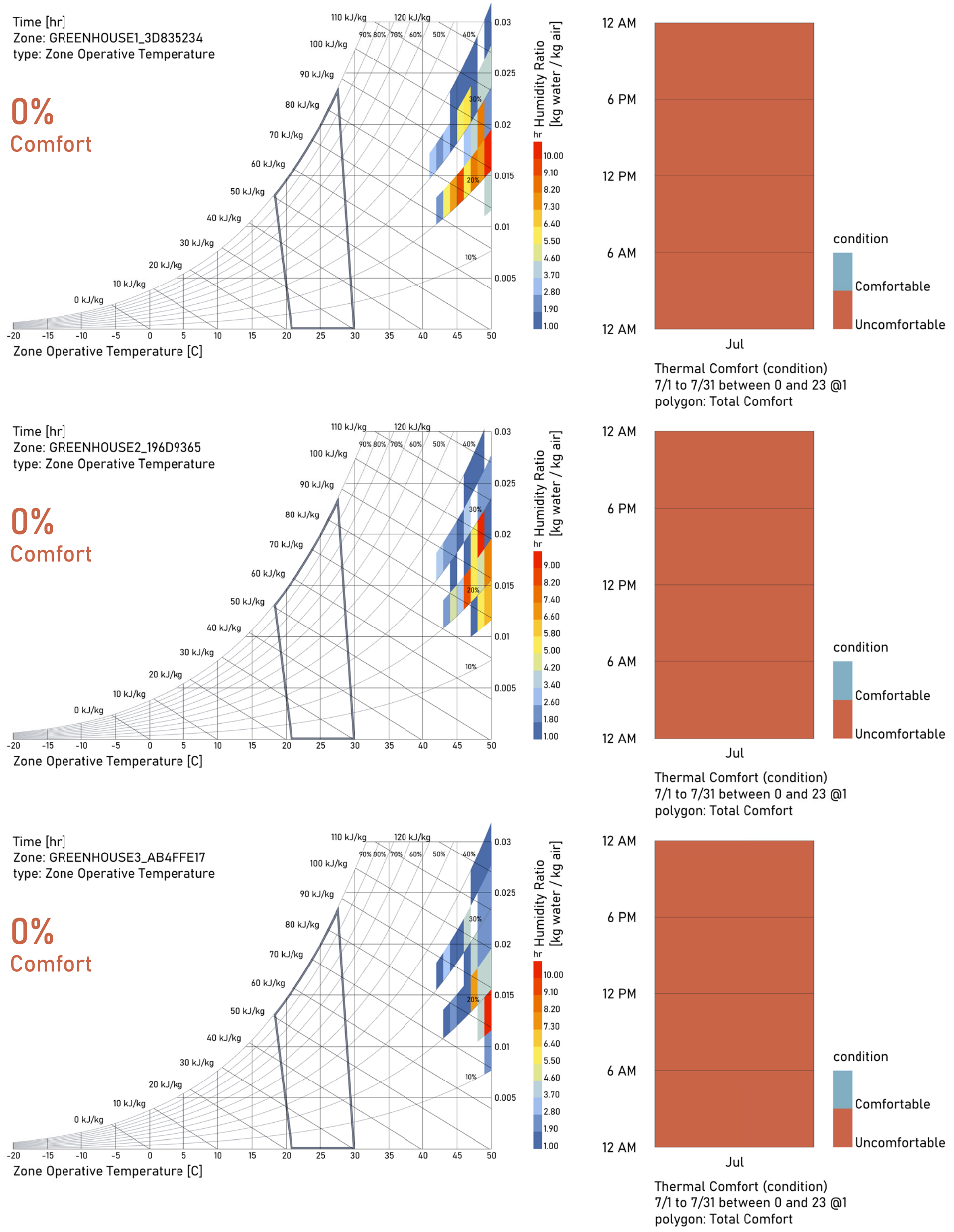


2021

Left: Figure G.9
July 2021 Base Case Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

2050

Right: Figure G.10
July 2050 Base Case Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.



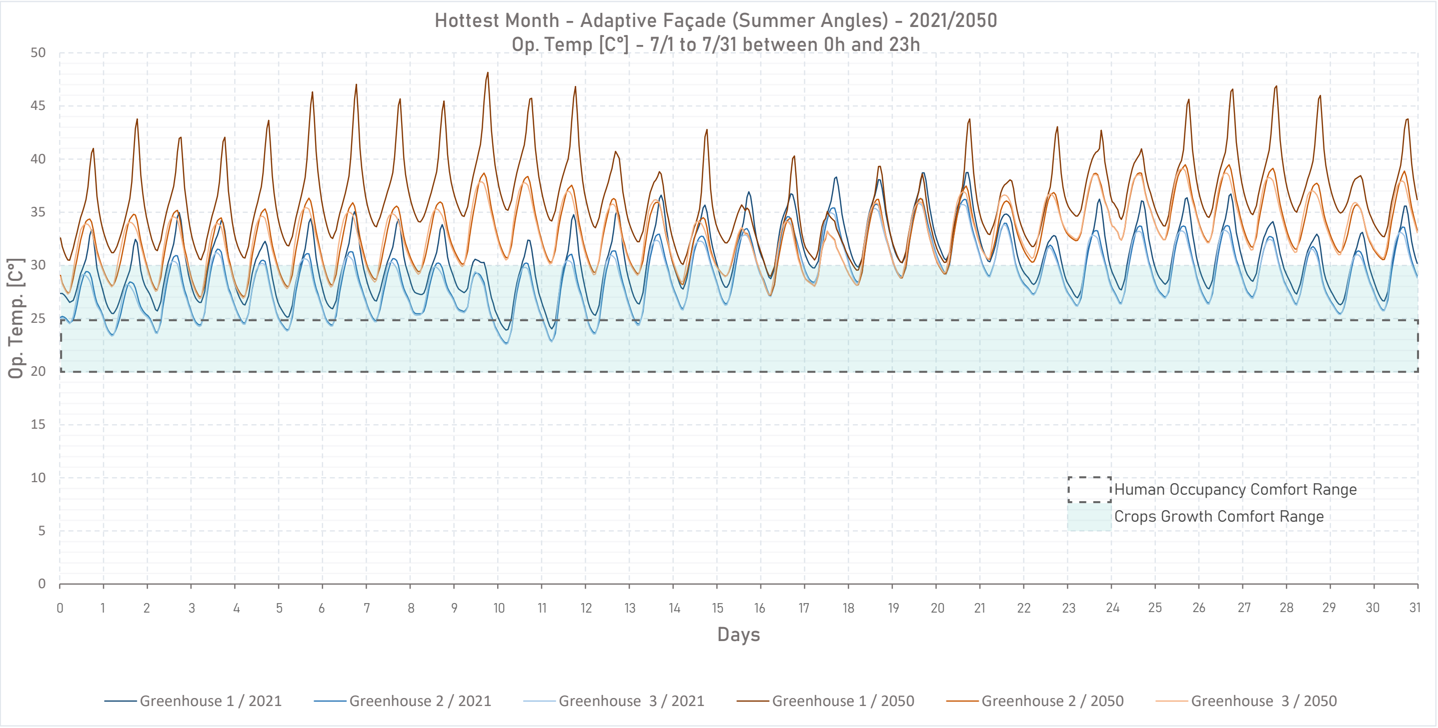
07.2.2 Adaptive Façade (Summer Angles)

The following case presents only the solar shading strategy with the summer angles previously presented.

In the Operative Temperature graph, it could be observed that less than half of the 2021 Greenhouses data is comprised within the crops growth comfort range, while a minimum reaches the human occupancy thermal comfort range. On the other hand, most of the 2050 data is higher than the crops production range.

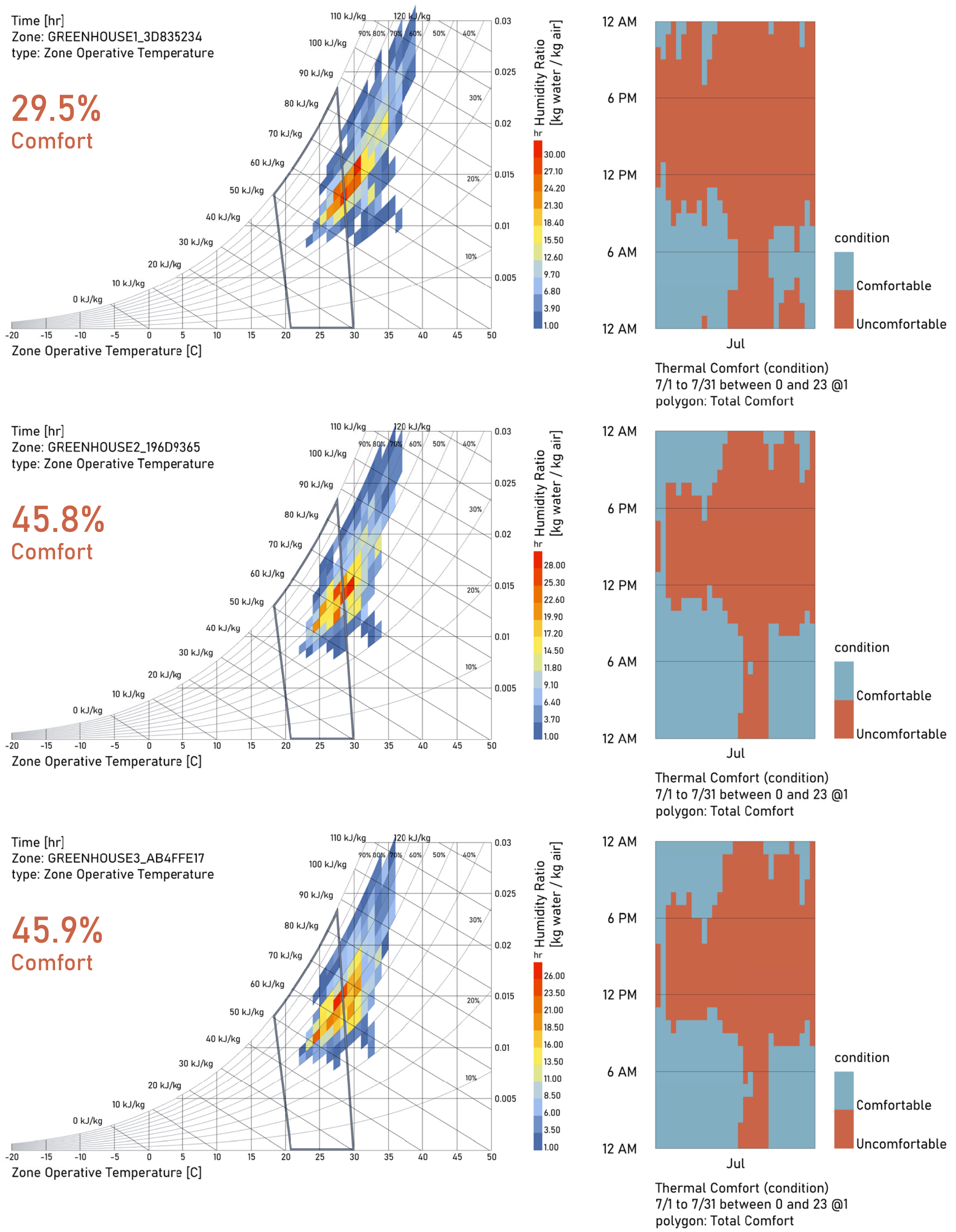
Alternatively, it could be observed with the psychrometric charts, that the Greenhouses spaces data of 2021 present a thermal comfort between 29% and 45% of the time, while the Greenhouse spaces data of 2050 present a lower comfort than 10% of the time.

