Climate Mutants

The rise of the extremophiles

Casper Klarén & Johannes Welander

Examiner: Kengo Skorick
Supervisor: Jonas Lundberg

Chalmers School of Architecture
Department of Architecture and Civil Engineering

Spring 2023

Climate Mutants

The rise of the extremophiles

Casper Klarén & Johannes Welander

Examiner: Kengo Skorick
Supervisor: Jonas Lundberg

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Master’s Programme of Architecture and Urban Design (MPARC)
Spring 2023

ABSTRACT

An architectural climate mutant is a structure designed with innovative materials, technologies, or design strategies to function effectively in response to changing climate conditions. It deviates from traditional architectural practices and embodies a response to the challenges posed by climate change.

The geological epoch entailing the era where mankind has evoked an escalated impact on our planet's geology and ecosystems, is designated the Anthropocene. The epoch indicates that humans have become the planets dominating species in shaping its future. With the repercussions of this developing into more frequent global examples of climate change in an alarming pace, there's a growing need for an architectural adaptation to the transitioning environments.

Extreme environments can be defined as geographical locations that are beyond the optimal range for development of living organisms. However, this does not mean that life cannot be found in extreme environments. By definition, the organisms that are able to adapt and thrive in extreme environments are known as extremophiles.

This thesis aims to form an investigative perspective regarding human habitats in extreme environments. Rather than analyzing ways of mitigating and decreasing the risk of climate change, this thesis aims to contextualize what role architecture has in adapting to a more extreme world. Through exploration of both historical and contemporary strategies for vernacular design dealing with extreme environments, the goal is to form a toolkit for design in radically altered climates. By contextualizing the findings of the current knowledge, the thesis aspire to generate a variety of examples as different possibilities of adapting to the effects of the Anthropocene.

By utilizing an array of scenarios for extreme environment habitats, the project aims to deliver proposals for how the architecture can form a crucial part in relieving the risks posed to humans in a growing number of extreme environments across the world.

STUDENT BACKGROUNDS

Casper Klarén

MSc, Architecture and Urban Design 2020 — 2023
Chalmers University of Technology

Junior Architect 2022 -
Bjarke Ingels Group, Copenhagen

Architect Intern 2021 — 2022
Bjarke Ingels Group, Copenhagen

BA, Architecture and Fine Arts 2017 — 2020
Umeå School of Architecture

Johannes Welander

MSc, Architecture and Urban Design 2020 — 2023
Chalmers University of Technology

Junior Architect 2022 -
Kaminsky Arkitektur

Architect Intern 2021 — 2022
Kaminsky Arkitektur

BA, Architecture and Fine Arts 2019— 2020
Umeå School of Architecture

Tongji / UNSW Dual Bachelor Degree in Architecture 2016-2017
University of New South Wales

Tongji / UNSW Dual Bachelor Degree in Architecture 2014-2015
Tongji University

CONTENTS

RESEARCH QUESTIONS

How can architecture and building technologies aid human settlements in adapting to radically altered climates?

To what degree could Sweden still be habitable despite turning into an extreme climate?

PURPOSE & AIM

The intention of this master's thesis is to investigate how climate change and an increase of extreme weather conditions will affect the way we live and thereby how it affects the architectural qualities of the structures we inhabit.

The thesis aims to explore vernacular architecture in what is defined as extreme climates, and through a speculative and iterative process investigate which building technologies can be extracted and superimposed on specific sites.

The approach to this master thesis is design by research and aims not to produce objectively good or beautiful architecture. Rather, the goal of the thesis is to contribute to the knowledge of extreme environments and to spark an interest for further speculation about future architecture in a world much different from today.

Focusing on speculation regarding future architecture, the thesis highlights existing qualities of different types of architecture from around the world and the importance of celebrating culture and heritage through the architectural process.

In addition to the above, it aims to investigate the role and responsibilities of the architect and aims to act as a complementary research and speculation about human habitats in unknown terretories.

The purpose of this thesis is therefore not to resolve existing or future climate change, but rather to initiate speculations on various ways to adapt to the consequences of the growing development.

METHODOLOGY

Phase 1.
The initial phase consists of research about climate change, extreme weather and human adaption. Furthermore, it includes various architectural implications that comes with the premises of being located in what is defined as an extreme environment. Additionally, it uses case studies to construct a toolkit of extracted objects, functions and materials to be used as a library for the following parts of the thesis.

Phase 2.
This phase uses prototyping as a way to look into extreme environments in order to speculate and gain knowledge of both low tech, vernacular solutions, high tech, modern applications and emerging or future technologies.

Phase 3.
A series of scenarios are defined and habitats are designed for them. Combination of findings from the toolkit, prototypes and vernacular architecture extracted from the site. Physical and computer based climate simulations.

DELIMITATIONS

ABOUT

Architecture and human habitats in extreme environments.

NOT ABOUT

No consideration has been given to any current Swedish building regulations and the focal point should be on the functionality and tectonics of the materials and geometries in a world that is different from what we see today.

The thesis does not strive to answer questions relating to architectural aesthetics The site in the architectural realization was chosen with a main purpose of acting as test beds helping to answer questions prompted during the research phases.

GLOSSARY

Extreme Environment	Habitat that is considered difficult to survive in due to its considerably extreme conditions
Extreme Climate	Long term pattern of weather in a specific area that offers disadvantageous living conditions.
Extreme Weather	Short term weather changes that induces severe, unexpected or unusual weather such as droughts, cyclones, hurricanes etc.
Habitat	The physical manifestation of a species ecological niche.
Shelter	An architectural structure or natural formation that provides protection against the environment.
Mutant	A mutant is a creature that is physically different from others of the same species because of a change in its genes.
Extremophile	Organism that is able to live or thrive in extreme environments.
RCPs	Representative Concentration Pathways, greenhouse gas concentration trajectories
SSPs	Socioeconomic Pathways, greenhouse gas emission trajectories
Responsive	Reacting quickly and positively
Adaptive	The ability to change to suit changing conditions
Kinetic	Motion of material bodies and its forces
Portable	Ability to with ease be moved
Nomadic	Moving from one place to another rather than settling down in one geographical location
Expandable	Ability to grow larger with the same matter
Inflatable	The ability to grow by being inflated using aerosols
Resilience	Capacity to withstand or recover from difficulties

INTRODUCTION

INTRODUCTION

A major challenge for architects, in a more unpredictable future, is how to respond to the impacts of climate change and the growth of extreme weather conditions. The rise of effects rooted in climate change are quickly appearing and the uncertainty of the impact only makes it more difficult to adapt to. It is going to have a significant impact on the usability and functionality of the built environment, which is why it is crucial that it is considered throughout the entirety of the design process.

According to the Swedish Meteorological and Hydrological Institute (Sveriges Meteorologiska & Hydrologiska Institute – "SMHI") the development of extreme weather scenarios has been proved to be linked to climate change. Studies have shown that extreme weather scenarios such as heat waves, heavy precipitation and drought have increased as a result of the current climate development. In addition to the Earth becoming warmer, these types of weather conditions are considered to become more common and more severe in the future. (SMHI, 2023) Based of this development, this thesis aims to investigate how climate change and the increase of extreme weather conditions will affect how we live and how it affects the architectural qualities of the structures we inhabit.

Historically, these extreme conditions have been found to have a significant impact on the development of human settlements and consequently forcing architecture to adopt a new paradigm. A paradigm, where flexibility and resilience is a focal point. The built environment is by default under pressure by harsh weather conditions, and with conditions getting worse it requires resilient designs that can withstand strong winds, copious rainfall, and flooding scenarios among some of the extreme.
Taking the severity of these scenarios into account, the approach of this thesis is design by research. The thesis' goal is to contribute to the knowledge of extreme environments and to spark an interest for speculation about future architecture rather than producing objectively good or beautiful architecture.

Humankind has had to face great challenges by establishing itself in extreme regions from scorching deserts to freezing tundras. These settlements, often located in isolated geographical pockets, have passed down their survival strategies over generations.

All around the globe, settlements have proved to adapt to various hostile environments and surroundings. Over time, settlements have developed ingenious solutions of how to combat their opposed climate. Pressured by harsh outer conditions, with the use of curated materials and building methods, the architecture still has managed to ensure the security and durability of the structures and its inhabitants. This thesis wishes to highlight qualities from previous settlements and different types of architecture from around the world.

As science and engineering rapidly progresses, new possibilities for building sustainable habitats are provided by cutting-edge technologies. Our ability to understand, predict, and adapt to extreme weather conditions is made possible by technological developments, ranging from advanced climate modeling to off-grid renewable energy solutions. By utilizing these solutions, architects can build communities that creates a symbiosis between ecological integrity and human needs.

Produced by Authors using Midjourney, 2023

BACKGROUND

As the intention of this master's thesis is to investigate how an increase of extreme weather conditions will affect the way we live and the structures we inhabit, an early understanding of environmental patterns and the ongoing change in said patterns is essential to understand the research conducted throughout this master thesis.

According to the United Nations (2022), the global mean temperature in 2021 was about 1.1°C above the pre-industrial level and the years from 2015 to 2021 were the seven warmest on record. Further, they estimate that up to 3.6 billion people live in areas that are highly vulnerable to climate change.

In IPCCs (Intergovernmental Panel on Climate Change) latest climate report "AR5", from 2014, they use four different scenarios to calculate future climate changes. The scenarios defines are called the RCPs (Representative Concentration Pathway) and is used as ways to inform about the consequences of climate change related to different levels of greenhouse gas concentration. (IPCC, 2023)

Other than defining what is needed in order to meet the climate goals internationally collectively set, the RCPs are used as a base framework for the research on what might happen in scenarios where we don't meet the said goals.

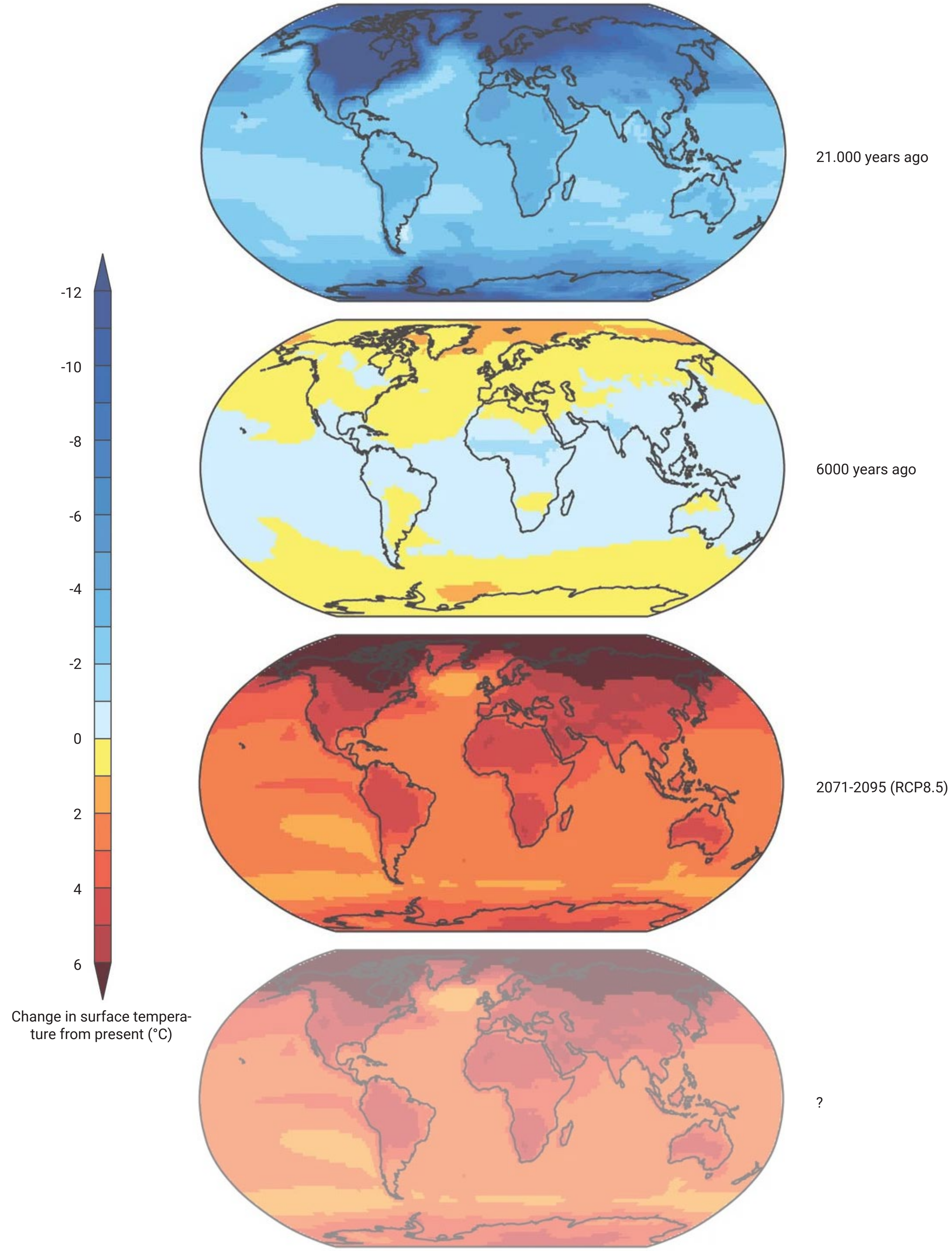
In the AR5 report, IPCC also presented research that shows a direct correlation between the increase of many extreme weather conditions and the rise of average global temperatures, which in turn directly correlates with human activity and the burning of fossil fuels. (Seneviratne et al., 2021)

IPCC here state how scientists now are able to depict the human impact on both the magnitude but also the probability of many extreme weather events.