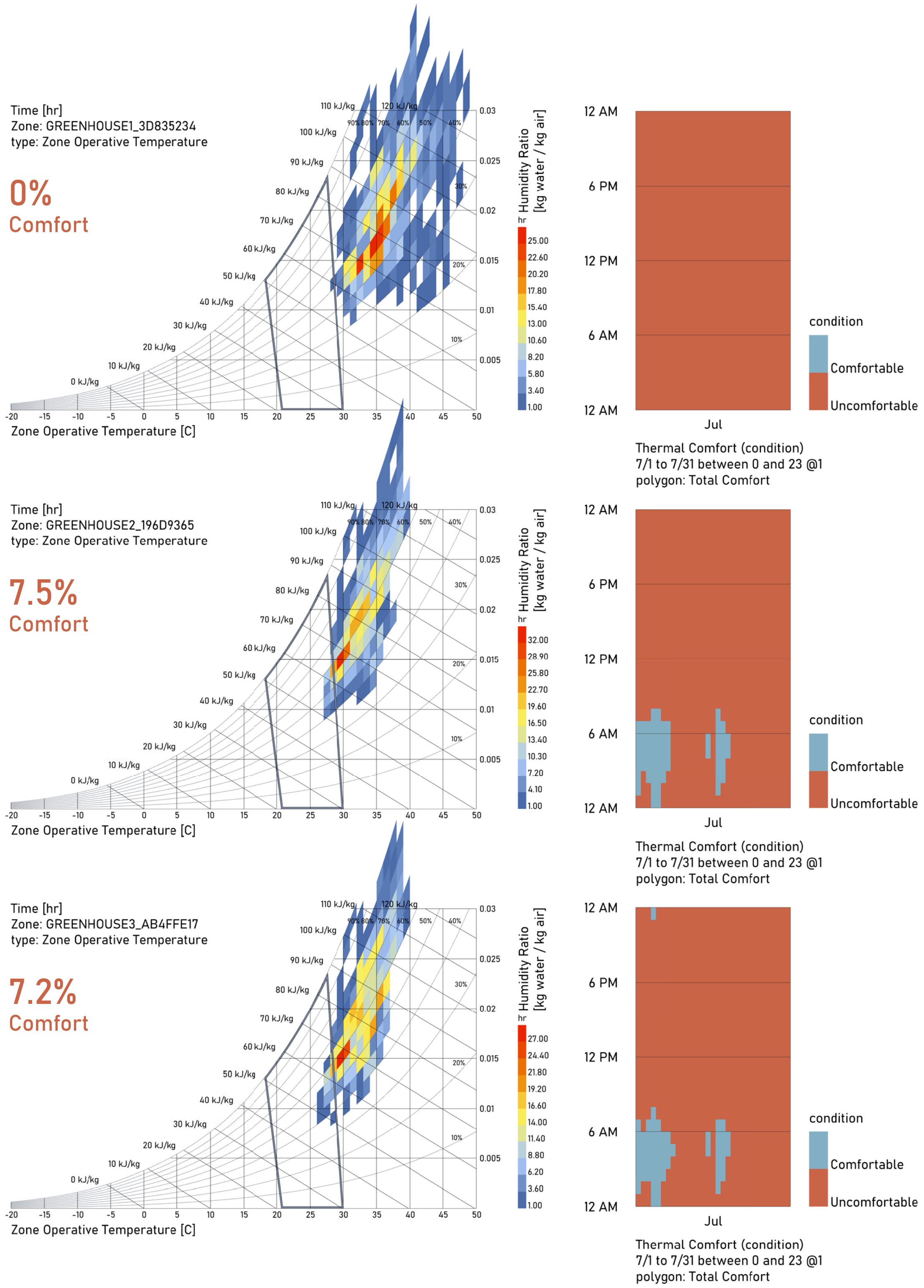
Bottom: Figure G.11
Hottest Month Adaptive Façade (Summer Angles) 2021/2050.
Source: Created by the author.



2021

Right: Figure G.12
July 2021 Adaptive Façade Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.





2050

Left: Figure G.13
July 2050 Adaptive Façade Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

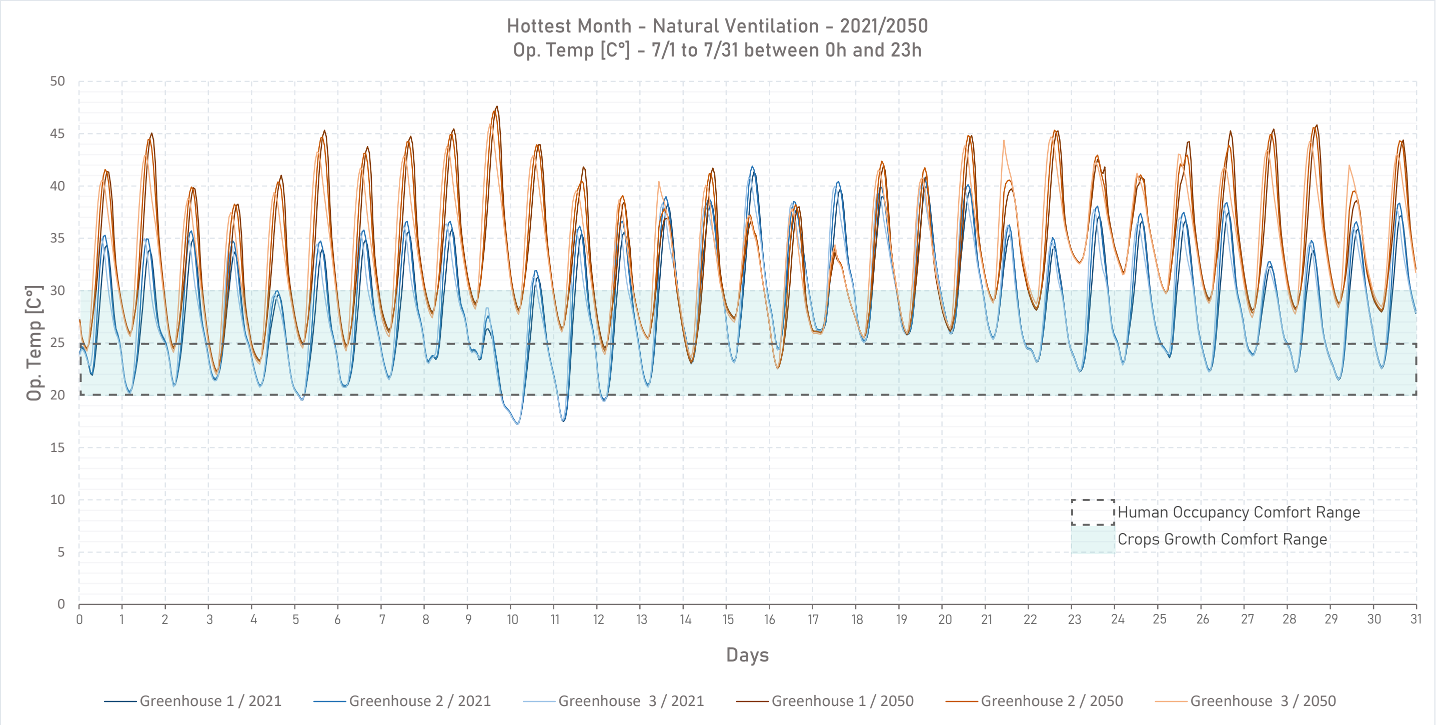
07.2.3 Natural Ventilation

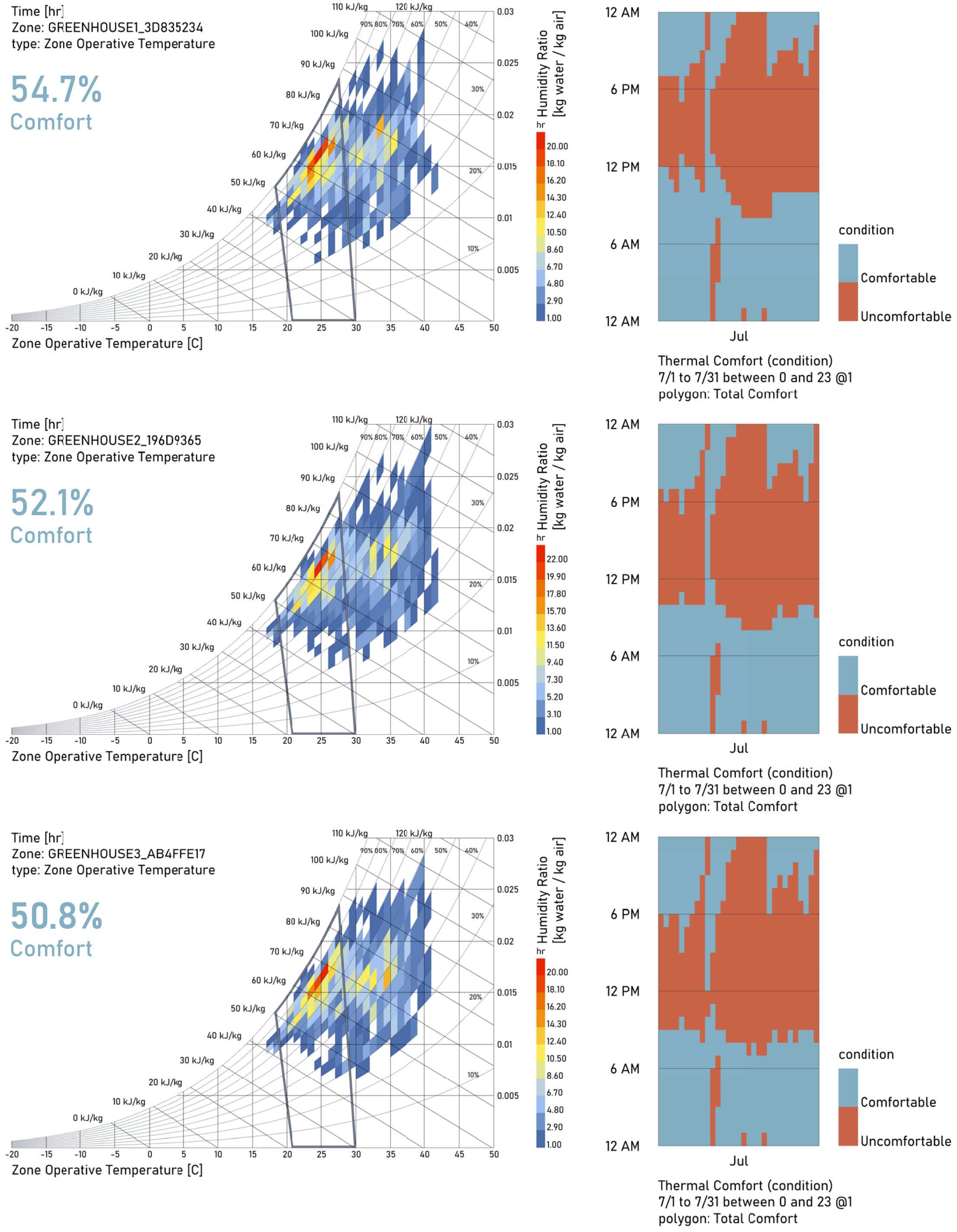
The following case presents only the natural ventilation strategy as an overheating counter measure.

In the Operative Temperature graph, it could be observed that more than half of the 2021 Greenhouse data is comprised within the crops growth comfort range and the human occupancy thermal comfort range. On the other hand, most of the 2050 data is higher than the crops production range.

Alternatively, with the psychrometric charts, the Greenhouse spaces data of 2021 present a thermal comfort between 50% and 55% of the time, while the Greenhouse spaces data of 2050 present a lower comfort between 19% and 22% of the time.

Bottom: Figure G.14
Hottest Month Natural Ventilation 2021/2050.
Source: Created by the author.



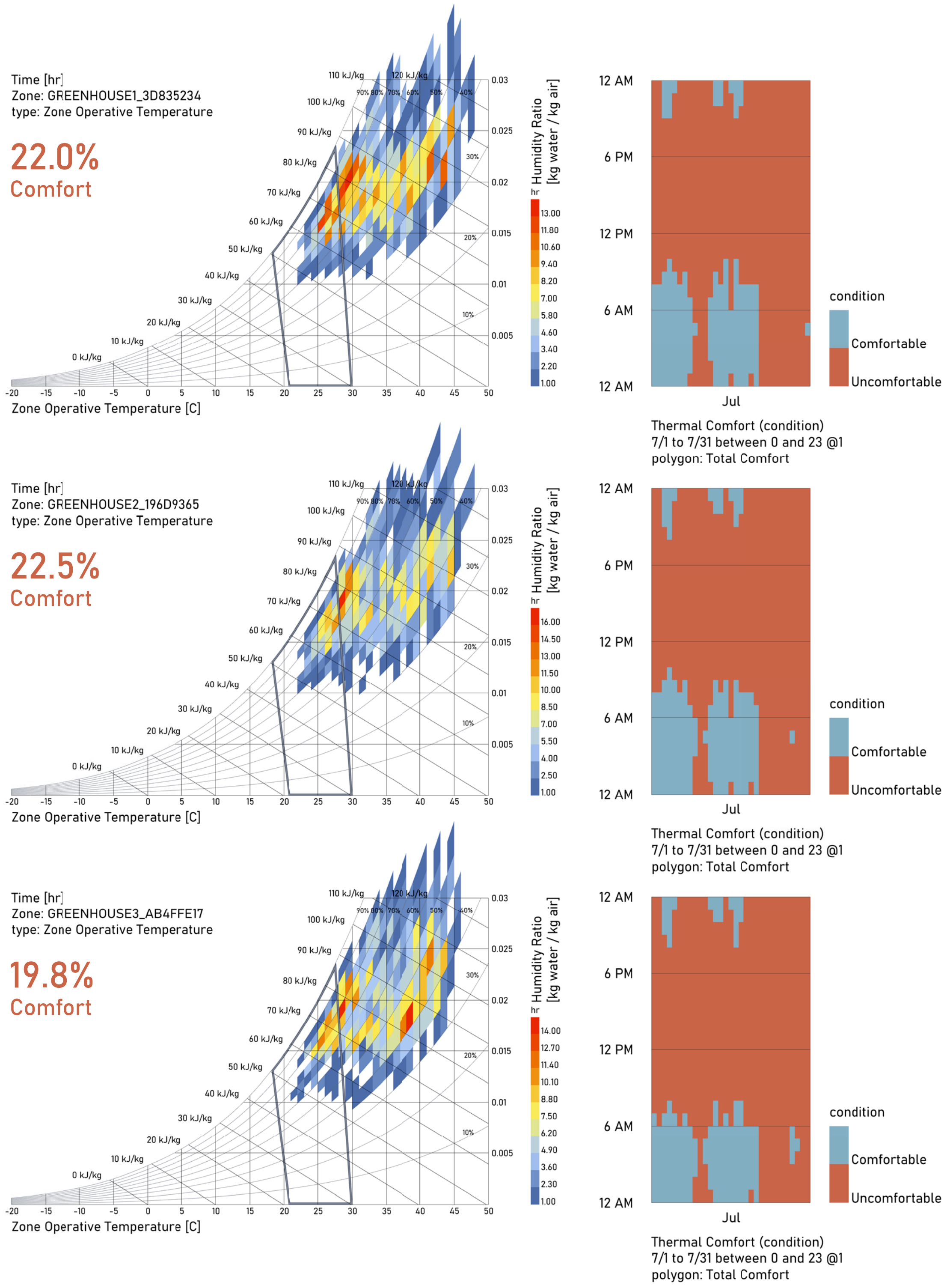


2021

Left: Figure G.15
July 2021 Natural Ventilation Performance & Comfort Levels.
Source: Created by the