The scenarios presented in the report however stretches only as far as 2100 and as architects we need to design both contemporary but also sustainable. Meaning we have a responsibility to include the entire buildings life cycle in the design process. This creates a alarming duality between the fact that we have climate scenarios that only stretches 80 years into the future and the role of the architect to design a building that hopefully will be standing far past that.

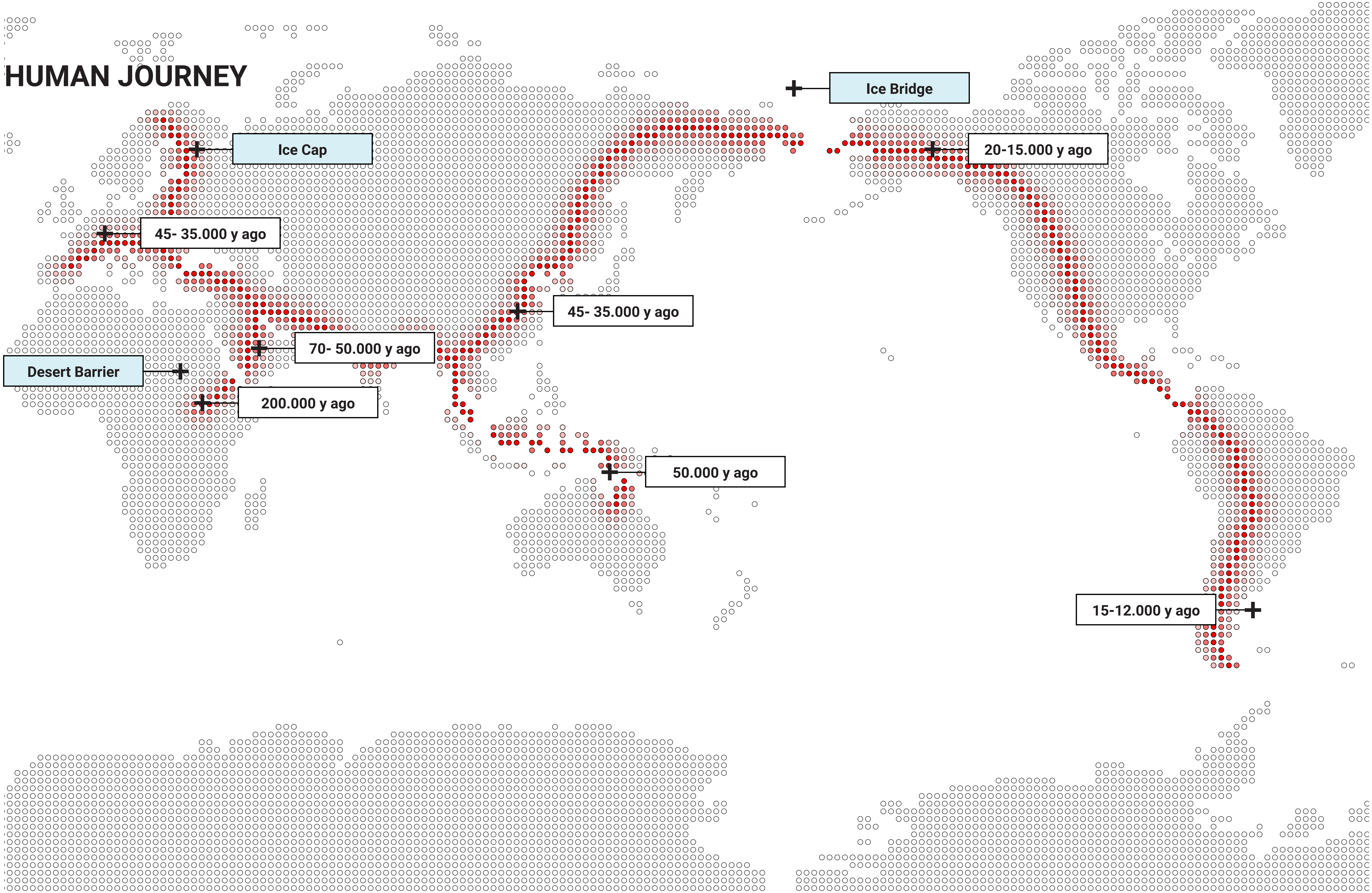
Therefore, the research conducted throughout this thesis focuses on events that occur past the climate scenarios presented by IPCC. Looking at the history as a step into the future and designing for a world unknown.

This thesis does not seek to question the responsibility the architect have in regards to climate change and whatever impact the human race has had on it. Rather it speculates on what we as architects can contribute with, answering to the challenges that lays ahead. Because the truth is, while we have research and statistics, we also have no idea.



World Bank Group, Model-simulated global temperature anomalies for the Last Glacial Maximum (21,000 years ago), the mid-Holocene (6,000 years ago), and projection for 2071–2095, under RCP8.5, 2016

HUMAN JOURNEY



HUMAN ADAPTION

The development of the climate has always been a catalyst for human migration as communities has had to face the consequences of various environmental events. Extreme weather events such as rising sea levels, droughts and landslides are forcing an increased amount of human settlements into displacement.

Environmental, social and economic challenges are intensified by the pressure of climate change, forcing people to look for more sustainable living conditions. Coastal communities, small island nations and regions heavily dependent on agriculture have lately experienced the impacts of the climate development, leading them to migration. In search of safe haven and resources, these climate refugees are forced to relocate to areas better protected from climate-related risks.
(UNHCR, 2022)

Throughout the history though, humankind has gone through and adapted to a number of environmental changes, including geographical transformations and impacts of climate change. This has forced societies to adapt the built environment, demonstrating resiliency and ingenuity.

Architecture has been essential in order for humans to adapt to these changes and the built environment has been designed to adapt to its surrounding and to weaken the impact of the environment.

Recent years has seen an emergence of various ingenious architectural solutions to deal with the impacts of climate change.

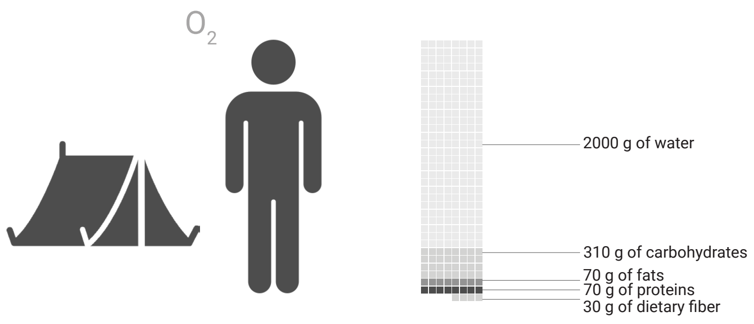
Flood resistant infrastructure such as raised structures, flood resistant materials and man made embankments are put in place to protect coastal settlements. Green roofs and vertical gardens are used to reduce impacts of urban heat islands, increase biodiversity and offset vegetation loss.

The building industry and architecture play a huge role in creating solutions to combat climate change. With that said, in 2021 the construction sector alone accounted for around 37% of the energy and process related emissions. (United Nations Environment Programme, 2022) This, in itself, is making the quest to reach the global goals even more crucial as the effects of climate change become more tangible.

The Sustainable Development Goals (SDGs) was framed as a blueprint for the future of humankind. (United Nations, 2015) When previously the effort to adapt to a developing planet has been on an individual level, this is the first time we as all humans have a common plan for the future development of our planet.

Even though they are designed to work integrated and indivisible, throughout this thesis there has been focus on some of the goals more than others and has acted as a basis for the design project.

United Nations Sustainable Development Goals, 2015



Basic Human Needs

HUMAN BASIC NEEDS

There are arguably many more traits that are a necessity for humans to thrive, but NASA's definition of the basic needs for human beings to survive are; access to food, water, air and proper shelter from the surrounding environments. When one of these basic needs is not met, humans cannot survive. (NASA, 2023)

For humans to thrive or merely survive, clean water is critical. In many extreme environments, there is often a limitation of usable land and a scarcity of fresh water. Historically, settlers have used innovative approaches to optimize the use of water, and to ensure sustenance. To secure food and water in an extreme environment is a complex challenge that requires innovative approaches and resourceful strategical thinking.

Examples of these are hydroponics or terracing, both which are strategies that optimize the land, as well as, water usage. (Robbins, 2021) Other sustainable farming methods that can aid self-sustainability in challenging environments are aquaponics or vertical farming.
To guarantee that these fundamental requirements are satisfied, the structures in our design project are designed to include suitable water treatment and air ventilation systems.

Ultimately, a human's ability to live is generated by a diet of approximately 3000 kcal with a necessary intake of carbohydrates, fats, proteins and dietary fiber. (National Academies Press, 1989) Delimitations and investigations in this thesis are based on the before mentioned statistics.

The structures designed include a food production facility, such as aquaponics or hydroponic farming. By doing this, it is possible to guarantee that the dwellers have access to wholesome food even in harsh regions, where conventional agriculture is not practical.

Essential for human well-being is shelter. Moreover, in harsh conditions, a construction resilient to its surroundings is essential. In the most harsh environments on earth, we often find traditional building techniques, utilizing locally available materials to optimize protection against the elements. (Choi, 2017) From igloos in polar regions to thick walled mud houses towards the equator, the structures demonstrate human ingenuity and craftsmanship as a way to shelter from the climate.

The idea of safety includes both physical and mental health. Natural disasters that pose threats to humans, such as flooding, sandstorms or avalanches, often occur in what is categorized as extreme environments. To protect against such events, many communities have evacuation plans or early warning systems to reduce the danger. Characteristic for many settlements in extreme environments are their strong social relationships, as they rely on each other to cope with the effects of living in harsh conditions. (Rothschild & Mancinelli, 2001)

A combination of resiliency and ingenuity is required in extreme conditions to fulfill basic human needs, as well as knowledge of the surroundings. By meeting the fundamental human needs of food, water, air and shelter, communities can not only adapt and survive, but ultimately thrive, develop and overcome the environmental challenges posed.

EXTREMES

The word "extreme" usually refers to something that goes beyond what is typical or average. "Extreme" suggests a level of intensity or magnitude that is much higher than what would be commonly expected. (Cambridge Dictionary, 2023) The word is used to describe unusual occurrences that significantly affect the associated people or systems.