2050

Right: Figure G.16
July 2050 Natural Ventilation Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.



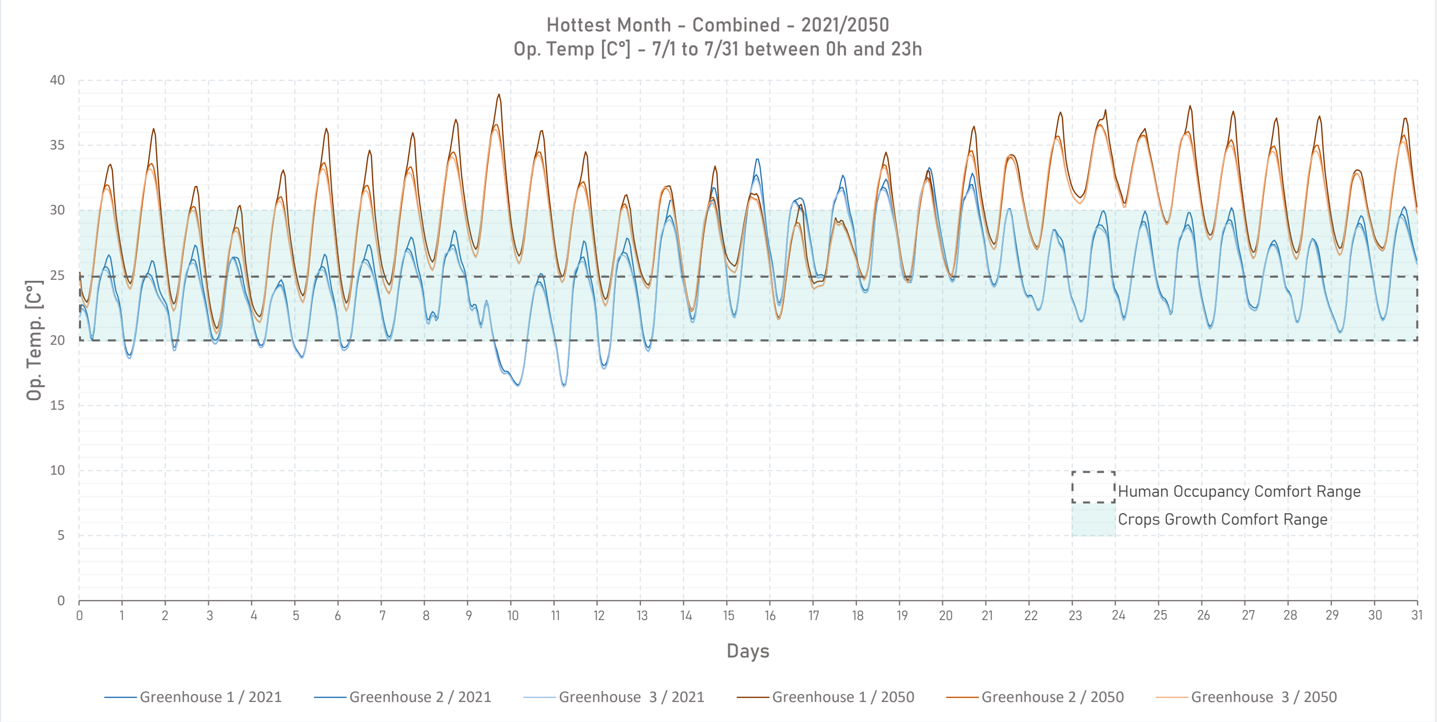
07.2.4 Combined

The following case presents the combined strategies of solar shading and natural ventilation.

In the Operative Temperature graph, it could be observed that a considerable portion of the 2021 Greenhouse data is comprised within the crops growth comfort range and the human occupancy thermal comfort range. On the other hand, less than half of the 2050 data is within the crops production range, while a minimum portion is within the human occupancy thermal comfort range.

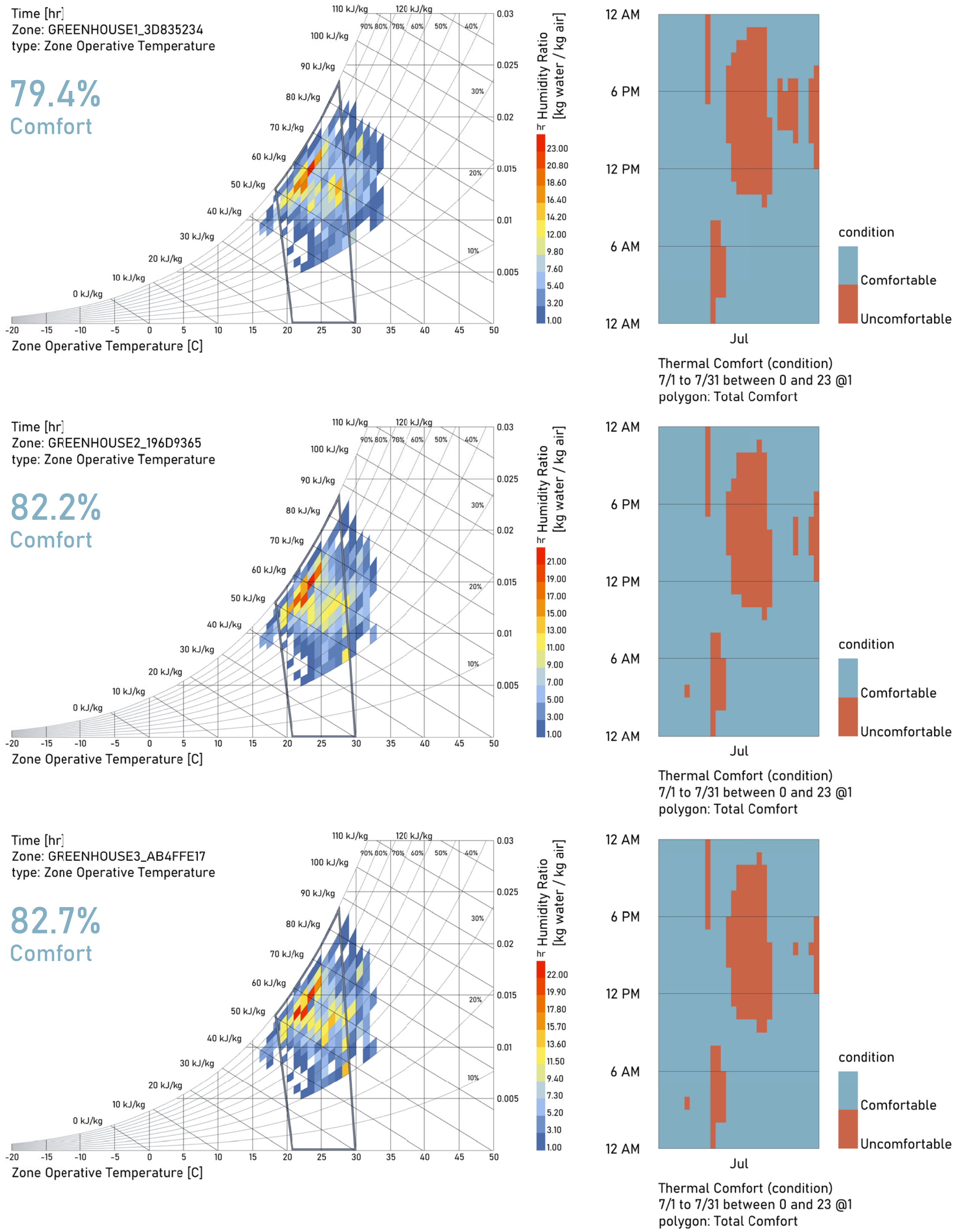
Alternatively, with the psychrometric charts, the Greenhouse spaces data of 2021 present an average comfort of 80% of the time, while the Greenhouse spaces data of 2050 present a comfort between 38% and 44% of the time.

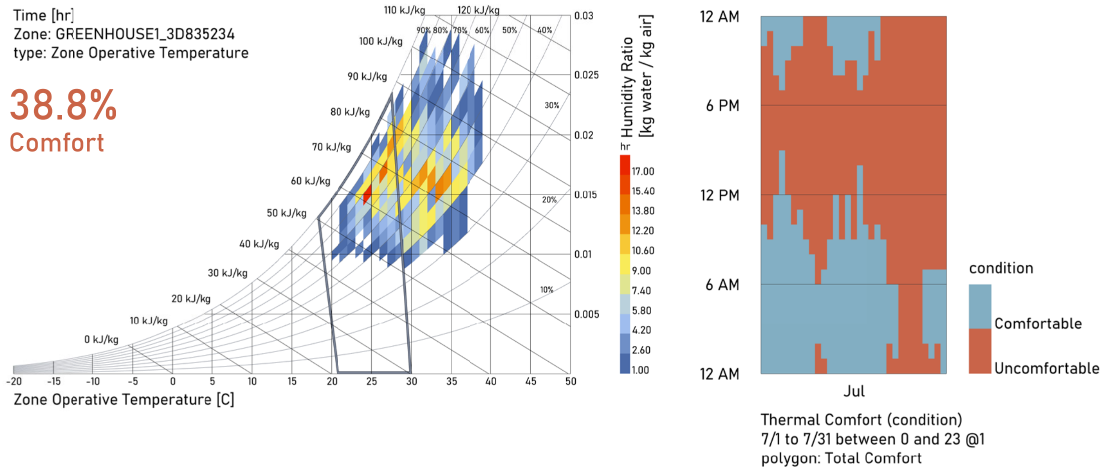
Bottom: Figure G.17
Hottest Month Combined 2021/2050.
Source: Created by the author.

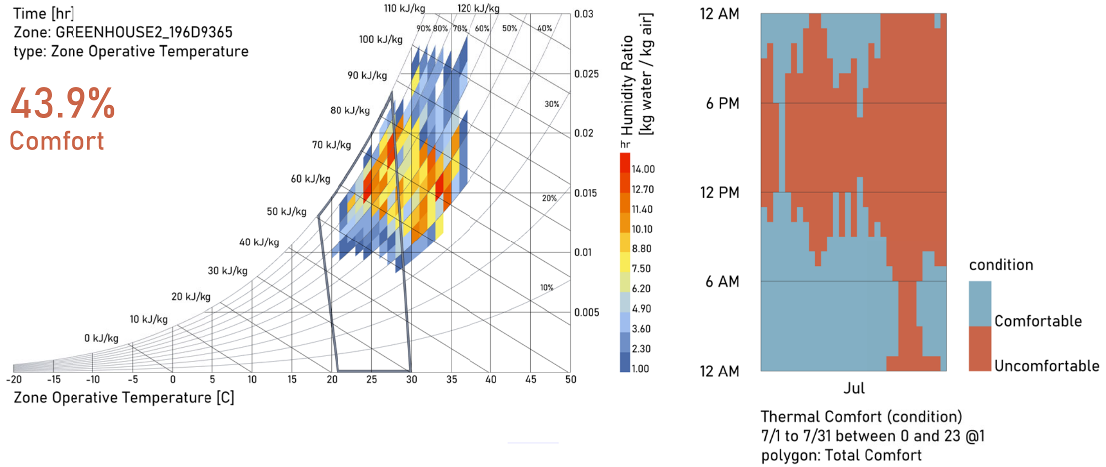


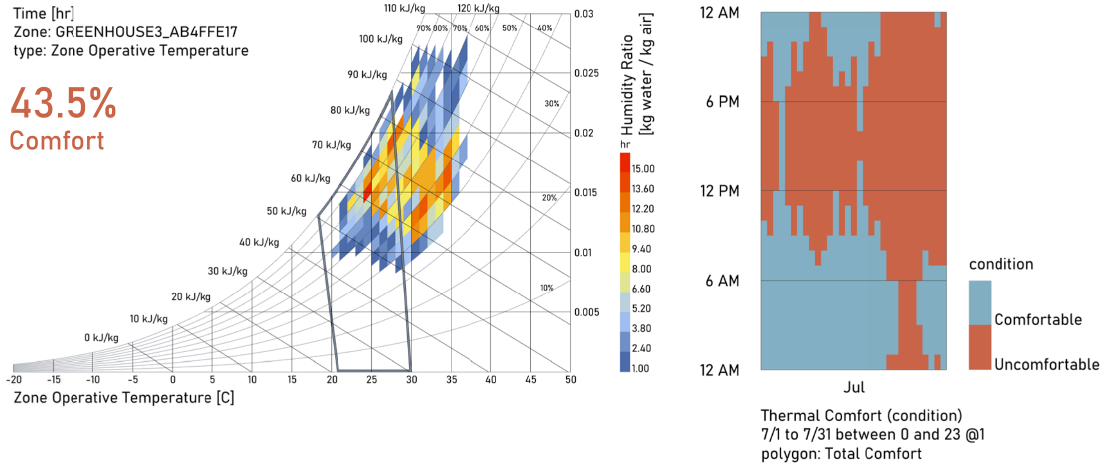
2021

Right: Figure G.18
July 2021 Combined Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.









2050

Left: Figure G.19
July 2050 Combined Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

07.3 COLDEST MONTH STRATEGIES SIMULATION

- *Base Case*
- *Adaptive Façade (Summer Angles)*
- *Adaptive Façade (Winter Angles)*

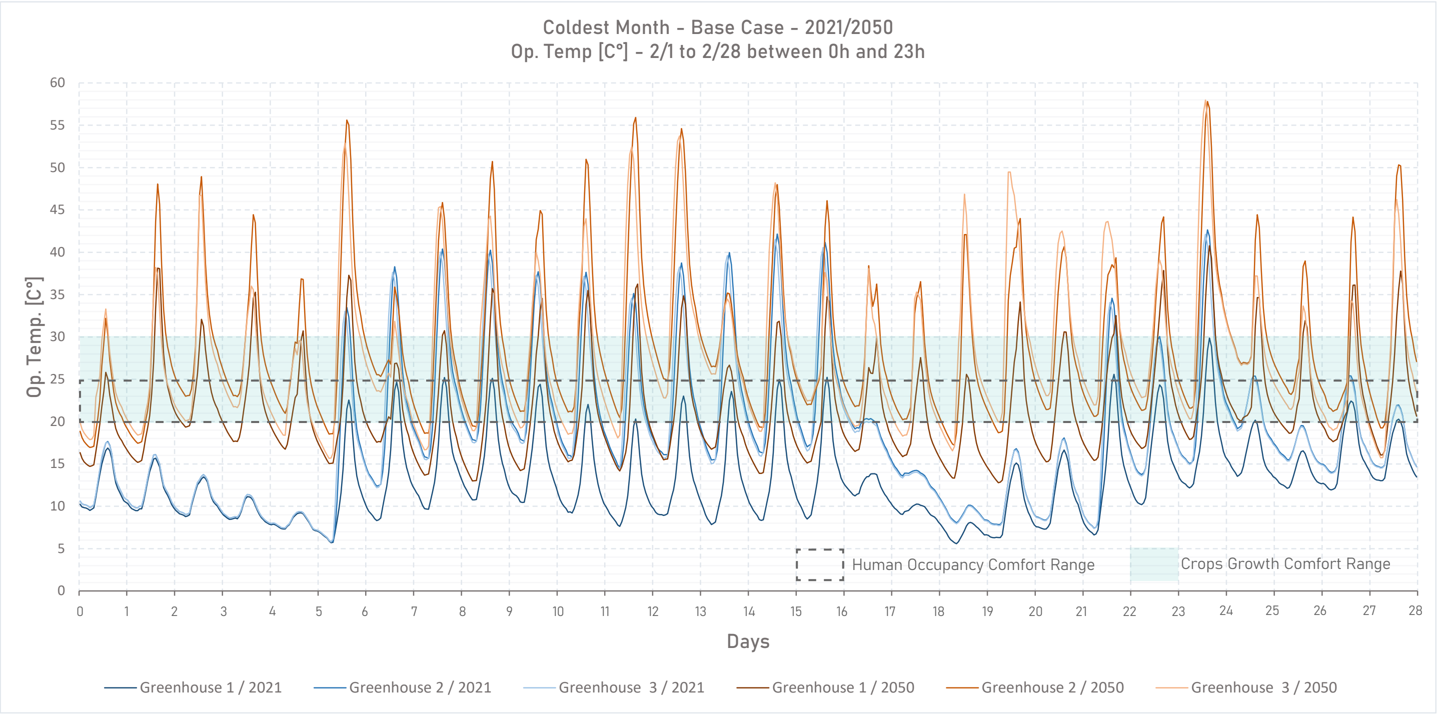
07.3.1 Base Case

Similarly to the hottest month base case, none of the bio-climatic strategies were used as a base point to present a highly fluctuating scenario to visualize later the impact of the solar shading strategies.

In the Operative Temperature graph it could be observed that both years data, 2021 and 2050, present a dramatic fluctuating behavior. For the coldest month of the year, very high temperatures are shown during the day hours while in the night hours the temperature falls.

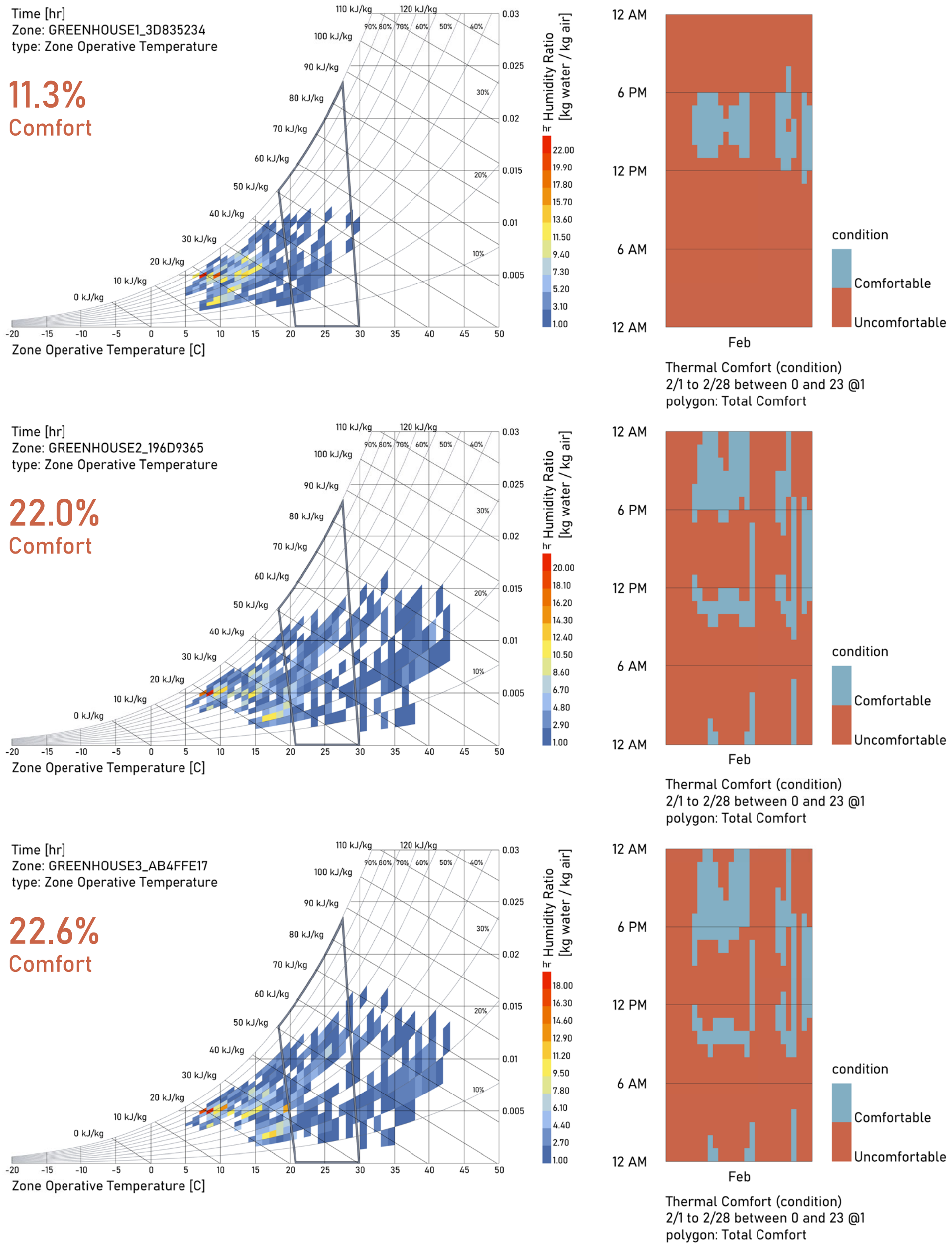
Alternatively, it could be observed with the psychrometric charts, that the 2021 Greenhouse spaces data present a low comfort between 11% and 23% of the time, while the 2050 Greenhouse spaces data present a higher comfort between 40% and 55% of the time due to the high temperatures.

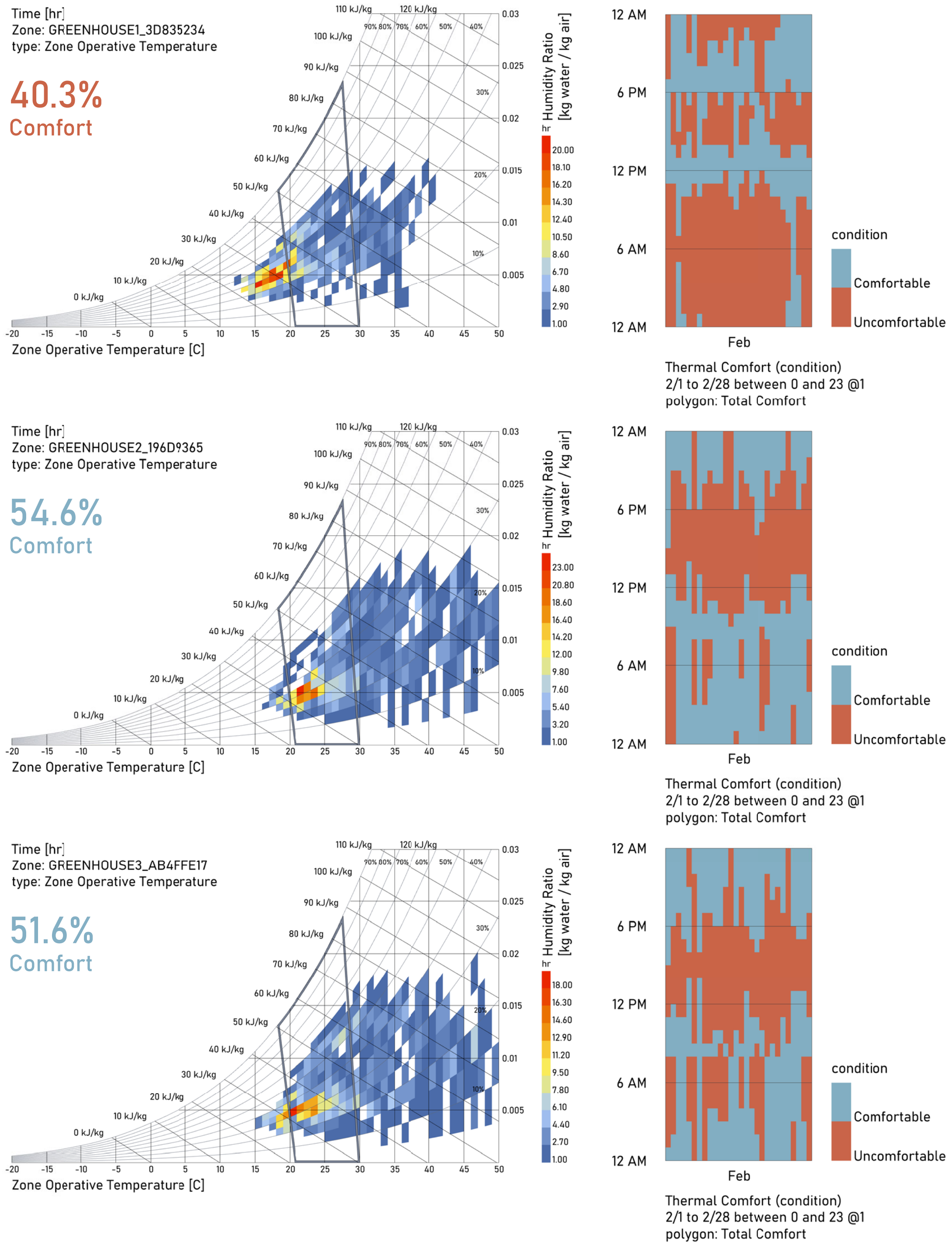
Bottom: Figure G.20
Coldest Month Base Case 2021/2050.
Source: Created by the author.