Extreme weather is defined as exceptional and severe weather circumstances that occur over a shorter period of time, hours or days, and significantly affects infrastructure and human life. (U.S Department of Agriculture, 2023) Some examples of extreme weather are hurricanes, tornadoes, heat waves, and blizzards. The term is often based that it stands out when looking at the recorded weather history of a given location. The effects can be seen in loss of human lives, increased economic costs, and drastic changes in ecosystems.

Extreme climate on the other hand, can be defined as disruptions in long-term typical weather patterns, spanning over a longer period of time; years, decades or centuries. These disruptions can be fluctuations in temperature, precipitation, or other climate factors, which causes extreme weather events to occur more frequently or with greater intensity. (U.S Department of Argiculture, 2023)

A place that for various reasons poses considerable difficulties for sustained life is referred to as an extreme environment. These environments are characterized by very harsh conditions such as excessive temperature, high or low pressure, and radiation.

Extreme environments are places that are beyond the optimal range for development of living species. However this does not mean that living organisms cannot be found in extreme environments. By definition, the organisms that are able to live in extreme environments are known as extremophiles.(Rothschild & Mancinelli, 2001)

Produced by Authors using Midjourney, 2023

CASE STUDIES

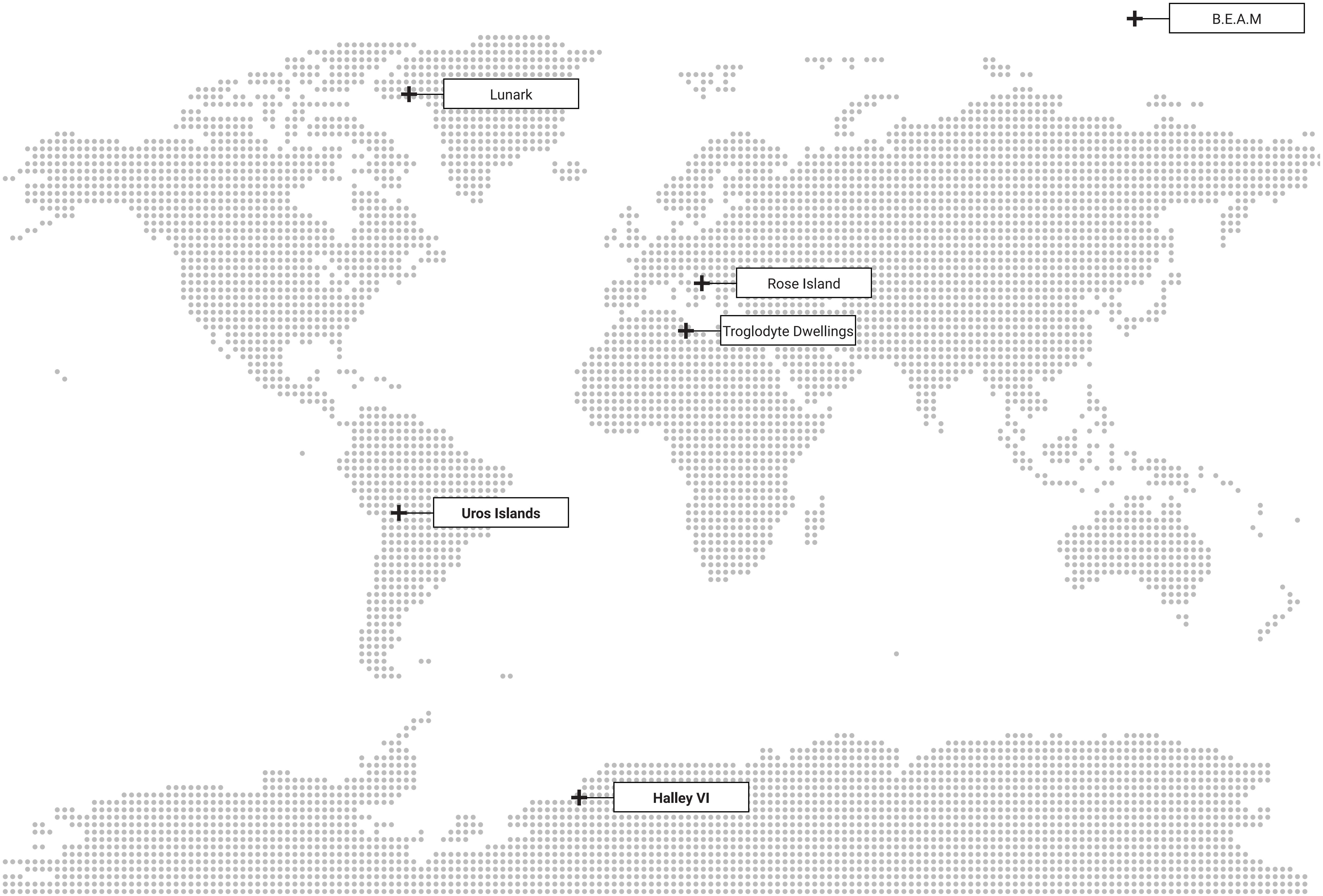
Mankind has, as previously mentioned, a need for a shelter to protect itself from the environment as a basic human need for survival. Vernacular architecture, from both a historical aspect as well as a contemporary, provides a multitude of perspectives on how to solve various extreme conditions posed on humans. Modern technological and seemingly primitive historical solutions have a big role in humanity's ability to adapt to these extreme environments.

The thesis will focus on human habitats in environments that are characterized as harsh and inhospitable, beyond that of the optimal range for the development of humans. The four different categories of environments selected are those relating to water, the arctic, the desert and to those beyond our planet.

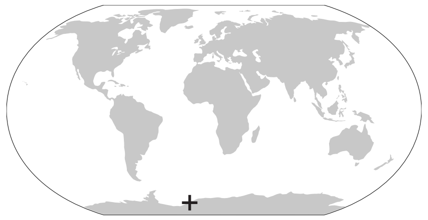
One of the most important benefits of studying historical examples is the ability to learn from past mistakes and successes. In the context of extreme environments, understanding the historical and contemporary experiences of vernacular solution in these environments provides valuable insight into preparing for and meeting the challenges posed by extreme environments.

The developments through time have allowed mankind to push the boundaries of what is possible, expand our knowledge and continuously improve living conditions in extreme environments. Learning from previous studies and examples will allow us to better understand the impact of a global climate change and how architectural interventions have the possibility to influence whether or not human habitats in extreme environments are possible.

Produced by Authors using Midjourney, 2023.


B.E.A.M
Lunark
Rose Island
Troglodyte Dwellings
Uros Islands
Halley VI

Morris, The Halley VI British Antarctic Research Station. 2017



Halley VI

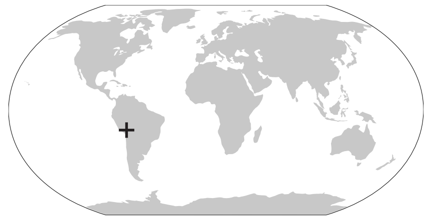
Brunt Ice Shelf, Antarctica

Halley VI is the sixth iteration of British research facilities located on the Brunt ice shelf in Antarctica. Established in 1956 with the aim to study the Earths atmosphere. The station officially opened in February 2013 and was the worlds first relocatable terrestrial research station.

The station was designed to withstand the harsh weather on Antarctica were the temperatures drop to -56 and the wind can reach speeds over 160km/h. On top of this, during winter time the inhabitants experience 105 days of darkness. Halley VI is made up of a modular design to be able to function independently if something happens to one of the modules. The first four iterations of the research station was buried by snow accumulation and crushed to inhabitability (Halley VI Research Station, 2023).

The architectural design was the result of an architectural design competition that was won by Faber Maunsell and Hugh Broughton Architects. The facility consists of eight modules that are jacked up on hydraulic legs to protect it from snow drift and accumulation. The skis on the bottom of the modules allow the building to be relocated if necessary. It was constructed in Cape Town, South Africa and after that shipped to Antarctica where it was assembled and dragged 15km by truck to site one by one. Halley VI's unique design also addresses the psychological and social needs of its inhabitants. The research station uses a special color palette and daylight simulation lamps to combat the 105 days of darkness during winter.

Titicaca Uros, 2017



Uros Islands

Lake Titicaca, Peru & Bolivia

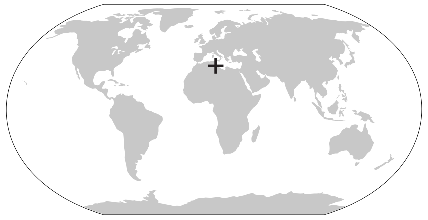
The Uros Islands in Lake Titicaca, located between Peru and Bolivia, illustrates how people have adapted to sustain in a harsh environment. The Uros People that inhabits these islands relies on the lake as their main source of income. It is where they hunt for food, construct their homes and boats, and sell handicrafts to visitors that come by the islands. Through the years, they have developed a lifestyle that is deeply rooted in their environments, as a continuation of their ancient beliefs and practices (Montali, 2022).

The weight of the islands themselves as well as that of the residents and other structures built on top of them are supported by layers of dense, buoyant material made of closely packed Totora reeds. As the existing reed layers break down over time, new ones are constantly added to the islands.

Totora reeds are also used to construct the buildings which often is decorated with the vibrant colors ornaments with intricate patterns and decorations, making it not only practical but also beautiful. Residents can communicate between islands through a network of floating walkways made of the same reeds.

Murray, 2016

Troglodyte Dwellings
Matmata, Tunisia

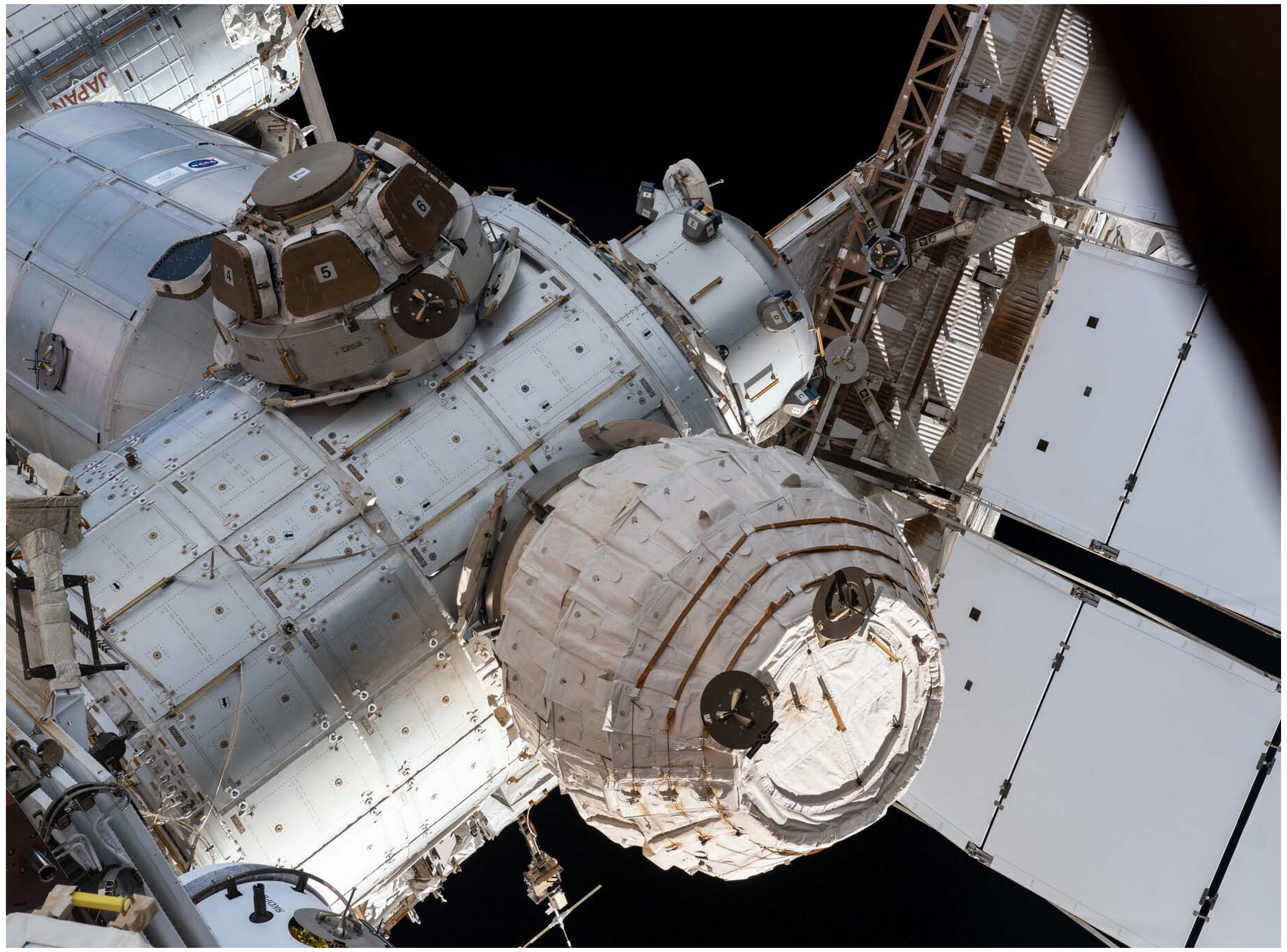


One unique example of responsive architecture is the underground dwellings in Matmata, Tunisia, which were constructed to act as natural insulation against the arid climate. The homes are dug into the ground rather erected above ground, resulting in a distinctive and sustainable typology that has been used for centuries.

A common design element for these structures is a central courtyard that acts as a hub for bigger social gatherings and gives access to the numerous chambers around it that have been excavated out of the walls. This architectural typology creates a sense of social connection among the residents, in addition to providing insulation from the desert's severe temperatures (Gualandris, 2021).

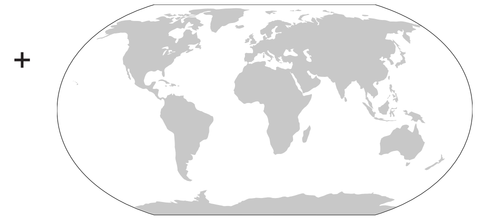
Many of the dwellings have been passed down through generations of families, however, several of the houses have later been turned into hotels throughout time, allowing outsiders to also experience this distinctive way of life (Boukhchim, 2018).

The residences themselves are utilitarian and useful, but they also possess a certain allure and beauty that are difficult to find in more conventional above-ground buildings. The design is a tribute to the resourcefulness of the locals and a reminder that often the simplest solutions are the most viable and useful ones.



NASA, 2022

B.E.A.M.
International Space Station



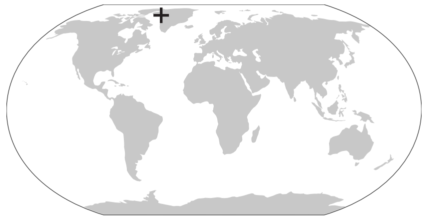
BEAM is a distinctive habitat that was created as a new type of space habitat with the ability to double in size after being deployed. It is made up of several layers of softer materials, compressed for launch, and then inflated with air when it reaches its destination. The answer permits the most effective launch while shielding humans from radiation, space debris, and micro-meteoroids
(Montali 2022).

The form of the habitat maximizes the inside volume while reducing the outer surface area. The interior design features inventive and practical architecture. Hosting a central core with life support systems, as well as a number of modules that can be customized to the mission's requirements.

It is an example of a contemporary design for a space habitat that blends usability, effectiveness, and safety. Its distinctive architecture is proof that creative design has the power to alter the course of future space travel.

Saga Space Architects, 2021

LUNARK
Moriusaq, Greenland



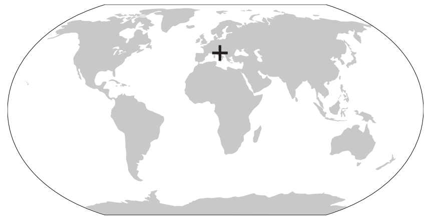
Lunark was designed for providing a functional living space for two, able to simulate the conditions that astronauts could encounter on another planet. In order to replicate many of the difficulties associated with surviving in a hostile and isolated environment, the structure was placed in a remote part of Greenland where it was subjected to high temperatures, extreme weather conditions, and scarce resources (SAGA Space Architects, 2021).

The habitat is made up of a number of connected modules, each serving a particular purpose, such as housing, workspaces, and recreation areas. It aims to construct a self-sufficient and sustainable ecosystem while providing a secure living space, reducing the need for resupply missions.

Materials were selected with sturdiness and sustainability in mind, with an emphasis on reducing waste and optimizing energy efficiency. The primary energy source is solar power, and water collection and recycling are built in to create a habitat that can support itself.

Pino, 1968

Rose Island
Adriatic Sea



Giorgio Rosa, an Italian engineer, proclaimed Rose Island an independent nation in 1968. It was an artificial island constructed as an elevated platform in the Adriatic Sea. The 400 square meter platform, which was made of steel and reinforced concrete, hosted a bar, restaurant, gift store, post office, and a few other services.

With its own electricity infrastructure, water supply, and sewage treatment, Rose Island was created with the intention of becoming entirely self-sufficient. Besides this, the island also contained a helipad and a radio station that allowed for access and communication with the outside world.

Rose Island was meant to be a sovereign nation and had its own flag, money, and administration. It was founded as a representation of liberty and independence, and it immediately attracted attention from across the world as a result of numerous tourists who came to experience the island.

Its existence was short and in 1969, the Italian government proclaimed the construction of the island to be unlawful and dispatched the navy to demolish it. However, the legacy of Rose Island still lives and to this day still sparks protests and discussions about the boundaries of national sovereignty (Farooqi, 2020).

PROTOTYPES

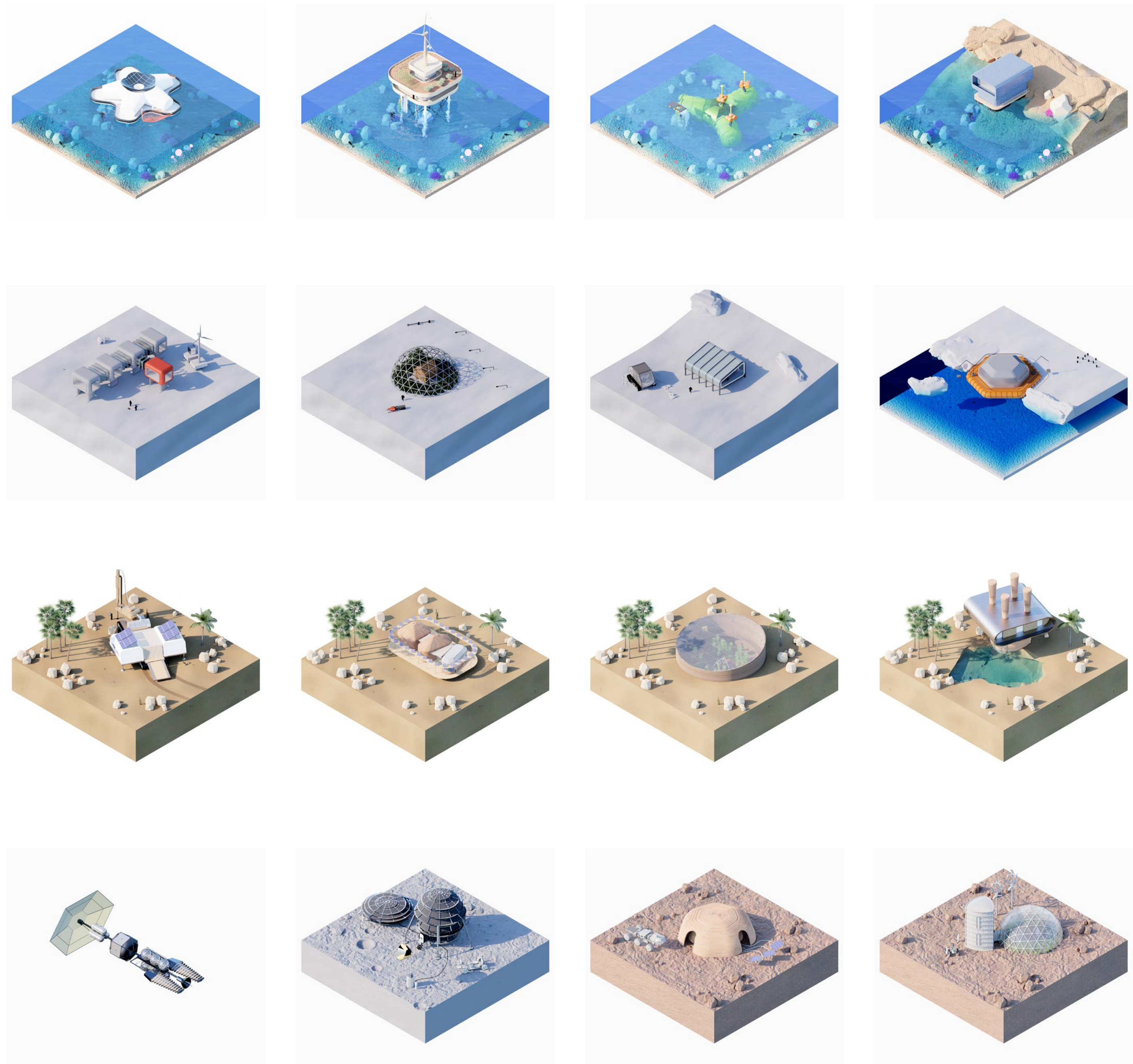
As an introductory crash course in designing for- and constructing in various extreme climates, we challenged ourselves to develop a series of prototypical habitats and shelters by looking at traditional, emerging and future building technologies from said climates.

A notional but climate wise defined site was constructed and acted as an early test bed for digital three dimensional exploring using the results and findings from our research and case study investigations.

We set out a base framework for what the architectural prototypes would need in order to be not always self sufficient but at least self supportive. The main focal point of the units are on the materiality and functionality of the structures and less development was put into the internal spatial qualities.

The prototype units are designed with the main idea that they should be resilient to the various harsh weather conditions exposed to. The units are different levels of self-sustainable and the materials and functions are to be responsive in a sense that they are chosen site specifically. Further the units aim to have minimal environmental impact, given their specific site constraints.

The 16 prototypes are divided equally on for four different extreme environments:
Arctic, Deep Sea, Desert, and Outer Space. Each of these environments were then defined as four different typologies that we thought could be good ways to respond to the given site.