2021

Right: Figure G.21
February 2021 Base Case Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.





2050

Left: Figure G.22
February 2050 Base Case Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

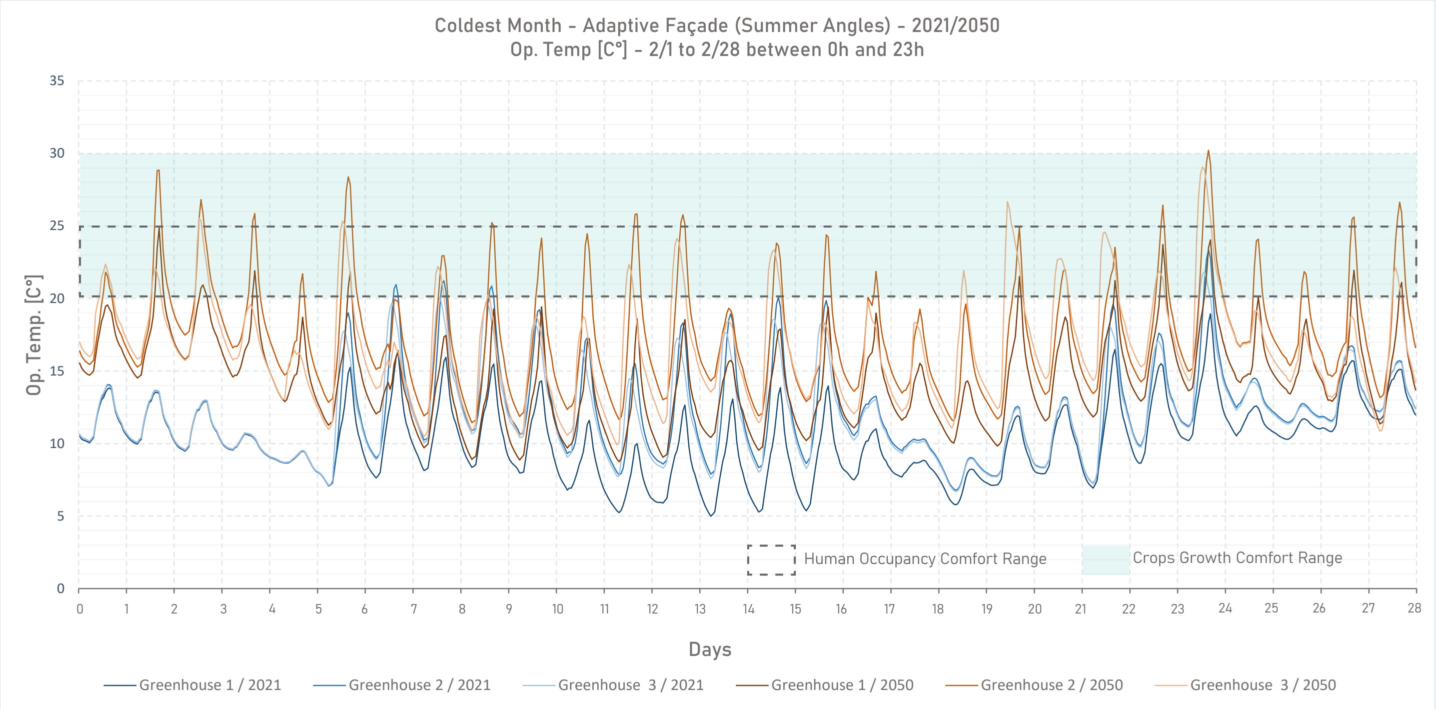
07.3.2 Adaptive Façade (Summer Angles)

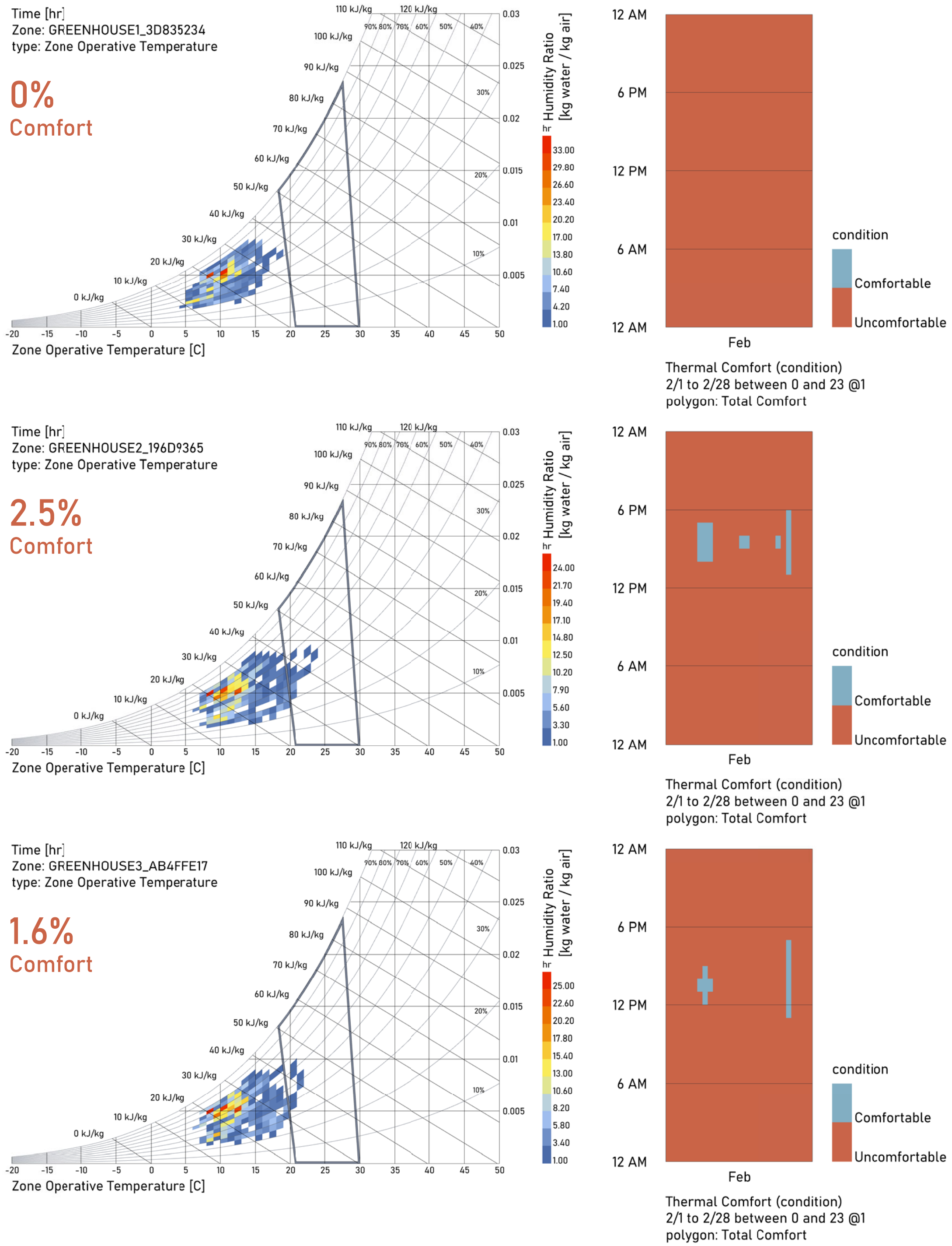
The following case presents the solar shading strategy with the summer angles as an afternoon overheating countermeasure.

In the Operative Temperature graph, it could be observed that most of the 2021 Greenhouse spaces data is below the crops growth comfort range and the human occupancy thermal comfort, while less than half of the 2050 Greenhouse spaces data is within the crops growth comfort range and the human occupancy thermal comfort in the afternoon and night hours.

Alternatively, it could be observed with the psychrometric charts, that the 2021 Greenhouse spaces data present a lower comfort than 3% of the time, while the 2050 Greenhouse spaces data present a subtle higher comfort between 6% and 25% of the time.

Bottom: Figure G.23
Hottest Month Adaptive Façade (Summer Angles) 2021/2050.
Source: Created by the author.



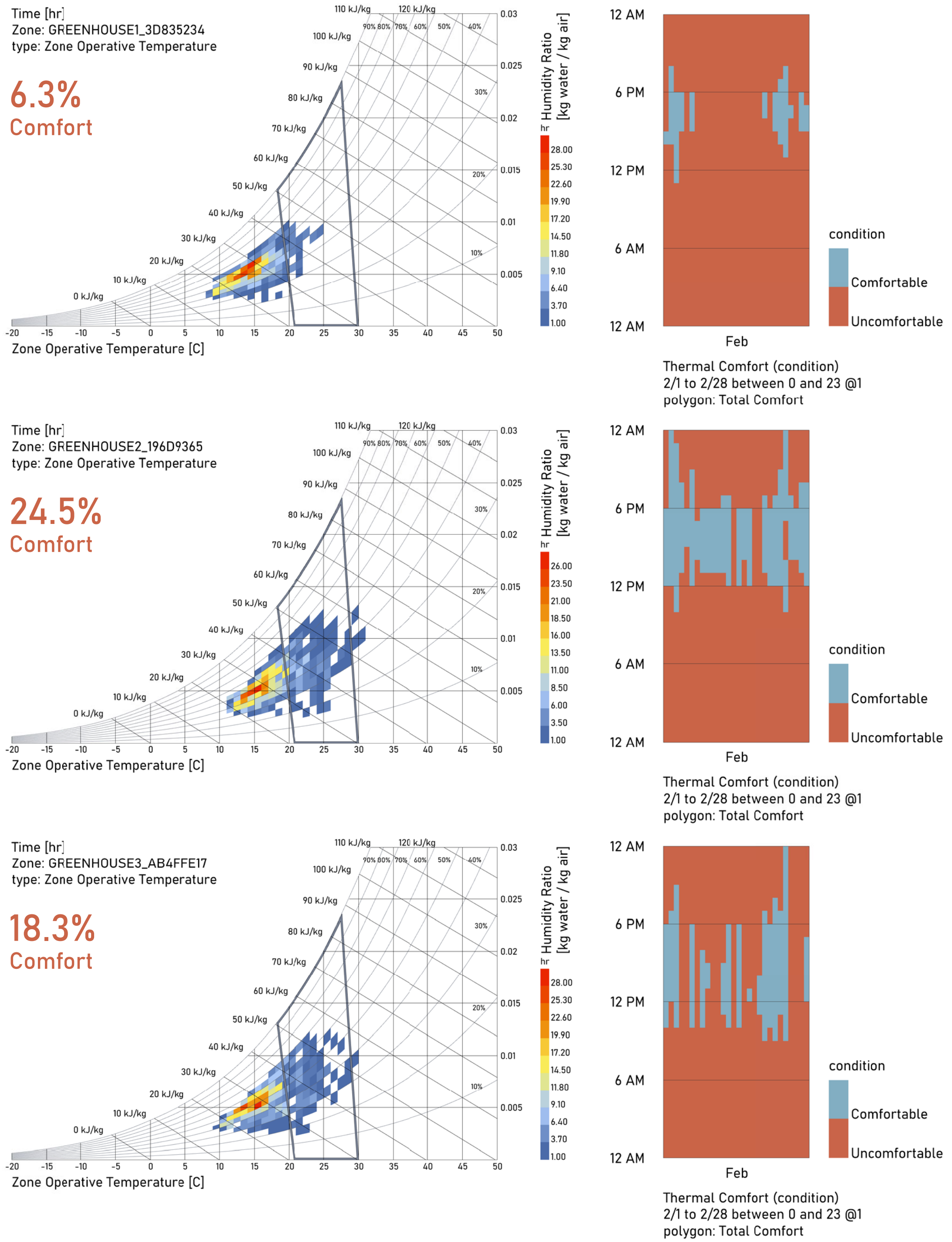


2021

Left: Figure G.24
February 2021 Adaptive Façade (Summer Angles) Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

2050

Right: Figure G.25
February 2050 Adaptive Façade (Summer Angles) Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.