CLIMATE MODELS

A climate model is a computer-based, three dimensional representation of the climate used to calculate how climate develops if the atmosphere changes in a certain way. The models are developed from combinations of physical laws, statistical relationships and data stemming from different sources, such as satellites, weather stations, and ocean buoys. (SMHI, 2014)

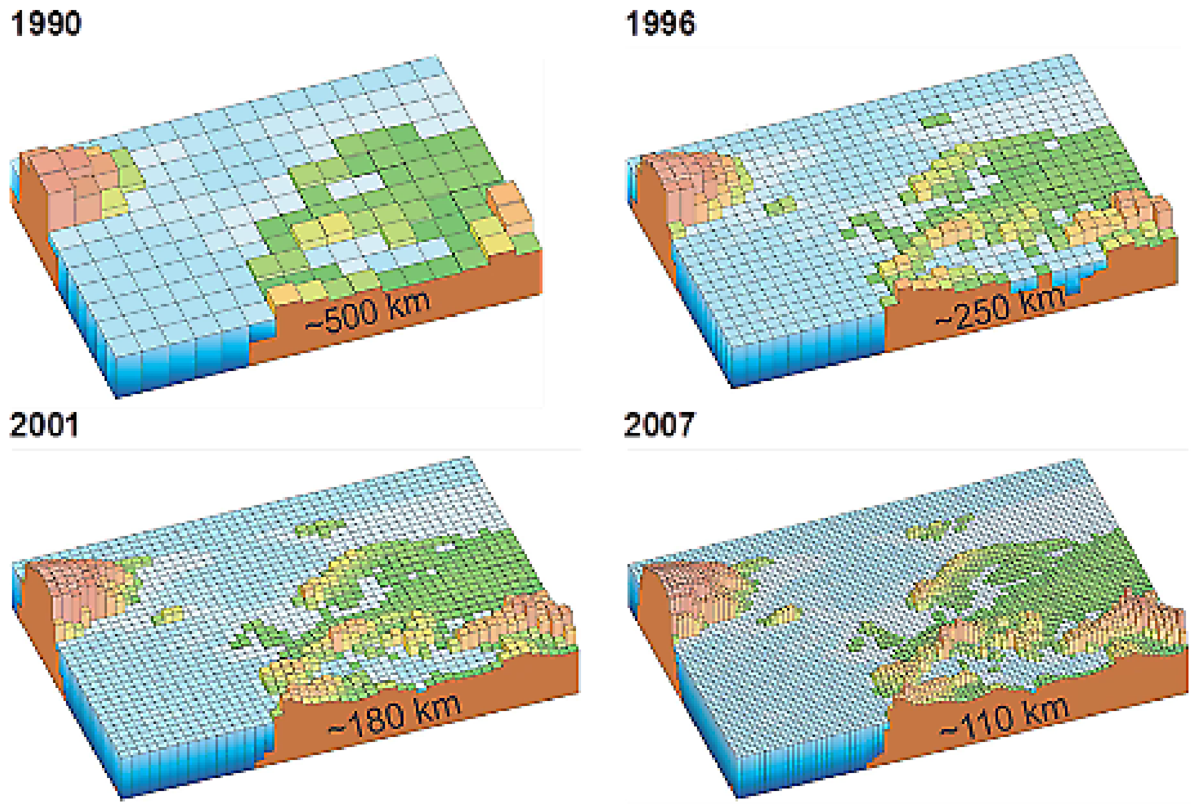
With the aid of climate models, scientists can understand historical changes, simulate current behavior and interactions of different parts of the climate to analyze and understand the future impact of changing weather patterns. A climate model makes it possible to describe; atmosphere, land surfaces, oceans, lakes, and ice - and express it through mathematical representations. (SMHI, 2014)

Climate models are made up of three dimensional grid cells representing the Earth's surface. The result of a process modeled in one cell is passed to the next one to exchange data over time. The smaller the grid, the higher level of detail in the model. With technological advancements the resolution of the models has became more detailed as a more subdivided grid enables more accurate results. (SMHI, 2014)

Foreseeing the weather or climate is impossible, but the climate models make it possible to project probability of different scenarios in relation to greenhouse gas emissions. One example of this is the Representative Concentration Pathways which provides a range of possible trajectories to how the Earth's climate would respond to various concentrations of greenhouse gas in the atmosphere. (IPCC, 2023)
The increase of availability of data for climate modeling helps to reduce uncertainty about the climate in some aspects. However, it introduces a dimension of uncertainty when overlaying and comparing different trajectories between one other. (Qian et al., 2016)

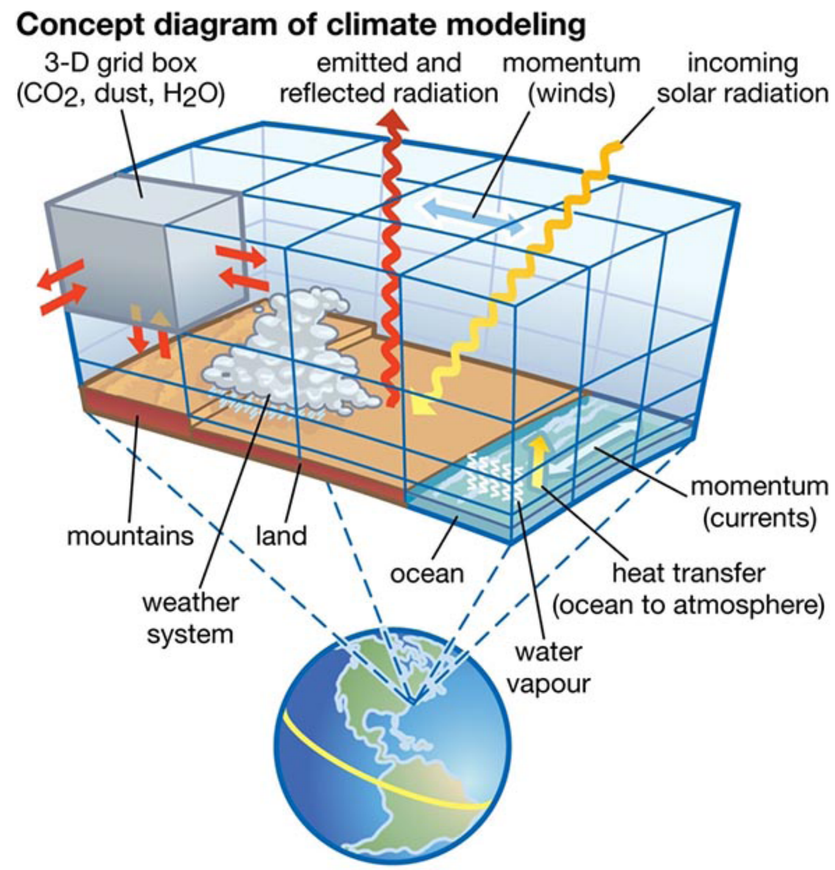
The climate models interprets the data in different ways, resulting in differences between the outcome. This means that when looking at a graph, it will always show different results as they are related to the models and the interpretation of the data behind them. Also, given that the history of the Earth goes further back than the time period of which we can collect data from, the models are by default to some degree always incomplete.

The main uncertainty - and the one this research finds most intriguing and challenging for architects - is the uncertainty related to future emissions scenarios. Climate models project future scenarios based on various emission scenarios and are to some degree just assumptions. Assumptions that are affected by technological, economical, and social factors among many others.



The concept of climate models. SMHI, 2021

- Numerical simulation of important physical processes involving the land, atmosphere, ocean, ice, etc, of the globe.
- For scientific understanding.
- Results are given also where and when there is no monitoring.



Concept Diagram of Climate Modeling. Ruddiman, 2000

SWEDEN

Influenced by its northern latitude, ocean currents and its close proximity to the north Atlantic ocean, Sweden and the other Nordic countries have a relatively mild climate with distinct seasonal variations, and relatively high levels of precipitation. (Visit Sweden, 2022)

Observing the trajectories from the climate model, the impacts of climate change in Sweden might not seem to be as extreme as other parts of the world. However, the cumulative effects of global warming are still significant. The projections point towards an increase of precipitation, floods, droughts and heavy storms in the Nordic region. (Naturvårdsverket, 2023)

The temperature changes will, if materialized, create a shift in both timing as well as duration of seasons, which also impacts both ecosystems and agricultural norms.

In addition to this patterns in precipitation are also changing. Already today, more intense rainfalls are occurring, leading to an increased risk of flooding in certain areas. (Naturvårdsverket, 2023)

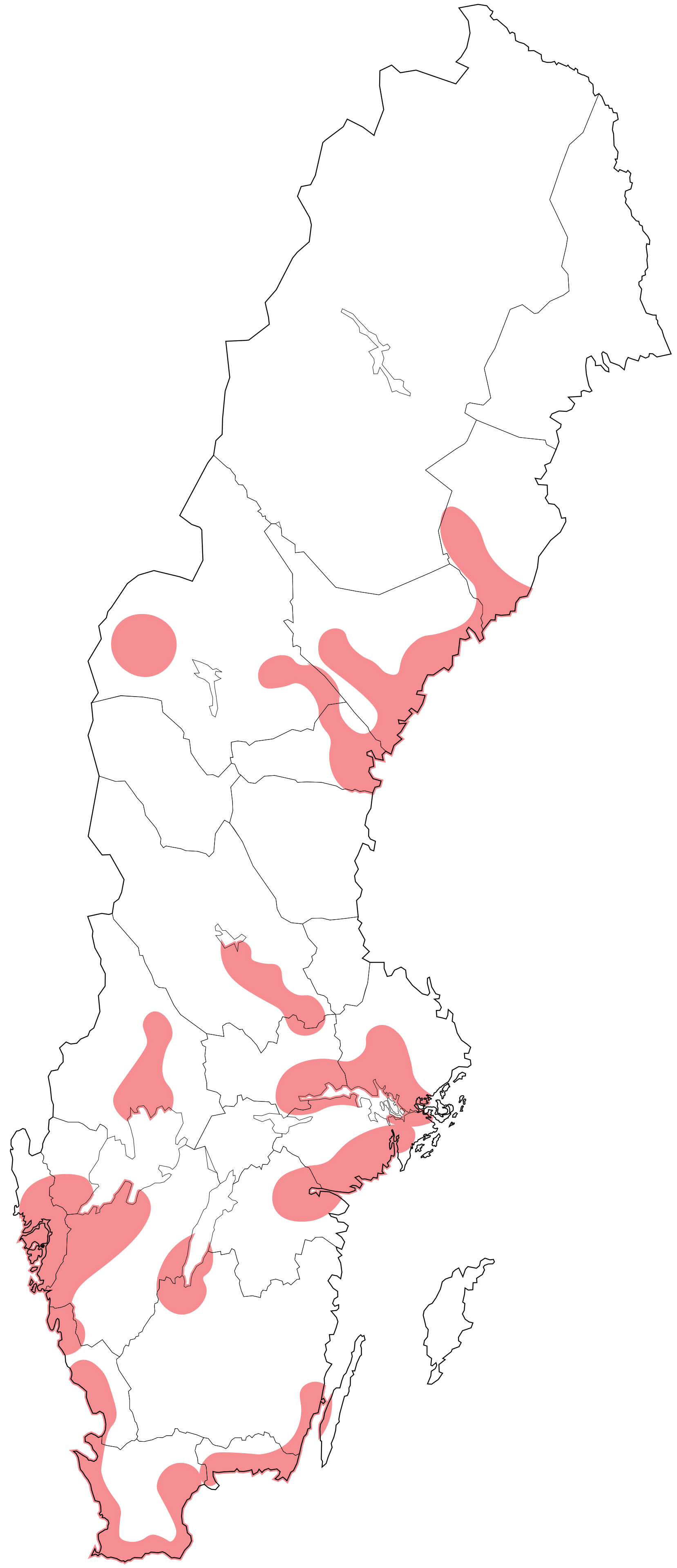
Heatwaves and droughts associated with rising temperatures can have adverse effects on not only agriculture, but also on vulnerable parts of the population, since it is increasing the risk of heat-related illnesses.

In Sweden, the civil contingencies agency (Myndigheten för Samhällskydd & Beredskap - "MSB") is responsible for preparing and guiding the population through major crises such as wars, natural disasters or other catastrophic events. (MSB, 2023)

In general, Sweden has implemented a few climate change adaptation strategies to protect land and infrastructure against the predicted effects of climate change. This includes strategies on how to deal with flooding, sea level rise, and other climate-related disasters. Additionally, investments have been made in infrastructure, land-use, and ecosystem-based strategies to increase societal resilience. (Swedish Government, 2018)

In a report from 2021, MSB identified ten areas in Sweden that are especially vulnerable to a series of climate change related events. The report states how events such as landslides, shore erosion and flooding will lead to major difficulties and increase costs for the society in the future. Up until 2100 is it estimate to cost Sweden up to 50 billion SEK, if no action is taken against them. (SGI & MSB, 2021).

On the premise of the above, it can be argued that it is crucial for Sweden to further expand on their research on the already identified vulnerable areas, becoming climate mutants.



Areas in Sweden defined by MSB with highest risks of flooding & erosion

SKÅNE

The northern part of Sweden is dominated by forest and mountainous regions. Meanwhile the southern part is lacking the post-glacial land uplift resulting in a flat and low landscape. (Lantmäteriet 2023) This makes the entire southwestern coastal region of Sweden vulnerable to extreme weather conditions and especially affected by sea level rise and erosion along the shores.