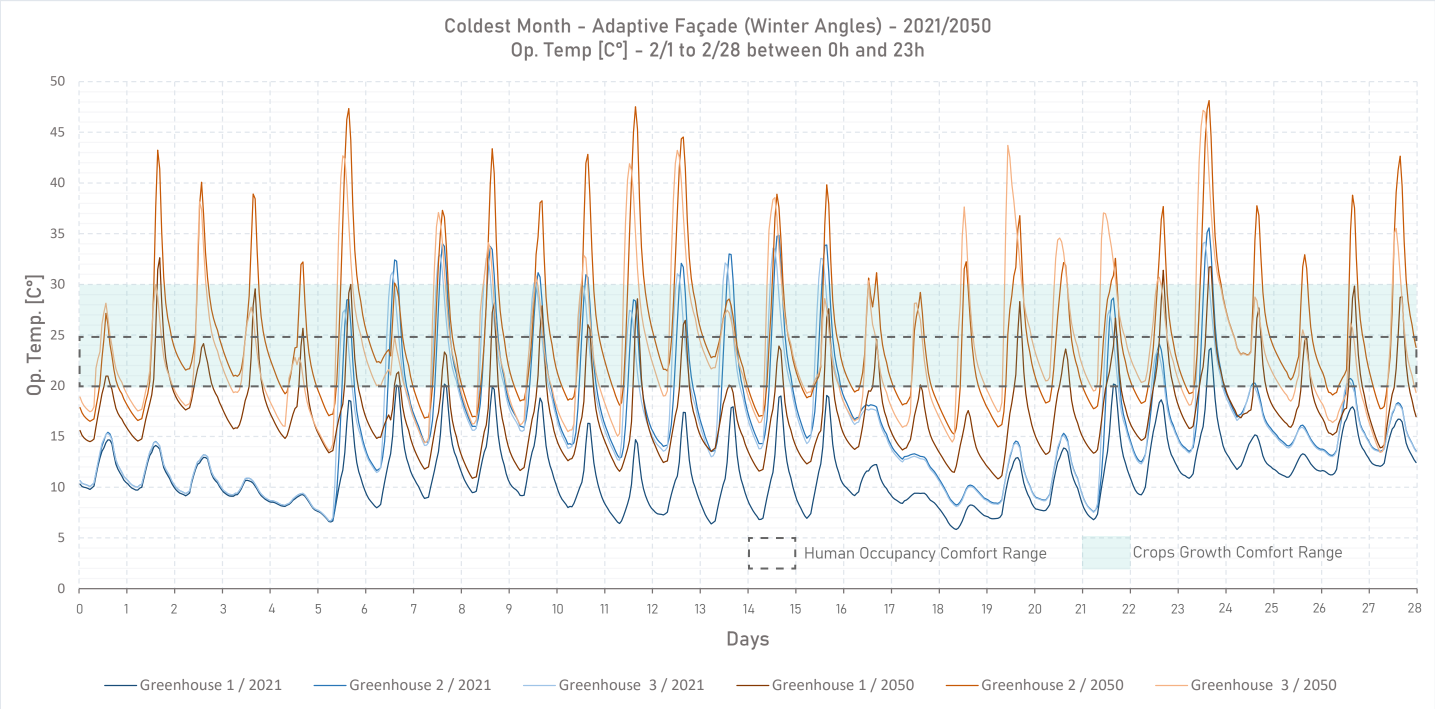
07.3.2 Adaptive Façade (Winter Angles)

The following case presents the solar shading strategy with the winter angles as a morning heating measure.

In the Operative Temperature graph, it could be observed that a lower portion of the 2021 Greenhouse spaces data is within the crops growth comfort range and the human occupancy thermal comfort, while a considerable higher portion of the 2050 Greenhouse spaces data is within both comfort ranges. However, there is afternoon overheating.

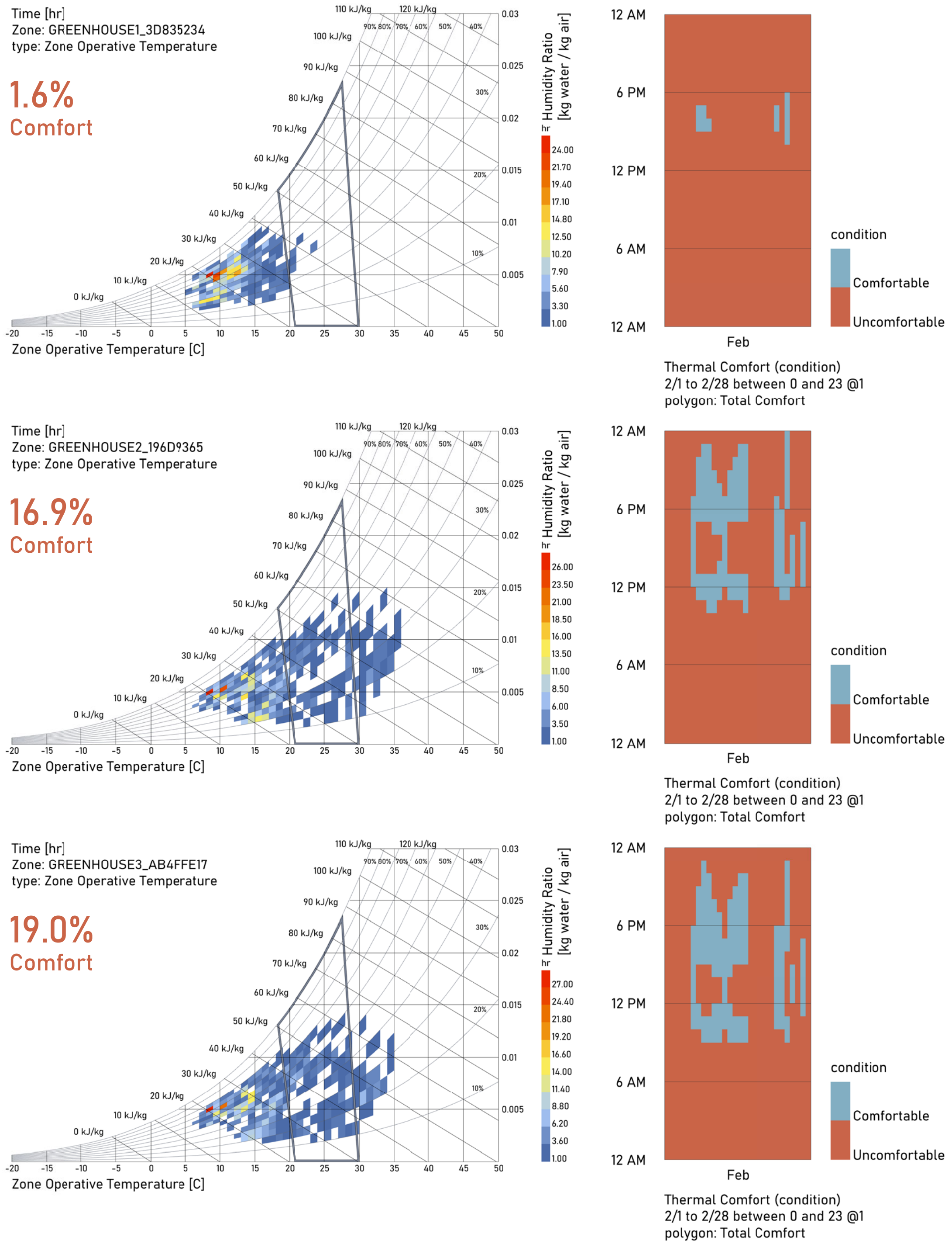
Alternatively, it could be observed with the psychrometric charts, that the 2021 Greenhouse spaces data present a lower comfort than 20% of the time, while the 2050 Greenhouse spaces data present mostly a comfort average of 53% with the exception of GH-1 with 24% of the time.

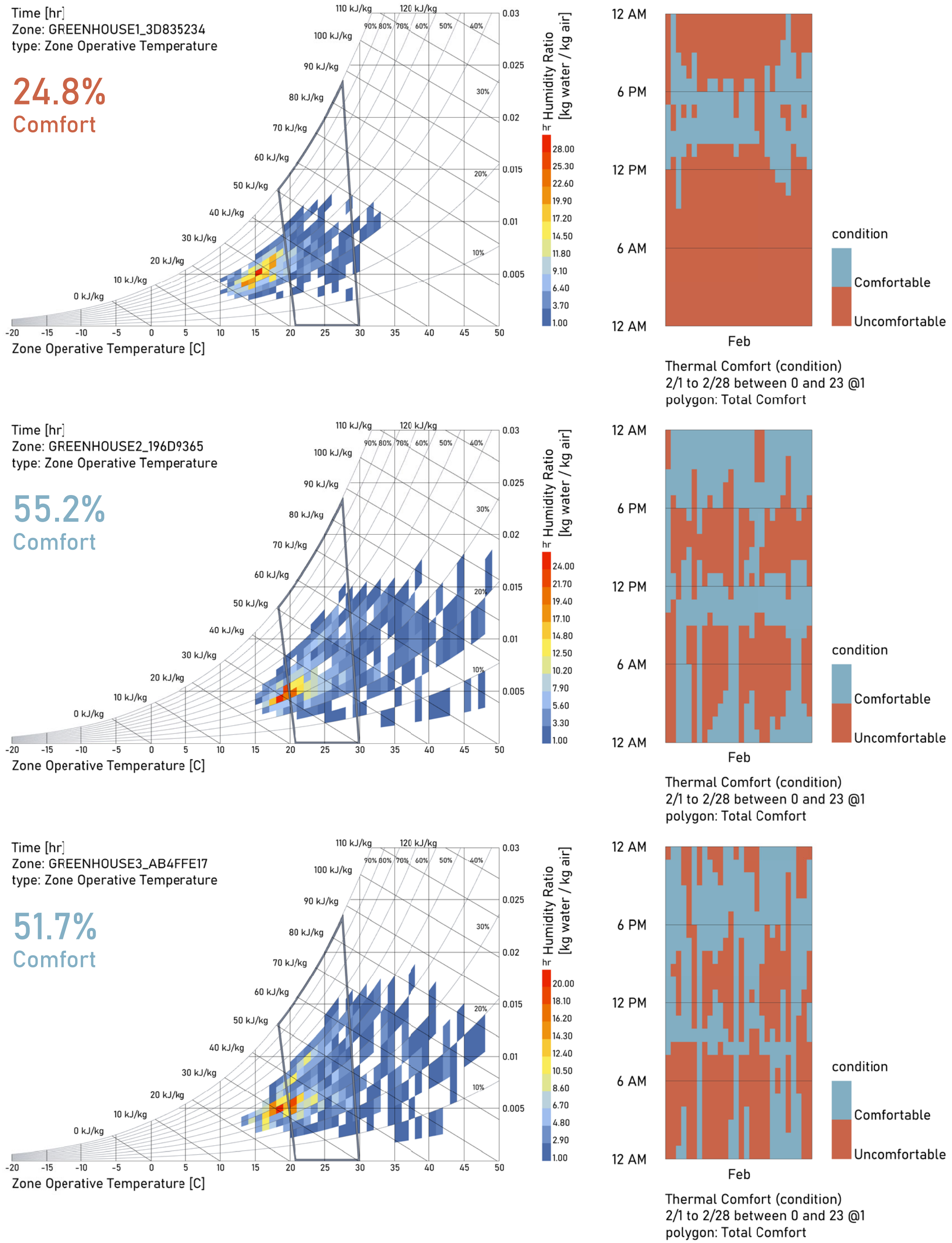
Bottom: Figure G.26
Hottest Month Adaptive Façade (Winter Angles) 2021/2050.
Source: Created by the author.



2021

Right: Figure G.27
February 2021 Adaptive Façade (Winter Angles) Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.





2050

Left: Figure G.28
February 2050 Adaptive Façade (Winter Angles) Performance & Comfort Levels.
Source: Created by the author with Ladybug Tools.

07.4 GREENHOUSE SIMULATION PERFORMANCE

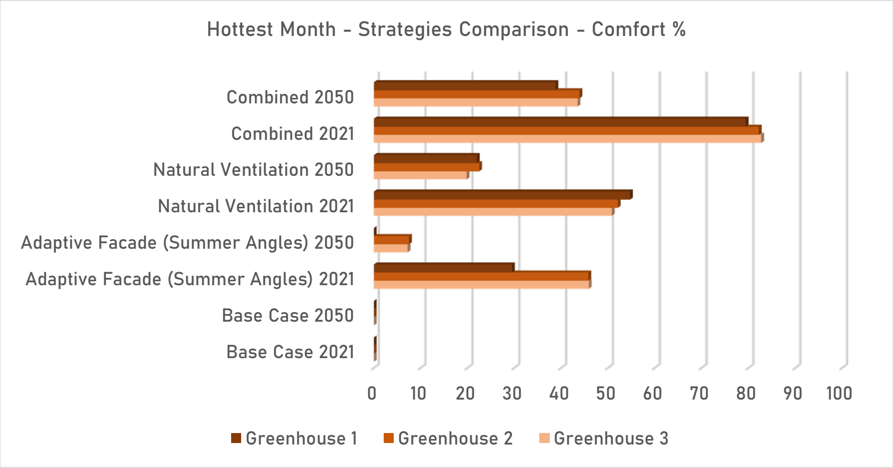
Strategies Comparison (2021/2050)

07.4.1 Strategies Comparison (2021/2050)

Hottest Month:

The hottest month simulations presented a gradual improvement scenarios depending on the different strategies used. The overheating presented during the day periods was countered more effectively by the natural ventilation strategy in comparison to the solar shading provided by the adaptive façade.

The natural ventilation during the day periods in 2021 reduced significantly the temperatures reaching a 50% hours of comfort in the three Greenhouse rooms, while the adaptive façade reached a range between 29% and 45% hours of comfort. On the other hand, the same behavior was repeated in the 2050 simulations, but with less effectivity, as natural ventilation reached around 20% hours of comfort, while the adaptive façade reached a range between 0% and 7% hours of comfort. Higher comfort levels could be reached with complete afternoon/night ventilation. Due to the SW orientation of Greenhouse 1, the strategies were less effective in both 2021 and 2050 simulations.



In 2021 simulations, the combined strategies presented the highest performance reaching an average of 80% hours of comfort.

In 2050 simulations, the natural ventilation strategy presented the highest performance reaching an average of 50% hours of

Left: Figure G.29
Hottest Month Strategies Comparison regarding Comfort %.
Source: Created by the author.

In 2021 simulations, the base case presented the highest performance reaching a range between 10% to 20% hours of comfort.

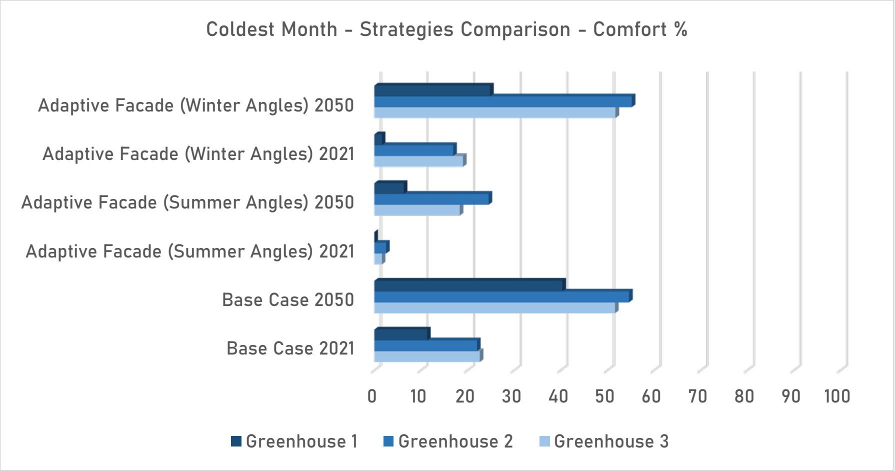
In 2050 simulations, the base case presented the highest performance reaching a range between 39% to 52% hours of comfort.

Right: Figure G.30
Coldest Month Strategies Comparison regarding Comfort %.
Source: Created by the author.

Coldest Month:

The coldest month simulations presented complex scenarios for many reasons. The nature of a greenhouse primarily involves heat gains during the day but causes overheated afternoons, even in winter.

The heat losses produced during the night periods reduced the comfortable hours of the Greenhouse spaces in 2021 in which the best strategies reached a maximum of 20% hours of comfort. On the other hand, the high temperatures of 2050, increased the comfort hours during the night periods but at the same time extending the overheating during afternoons limiting the best strategies to a maximum of 50% hours of comfort. Ironically, using none of the bio-climatic strategies in winter brings the higher comfort range in the 2050 climate projection due to higher temperatures that could be mitigated with controlled night ventilation that partially releases the heat without dropping the Op.Temp. below the comfort ranges in the coldest hours of the winter days. Due to the SW orientation of Greenhouse 1, the strategies were less effective in both 2021 and 2050 simulations.



08
CONCLUSIONS

*“It is not the strongest of the species that survives,
nor the most intelligent;
it is the one most adaptable to change.”*

*Charles Darwin
(English Naturalist)*

The following conclusive texts are the product of the reasoning and developing process of this research work from the state of art, design development, to the climate analysis. The contents could be identified as research answers, critical comments, results synthesis, foreseeing reflections, research achievements, and personal thoughts about the previous presented work.

*Cover: FloatScapes, "Acqua Alta", and "Portici" Collage
Andres Calero, 2023*

08.1 Research Achievements & Answers

When going into a retrospective of the presented research work, the initial main question opened a pathway in which floating architecture was tested in the realm of sustainability and Coastal Risk. It is true that if we apply "Adaptation" as main principle, the coming adversities look less harmful, or even better, they look with less power to affect us in future climate scenarios.

In this realm, the case scenario of the Venice Lagoon presented the ideal context to develop this test, look for execution solutions, and demonstrate the possible answers we were inferring at the beginning of this process about floating architecture. The most interesting fact of this study case, is the complexity of building over water as it presented significant demands that in comparison to a common project on land, are not even considered. In this way, the solutions proposed in this study case, go even further than standard off-site architecture thanks to the peculiar context.

It could be said immediately that Floating Architecture is potentially one of the few and best solutions for Coastal Risk, especially when countering Sea Level Rise as its adaptive condition just counters every possible sea level increment. Nonetheless, thinking from a holistic view of the LECZ (Low Elevation Coastal Zones), the global economy, and the population data projection about Delta Cities; the possible "Floating" solution has its own limitations, specially when thinking about higher scale developments as they could bring the actual land problems to the sea, which wouldn't be prudent at all. In addition, something important to consider when thinking about floating architecture is the potentially higher construction costs due to its own specific requirements.

In these terms, the scalability of floating architecture should be regulated if we want to keep a positive status quo in the future oceans of our planet, besides the already existing ones we are facing nowadays. In any case, optimism about the potential of sea development keeps rising globally without loosing focus on sustainability.

Furthermore, in the field of construction and architectural technology the topic of building with low-impact solutions to keep low embodied carbon in the lifecycle of buildings is a fascinating field that, in the case of floating architecture need further experimentation and research in the water environment to expand construction alternatives to more sustainable ones. In this realm, with the FloatScapes project, one of the main obstacle that the maritime context presented, was the materials choice.

In the lagoon context, water, humidity, and salt corrosion compose the perfect conditions for products decay if not chosen wisely. In addition, for buoyancy effectiveness, the weight of the materials was a key factor to ensure that the project will actually float. In this matter, FloatScapes proposal aimed for a composition of materials and products that together could be hermetic and light enough to ensure buoyancy, and at the same time, to keep away water from the project's stratigraphy.

Timber in this case, was the optimal choice thanks to its weight that with a further detailed development of the skin of the building, both transparent and opaque envelopes, the hermetic conditions were possible. It is also worth to mention that FloatScapes, with the Experience Platform development, explored Timber as the material that could also represent low environmental impact with the right practice, this information was key to understand where sustainability relies in a project of this kind.

08.2 Modular Design Achievements

The FloatScapes project reached a higher development in the field of construction and architectural technology through its Experience Platform. The careful design with the aim of minimizing the environmental impact within its own Lifecycle Stages, made the best possible of the project's unique lifecycle by including Lifecycle Thinking considerations, to reach an environmentally friendly design that could be developed in the future.

Therefore, the preceding Modular Design chapter outlined the several benefits and advantages that the project includes through the integration of Prefabricated Modular Design, Timber Environmental Impact, and Design for Disassembly principles. Principles that were tailored for such a challenging scenario where construction obstacles over water could have been more difficult to overcome without innovative construction systems, off-site reasoning, and strategical thinking, included in the planning of the Experience Platform.

It could be inferred that the main achievement in this field was related to understanding the behavioral process of a prefabricated building, but in a higher demanding context which is over water. By tackling from the beginning a floating project, the architectural perspective expanded the competencies when building with prefabricated elements over land due to the specific requirements, that along the process built a "know-how" knowledge in off-site architecture.

In the same way, a remarkable achievement regards the Circular Economy approach after the End of Life Stage where not only one, but two re-use scenarios were proposed for the project, summarizing the strong commitment to sustainable design that the project has behind it.

In addition, the sourcing understanding of the engineered wood products proposed for the project, played a key role thanks to the informed decision-making process that puts in evidence the specific conditions when a timber construction is sustainable: **After ensuring carbon sequestration beyond the end of life.**

However, this whole fascinating qualitative process regarding construction and architectural technology, opened new development doors that could be done in further studies regarding the quantitative process to measure the real environment impact of this case scenario. Data collection of the different products used in the project, transportation carbon emissions within other factors could be the starting points to go deeper in the field of LCA for this project.

08.3 Climate Analysis Synthesis

The FloatScapes project also presented pertinent considerations when thinking about the Use Stage of the Experience Platform, considering the circular economy future scenario. With the development of a present and future environmental performance assessment, a deeper understanding of Climate Change in the context of Venice-VE was achieved, by building up knowledge that could be significant for a Risk Management evaluation in terms of future decision making processes that could implicate stakeholders, as supporters of climate action and environmental impact.

In the Climate Analysis chapter, the specific and complex test for the Greenhouse spaces of the Experience Platform, followed the initial project principle of "Adaptation" with the comparative evaluation regarding the thermal performance of bioclimatic strategies, like Solar Shading and Natural Ventilation, applied to both years, 2021 and 2050 weather simulations.

With this comparative study, different comfort levels could be observed as an output of thermal behavior presented during the Hottest Month of July, and the Coldest Month of February with the use of only passive strategies. Nevertheless, as a global understanding of the analysis, it could be stated immediately that the performance in the Hottest Month simulations presented higher comfort levels for human occupancy and crops growth in comparison to the Coldest Month simulations.

In the Hottest Month simulation of July 2021, results showed an average of 80% comfort hours with Solar Shading and Natural Ventilation. Alternatively, in July 2050, results showed and average of 40% comfort hours with the same strategies. On the other hand, in the Coldest Month simulation of February 2021, results showed an average of 15% comfort hours with none of the passive strategies. Alternatively, in February 2050, results showed an average of 47% comfort hours without passive strategies.

The previous results could be understood as the simulated products of the variables and specific climatic conditions that corresponds to the location and months of the year, affecting the experiment in several ways. With this base information an assessment could be developed following the following reasoning:

-Building the energy demand awareness of the upcoming cooling and heating demands for the year 2050 with the possible systems (like HVAC) and strategies to supply this demand in a feasible way.

-In terms of accountability, the needed amount of energy and its future cost to build an Energy Model Improvement that complies with the requirements. In the Experience Platform scenario for example,

in July 2050 the 60% discomfort hours with cooling, and in February 2050 the 53% discomfort hours with heating.

-The integration of renewable energy systems, like Photovoltaic or Wind Power, will be even more imperative in 2050 to comply and support the coming energy demands.

-The improvement of the architectural design in terms of Thermal Performance with the stratigraphy corresponding modifications for the future climate scenario.

As mentioned before, the pertinence of this study relies on the outcomes of the experiment that transformed as base, could set the further goals for Building Energy Modeling and Transmittance Performance Improvements of the project in order to strategically plan better design modifications that could counter the future climate challenges, energy and cost demands, and feasibility for a project that could present a longer lifespan, meaning a safe investment in all these terms.

To foresee the future climate conditions and its effects on buildings will produce better design choices and decisions.

08.4 Final Thoughts

As final considerations about the project FloatScapes, and its creative process, its important to mention that several topics were studied with more detail than others as the nature of the research work was a topical one from the beginning. The goal of producing a thesis with a project that could raise Coastal Risk awareness in its unique context, directed the efforts to several fronts, in which some of them were more urgent and others more important. In this way, several paths were present during this research process that corresponds to specific points on the research process that showcases different levels of understanding, satisfaction, reflection, and projection. At the end, this thesis looked to the future.