In a report by MSB it is found that the coastal area of Skåne is a part of ten specifically identified risk areas related to climate events. (SGI & MSB, 2021) This is also the reason why many municipalities in Skåne have come further in the planning for sea level rise than other areas of Sweden, as they will be impacted first. Furthermore, MSB investigated areas for higher risk of flooding and found that out of 16 areas, nine of them are located around the coastal area of Skåne and Halland. (SGI & MSB, 2021).

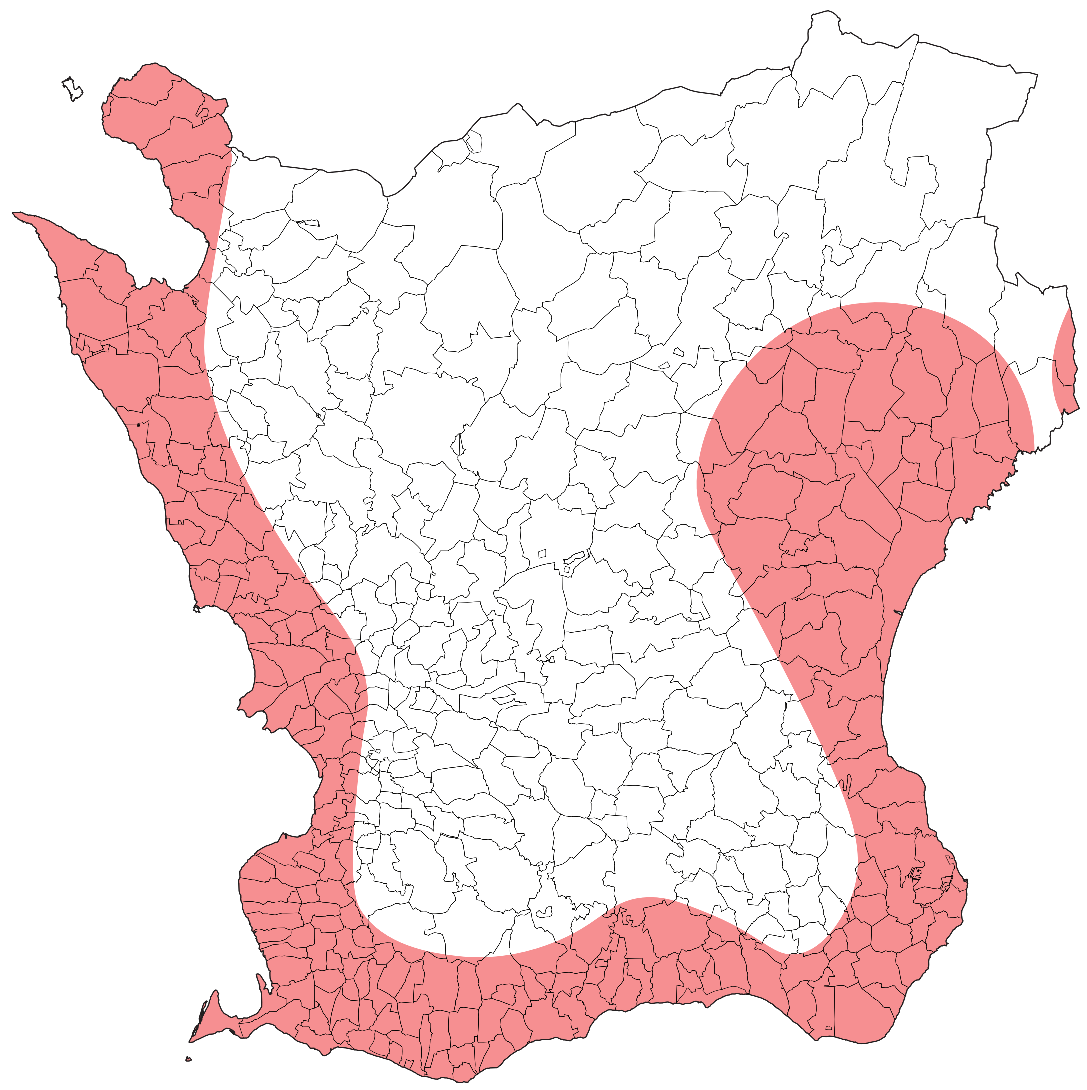
The risk is heighten through studies showing that an increased dominance of westerly winds resulting in the sea levels in the Baltic sea rising substantially. (Hieronymus et al., 2018) Which will likely impact the southwestern coastal region of Sweden both in terms of risk of flooding and increased erosion.

To combat the challenges posed to the built environments in the region, most municipalities in the coastal region have taken some sort of mitigating or defensive action against the impacts of climate change.

Examples of these defensive actions span wide; Cities such as Trelleborg are using protective embankments as a defensive measure against future sea level rise and flooding. (Trelleborgs Kommun, 2023) At the same time, around the city of Ystad, there has been several processes of artificially restoring beach areas. This is done by relocating sand from other places to the region. (Ystad Kommun, 2020)

Through a EU funded program there has also been various attempts to limit the impacts on the shore lines of Skåne. In some areas there have been eelgrass planted throughout the bottom of the ocean to stop erosion. In other areas, sand fences have been constructed to stop the sand from blowing back into the ocean. Furthermore, work is being done to remove invasive plants as well as reefs being established in the ocean to see if it can combat impacts from ocean waves and the increased westerly wind.
(Life Coast Adapt Skåne, 2023)

Additionally, Skåne is home to the most productive agricultural land in Sweden. However, it is also being threatened by the impacts of climate change. The total amount of growing days in a seasons is estimated to rise. However, the projection also includes an increase of extreme precipitation, as well as, severe droughts in the area. This will result in less useful land for growing, which in turn makes it more difficult for people in the region to be self-sufficient.
(Länsstyrelsen, 2011)



Areas in Skåne defined by MSB with highest risks of flooding & erosion

FALSTERBONÄSET

The architectural realization of this thesis is set in Skanör/Falsterbo on Falsterbonäset, a peninsula located in Skåne, Sweden. The peninsula is located quite low in relation to sea levels and in many parts less than 2 meters above the sea level. Today, the area is mildly impacted by its relation to the surrounding water on a regular basis, however often spared from more extreme weather conditions. Historically, the peninsula has however been drastically impacted.

In 1872 the southern Baltic Sea was hit by a temporary sea level rise of more than 3m, causing disastrous flooding not only around Falsterbonäset, but entire coastal regions of Sweden, Denmark, and Germany. Protective sea walls around the areas was not enough and during the extreme weather event 271 people died - and thousands were displaced and lost their homes.

Looking at historical data we know that it was an extreme, but not an isolated event. Continuing sea level rise together with more extreme precipitation increases the probability that a weather event like this will occur again. However, today the areas impacted are far more populated than in 1872, which means that a lot more people would be impacted, if a similar event was to occur today.

Today, there is a higher awareness for these events and measurements have been taken to some extent. Vellinge municipality, where Falsterbonäset is located has hired Sweco Architects, a architecture and engineering company, to analyze the situation and propose solutions to the issue. Sweco's strategy is to protect the area using current defense systems where possible, and constructing new protecting sea walls and other solutions where necessary.

Interestingly, there is a duality between the need for a protecting sea wall and the wants for nice ocean views the case of Skanör/Falsterbo. Some inhabitants of the towns have filed complaints against the construction of the protecting sea walls, arguing that it would obstruct their views towards the water.

Similar to this thesis' interest, Anna Ringqvist and Ulrika Eriksson at the Faculty of Social Sciences at Uppsala University conducted a series of interviews in 2020 with inhabitants of Skanör/Falster attempting to answer the unavoidable question "Why do people that have other options choose to live in a flooding-prone area?". Based on Ringqvists and Erikssons interviews, it can be argued that the interviewees experienced a general disbelief that the impacts of climate change would happen during their lifespan. Yet, they seemed to experience a belief that the responsibility to protect against the impacts of climate change was on the municipality/governments and not the residents themselves.

According to SMHI sea levels in the area will rise, however the amount is uncertain. Some models point towards a sea levels rising with 205cm in year 2150 in an SSP 5-8,5 scenario. But when the same models take into account uncertain melting of large ice caps they project up to 508cm rise in a catastrophe scenario.

The uncertainty of the climate models and their outcomes has triggered the design project of this thesis - a series of hypothetical climate scenarios, exponentially speculating in a more extreme climate where self-sufficiency gradually becomes more important.

Existing flood walls in the area of Skanör-Falsterbo

ARCHITECTURAL CONTEXTUALIZATION

“Hope for the best, plan for the worst.”

With global climate change becoming a widely accepted conclusion, there’s a need of not only trying to mitigate the causes of it, but also preparing for its effects. To try and answer our initial question regarding how architecture in Sweden can adapt to an increase of extreme weather conditions we required a test bed.

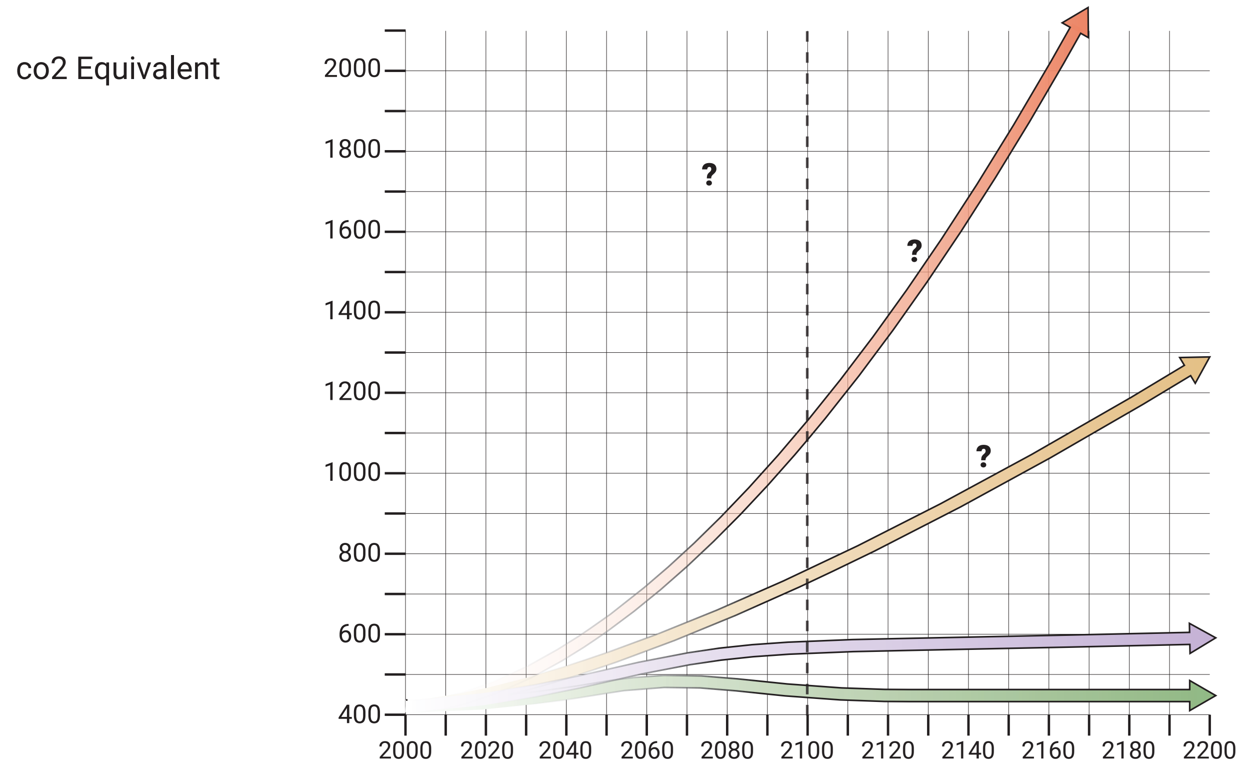
In the projected scenarios where much of the global population face dire consequences in the wakes of climate change, Sweden remains relatively unscathed in simulations. The projections, which we believe are limited by their scope of time and the absence investigations of externally inflicted events, man-made or environmental, are not only hypothetical, form a large gap for worsened extreme global climate events. This project thesis aims to provide a framework to deal with scenarios well beyond that of the current projections.

SCENARIOS

The scenarios represented in the thesis have their basis in scientific estimations of future global predictions. These scenarios are contextualized into local and fictional events that may or may not occur in the near future. The scenarios serve as a testbed to face extreme events in a Swedish setting as the effects of global warming and increased emissions become more evident. Each scenario plays out on its own as three unique, non-linear extremities based on three different multiverse timelines. They should not be regarded as events in a chronological order but as independent scenarios.

SITE

Skanör Falsterbo is a residential area on a peninsula in the most South-Western part of Sweden. It acts as a great test-bed for the first scenario due to its geographical environment and low terrain. Scenarios 2 and 3 are events that impact Sweden, and the world, to such a degree that we’ve remained on the same site to continue our investigations.



RCP-climate scenarios

Scenario 1

BACKGROUND

Karlsson family. Midjourney (2023)

The upcoming development of the Antarctic Ice sheet represents the greatest unpredictability when it comes to sea-level projections in the coming centuries. With increasing CO_2 emissions, the world has progressively seen an increase in the average global temperatures..The Antarctic Ice Sheet has recently seen a significant loss in mass at an unprecedented rate. Previous calculations and simulations of the Amundsen Sea sector of west Antarctica has been proven incorrect in their estimations for the deterioration for the ice sheet. If the West Antarctic Ice sheet is discharged into the ocean, the world would witness an global increase of the sea-level by approximately 3 meters (Feldmann & Levermann, 2015).

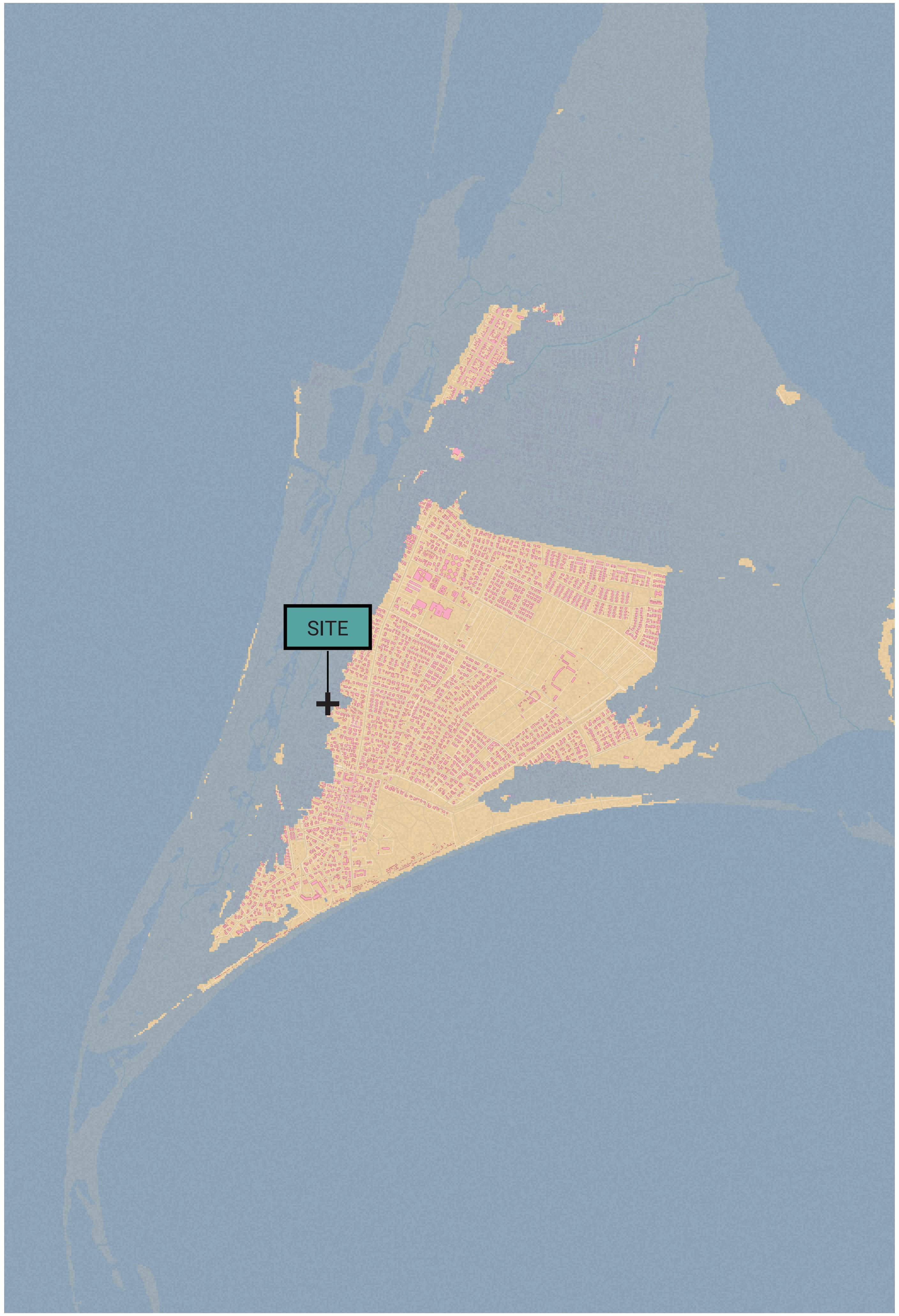
SCENARIO

This fictive, but somewhat likely scenario begins with the inevitable discharge and demise of the west Antarctic Ice sheet. For Sweden in general, immediate preparations are made to accommodate the rising sea levels in all major cities. Skanör-Falsterbo, a municipality located on a peninsula in the most South-western edge of Sweden faces dire consequences. It's highest point, which accommodates for approximately 8 percent of its area, is merely 5 meters high. The area will be almost completely flooded at a 3 meter increase and will go from a peninsula to an islet in a matter of years. Whilst most flee from the area, some endure and commit to face the pending eradication of what once was Skanör-Falsterbo. The increased sea levels generates an inflation of general living costs, placing an emphasis on resources and food production.

USERS

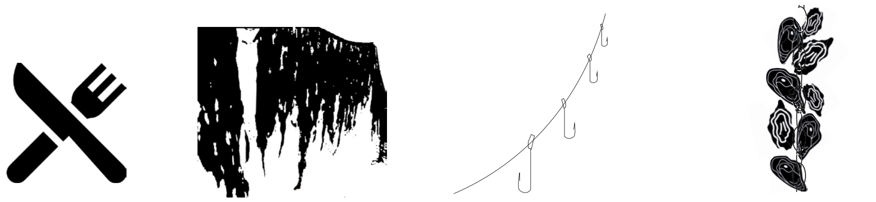
This scenario revolves around the Karlsson family, consisting of Urban, Liselott and their daughter Ida. The family, having lived in Skanör-Falsterbo for generations, see the peninsula as their home. A few of their neighbors have also planned on enduring the oncoming flood, which would effectively induce a community. The Karlsson family theorize the advantage of residing on the site, as the imminent sea level rise would create an abundance of materials in the form of oceanic plastic waste from towns in the South Western part of the Baltic sea and an increase in the natural oceanic vegetation.

Right: Site plan. 1 : 30 000

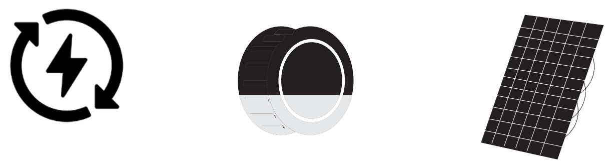


Tools

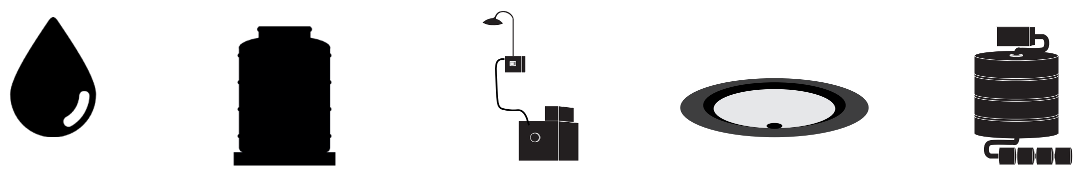
Porthole window | Radio Equipment | 3D printer | Boat | Upcycled Ocean Plastic flotation



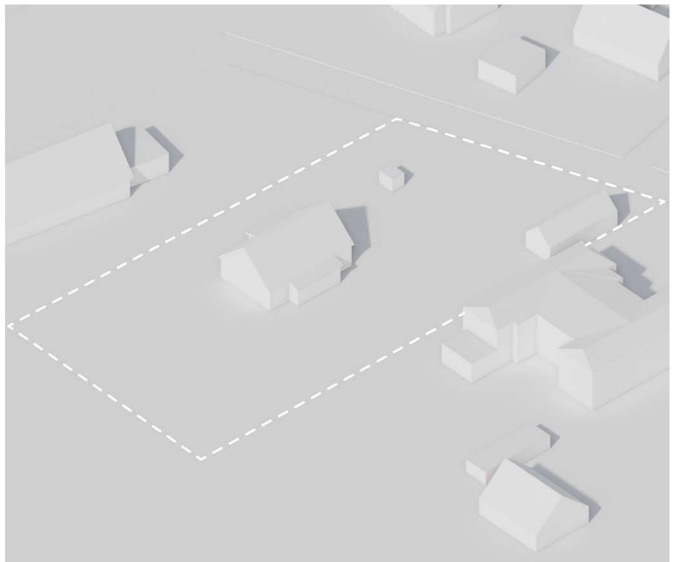
Kelp farming | Fishing line | Oyster Farming



Wave Turbine | Solar cells

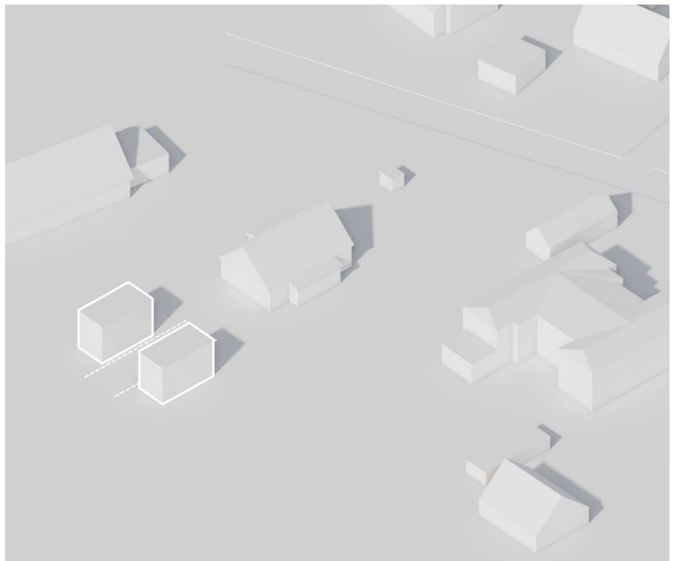


Indoor water tank | Grey water recycling | Rainwater collector | Saltwater purifier

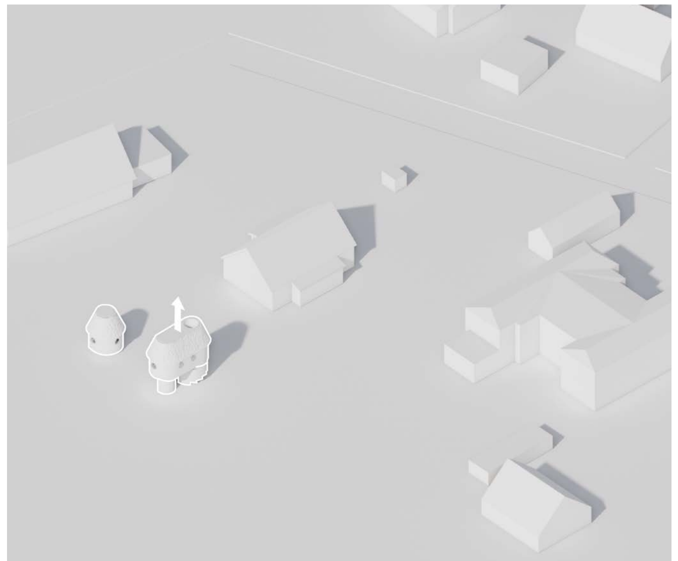


The site is located on Prästaledsvägen 3 in Skanör Falsterbo

With the necessary requirements for 3 inhabitants, a workshop and a food harvesting station