- Construction over water is a broad field in architecture and should be explored more often within academy. It is a valuable exercise that tests the common thinking of an architect, delivering new and effective knowledge reinventing the architect reasoning more or less like a sailor, as nautical architect.

- The future of architecture from a personal point of view, goes in the direction of prefabrication and dry assemblage. The extensive benefits it includes as construction process could be potentiated with the right practices. In the case of timber construction, all the aspects that involves carbon sequestration should be a must in order to avoid unethical practices.

- In the case of FloatScapes Climate Analysis, understanding a future climate projection and confronting it to todays climate conditions is impactful, worrying, and revealing at the same time. The assessment that this type of analysis delivers, brings the severe reflections needed for future designs in terms of human comfort and sustainability.

- In order to continue in the realm of Building Physics, a further step to develop would be BEM (Building Energy Modeling) to continue the test and error process for improvements of the building in terms of stratigraphy, energy consumption, energy systems dimensioning, to reach an accurate feasibility evaluation.

- As floating architecture is less known in the Italian context, the right logistic process for construction would need proper assessment for the real construction of a floating project. The study developed in the Modular Design chapter follows the guidelines of common prefabricated architecture and its probably missing procedures related to permits for water transportation, specially in Venice.

- The execution of the project FloatScapes, or at least the Experience Platform, would need a physical model in a detailed scale to evaluate the possibility of a prototype. A big scale test would provide the needed information about the proposed fastening and anchoring techniques in addition with the verification of the geometry complex joints. By doing this procedure, construction documents could be later developed for the manufacturing of the different elements, components, panels, and modules of the project.

- Finally, the gained experience through the research work has hes been quite satisfactory as many competencies have been developed to build a solid personal practice as architect. The discovery of a new passion in relation to the sea is also well received from the work, producing huge interest in the maritime world of sailing, and the possibility of new endeavors.

Sources and References

Aitchinson, M., 2018. **Prefab Housing and the Future of Building: Product to Process.** (1st ed.) Lund Humphries, London, UK

Ambica, A., Venkatraman, K., 2015. **Wetland Wastewater Treatment System for Small City Suburbs – A Review**. Indian Journal of Science and Technology 8. doi.org/10.17485/ijst/2015/v8i32/88880

Amin, I., Ali, M.E.A., Bayoumi, S., Oterkus, S., Shawky, H., Oterkus, E., 2020. **Conceptual Design and Numerical Analysis of a Novel Floating Desalination Plant Powered by Marine Renewable Energy for Egypt**. JMSE 8, 95. doi.org/10.3390/jmse8020095

Bagheri-Gavkosh, M., Hosseini, S.M., Ataie-Ashtiani, B., Sohani, Y., Ebrahimian, H., Morovat, F., Ashrafi, S., 2021. **Land subsidence: A global challenge**. Science of The Total Environment 778, 146193. doi.org/10.1016/j.scitotenv.2021.146193

Bixler, G.D., Bhushan, B., 2012. **Biofouling: lessons from nature**. Phil. Trans. R. Soc. A. 370, 2381–2417. doi.org/10.1098/rsta.2011.0502

Boucher, O., Forster, P.M., Gruber, N., Ha-Duong, M., Lawrence, M.G., Lenton, T.M., Maas, A., Vaughan, N.E., 2014. **Rethinking climate engineering categorization in the context of climate change mitigation and adaptation.** WIREs Climate Change 5, 23–35. doi.org/10.1002/wcc.261

BPIE (Buildings Performance Institute Europe) (2022). **Whole-life carbon and industrial renovation.** https://www.bpie.eu/publication/whole-life-carbon-and-industrial-renovation/

Brookes, A., Grech, C., 1992. **HI-TECH I dettagli dell'involucro.** (1st ed.) BE-MA editrice, Milano, Italia

Brown, S., Nicholls, R.J., 2015. **Subsidence and human influences in mega deltas: The case of the Ganges–Brahmaputra–Meghna.** Science of The Total Environment 527–528, 362–374. doi.org/10.1016/j.scitotenv.2015.04.124

Burlakova, L.E., Karatayev, A.Y., Karatayev, V.A., 2012. **Invasive mussels induce community changes by increasing habitat complexity.** Hydrobiologia 685, 121–134. doi.org/10.1007/s10750-011-0791-4

Callow, M.E., Callow, J.A., 2002. **Marine biofouling: a sticky problem. Marine biofouling.**

Cazenave, A., Palanisamy, H., Ablain, M., 2018. **Contemporary sea level changes from satellite altimetry: What have we learned? What are the new challenges?** Advances in Space Research 62, 1639–1653. doi.org/10.1016/j.asr.2018.07.017

Cerro, C., 2016. **Floating architecture in the developing world.** Presented at the SUSTAINABLE CITY 2016, Alicante, Spain, pp. 663–669. doi.org/10.2495/SC160551

Choi, Y.-K., 2014. **A Study on Power Generation Analysis of Floating PV System Considering Environmental Impact.** IJSEIA 8, 75–84. doi.org/10.14257/ijseia.2014.8.1.07

European Commission. Directorate General for Energy., 2023. **Study on regulatory barriers and recommendation for clean energy transition on EU islands**. Publications Office, LU.

Fischer, G., Hizsnyik, E., Prieler, S., Wiberg, D., n.d. **Scarcity and abundance of land resources: competing uses and the shrinking land resource base.**

Goldburg, R., Naylor, R., 2005. **Future seascapes, fishing, and fish farming.** Frontiers in Ecology and the Environment 3, 21–28. doi.org/10.1890/1540-9295(2005)003[0021:FSFAFF]2.0.CO;2

Graaf, R. de, 2012. Adaptive urban development: a symbiosis between cities on land and water in the 21st century. Rotterdam University Press, Amsterdam.

Gugliuzzo, E., 2018. The "Serenissima" at hazard: the Historical Phenomenon of Acqua Alta in Venice. Humanities Vol 6, 33-45 Paginazione. doi.org/10.6092/2240-7715/2017.2.33-45

Habibi, S., 2015. Floating Building Opportunities for Future Sustainable Development and Energy Efficiency Gains. J Archit Eng Tech 04. doi.org/10.4172/2168-9717.1000142

Herrera, J., Sierra, S., Ibeas, A., 2021. Ocean Thermal Energy Conversion and Other Uses of Deep Sea Water: A Review. JMSE 9, 356. doi.org/10.3390/jmse9040356

Kaufmann, M., Remick, C., 2009. Prefab Green. (1st ed.) Gibbs Smith, Layton, Utah, US

Kriebel, D.L., Geiman, J.D., Henderson, G.R., 2015. Future Flood Frequency under Sea-Level Rise Scenarios. Journal of Coastal Research 315, 1078–1083. doi.org/10.2112/JCOASTRES-D-13-00190.1

Laukkonen, J., Blanco, P.K., Lenhart, J., Keiner, M., Cavric, B., Kinuthia-Njenga, C., 2009. Combining climate change adaptation and mitigation measures at the local level. Habitat International 33, 287–292. doi.org/10.1016/j.habitatint.2008.10.003

Lawson, M., Ogden, R., Goodier, C., 2014. Design in Modular Construction. (1st ed.) CRC Press, Boca Raton, Florida, US

LETI, 2023. Low Embodied Carbon Specification and Procurement Guide. (1st ed.) LETI Publication, London, UK

Levermann, A., Clark, P.U., Marzeion, B., Milne, G.A., Pollard, D., Radic, V., Robinson, A., 2013. The multimillennial sea-level commitment of global warming. Proc. Natl. Acad. Sci. U.S.A. 110, 13745–13750. doi.org/10.1073/pnas.1219414110

Lin, Y.-H., Chih Lin, Y., Tan, H.-S., 2019. Design and functions of floating architecture – a review. Marine Georesources & Geotechnology 37, 880–889. doi.org/10.1080/1064119X.2018.1503761

Lionello, P., Barriopedro, D., Ferrarin, C., Nicholls, R.J., Orlić, M., Raicich, F., Reale, M., Umgiesser, G., Vousdoukas, M., Zanchettin, D., 2021a. Extreme floods of Venice: characteristics, dynamics, past and future evolution (review article). Nat. Hazards Earth Syst. Sci. 21, 2705–2731. doi.org/10.5194/nhess-21-2705-2021

Lionello, P., Nicholls, R.J., Umgiesser, G., Zanchettin, D., 2021b. Venice flooding and sea level: past evolution, present issues, and future projections (introduction to the special issue). Nat. Hazards Earth Syst. Sci. 21, 2633–2641. doi.org/10.5194/nhess-21-2633-2021

Michel, J.H., Powell, C.A., Hempstead, H., Michels, H.T., n.d. 11352: An Assessment of the Biofouling Resistance and Copper Release Rate of 90-10 Copper-Nickel Alloy.

Moon, C., 2014. Renewable Energy Application in Floating Architecture.

Moon, C., 2014b. Three dimensions of sustainability and floating architecture. International Journal of Sustainable Building Technology and Urban Development 5, 123–127. doi.org/10.1080/2093761X.2014.908809

Neumann, B., Vafeidis, A.T., Zimmermann, J., Nicholls, R.J., 2015. Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment. PLoS ONE 10, e0118571. doi.org/10.1371/journal.pone.0118571

Noeiaghaei, T., Mukherjee, A., Dhami, N., Chae, S.-R., 2017. Biogenic deterioration of concrete and its mitigation technologies. Construction and Building Materials 149, 575–586. doi.org/10.1016/j.conbuildmat.2017.05.144

Penning-Rowsell, E., 2020. Floating architecture in the landscape: climate change adaptation ideas, opportunities and challenges. Landscape Research 45, 395–411. doi.org/10.1080/01426397.2019.1694881

Perveen, R., Kishor, N., Mohanty, S.R., 2014. Off-shore wind farm development: Present status and challenges. Renewable and Sustainable Energy Reviews 29, 780–792. doi.org/10.1016/j.rser.2013.08.108

Piccardo, C., 2015. Sostenibilità degli edifici in legno. (1st ed.) Francoangeli, Milano, Italy

Porporato, G., 2023. Assessment of the environmental impacts of floating architecture on local ecosystems. Research Essay, Politecnico di Torino.

Ross, P., Downes, G., Lawrence, A., 2009. v (1st ed.) TRADA, Buckinghamshire, UK

Schrenk, M., Verein CORP - Competence Center of Urban and Regional Planning (Eds.), 2016. REAL CORP 2016: Smart me up! How to become and how to stay a smart city, and does this improve quality for life?: Proceedings of 21st International Conference on Urban Planning, Regional Development and Information Society. Presented at the REAL CORP, Selbstverlag des Vereins CORP, Wien, Österreich.

Smith, R., 2010. Prefab architecture: a guide to modular design and construction. (1st ed.) John Wiley & Sons, Inc., Hoboken, New Jersey, US

Stopp, H., Strangfeld, P., 2010. Floating houses–chances and problems. Presented at the ECO-ARCHITECTURE 2010, La Coruna, Spain, pp. 221–233. doi.org/10.2495/ARC100191

Szabo, S., Brondizio, E., Renaud, F.G., Hetrick, S., Nicholls, R.J., Matthews, Z., Tessler, Z., Tejedor, A., Sebesvari, Z., Foufoula-Georgiou, E., Da Costa, S., Dearing, J.A., 2016. Population dynamics, delta vulnerability and environmental change: comparison of the Mekong, Ganges–Brahmaputra and Amazon delta regions. Sustain Sci 11, 539–554. doi.org/10.1007/s11625-016-0372-6

Tosi, L., Lio, C., Teatini, P., Strozzi, T., 2018. Land Subsidence in Coastal Environments: Knowledge Advance in the Venice Coastland by TerraSAR-X PSI. Remote Sensing 10, 1191. doi.org/10.3390/rs10081191

Visitsak, S., Haberl, J.S., 2004. An analysis of design strategies for climate-controlled residences in selected climates.

Vo, T.T.E., Ko, H., Huh, J., Park, N., 2021. Overview of Possibilities of Solar Floating Photovoltaic Systems in the OffShore Industry. Energies 14, 6988. doi.org/10.3390/en14216988

Zanchettin, D., Bruni, S., Raicich, F., Lionello, P., Adloff, F., Androsov, A., Antonioli, F., Artale, V., Carminati, E., Ferrarin, C., Fofonova, V., Nicholls, R.J., Rubinetti, S., Rubino, A., Sannino, G., Spada, G., Thiéblemont, R., Tsimplis, M., Umgiesser, G., Vignudelli, S., Wöppelmann, G., Zerbini, S., 2021. Sea-level rise in Venice: historic and future trends (review article). Nat. Hazards Earth Syst. Sci. 21, 2643–2678. doi.org/10.5194/nhess-21-2643-2021

Politecnico
di Torino

Torino, September 2023