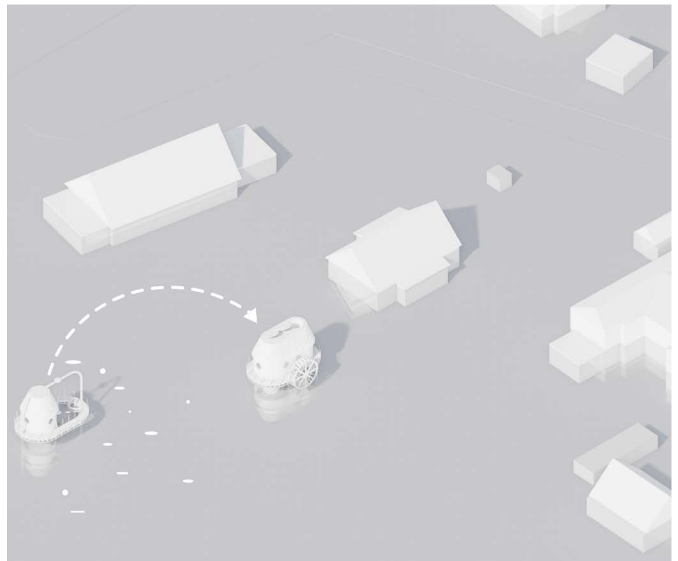


Housing is separated from workshop & food harvesting station

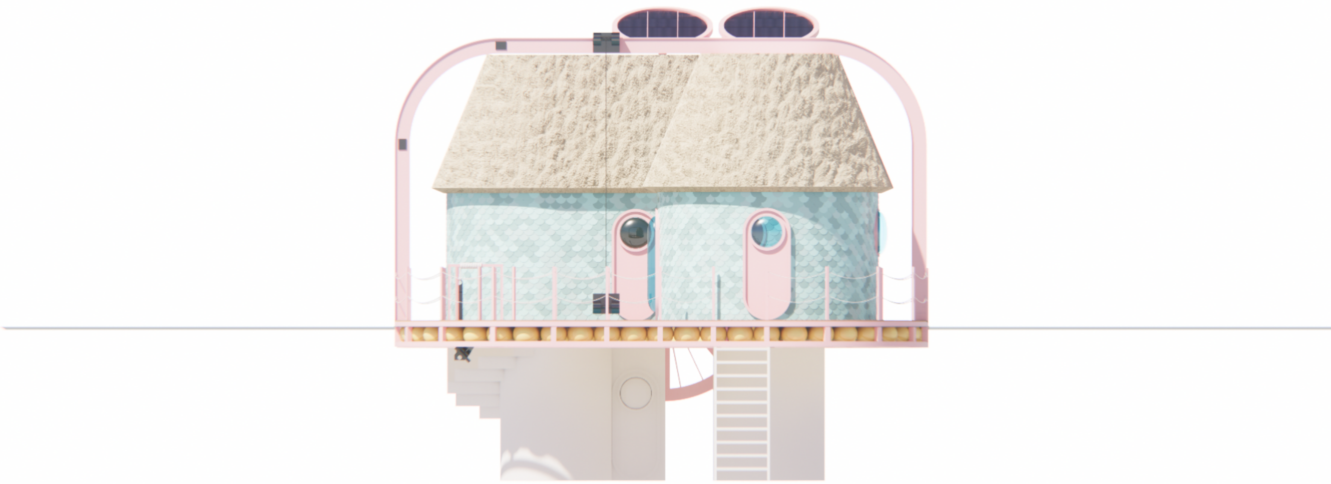


Housing is elevated to 2 floors, and to accommodate for stability, two keels are placed in the bottom. The larger keel also acts as a stairwell for access to the main structure. Workshop is made minimal

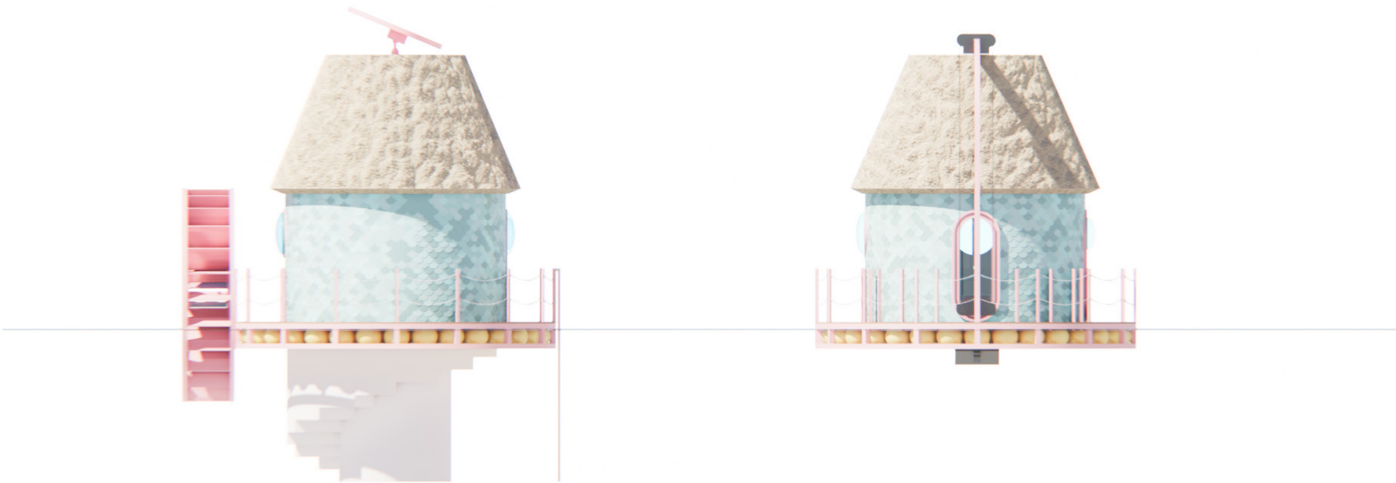
Floating structures are added around the structures, acting as platforms and bridge to increase sea stability. As the water rises, the workshop is lifted up and the tools can now be implemented.



The workshop gathers material for the housing pod, 3D-printing shingles from the vast amounts of ocean plastic. Food is grown and harvested from the workshop.

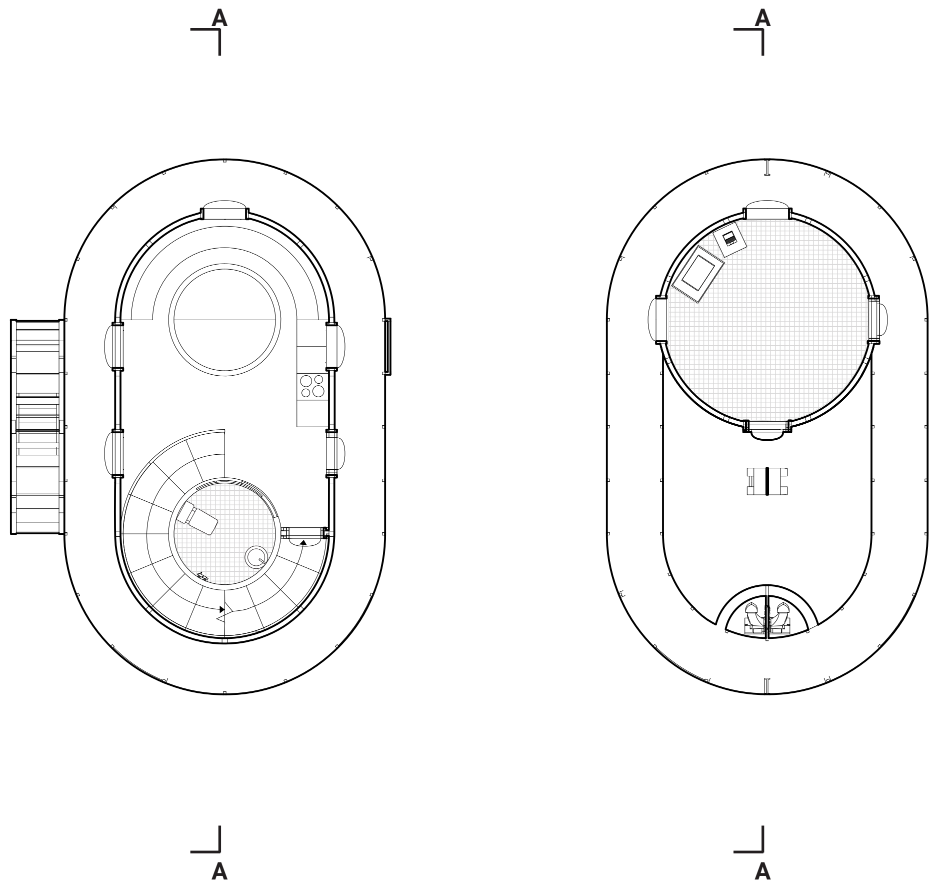


Elevation South-East. 1 : 200

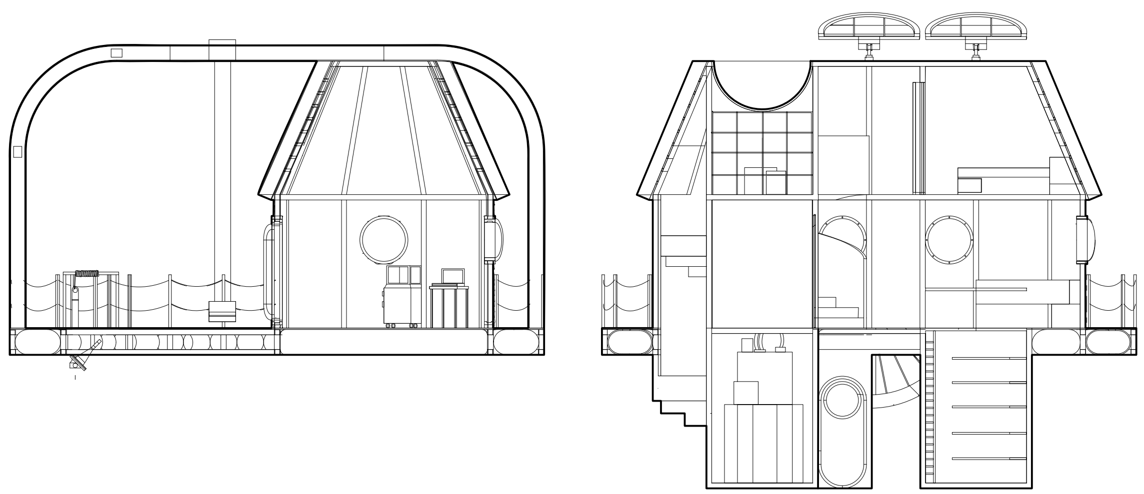


Elevation South-West. 1 : 200

Site plan. 1 : 500



Floor plan. 1 : 200



Section A - A. 1 : 200

Before the flooding of the site, the buildings are constructed.

As the water rises, the workshop and food production barge can gather resources.

When fully submerged, the housing unit now floats freely and can relocate

Interior Perspective

Exterior Perspective.

Scenario 2

BACKGROUND

The Atlantic meridional overturning circulation, known to most as the Gulf stream system, has recently been shown to be the weakest in over 1000 years. This is believed to be linked to greenhouse emissions and human induced climate change. (Caesar et al. 2021). Researchers at the Potsdam Institute for climate Research warns that the Gulf stream could be diminished by an additional 45 percent until the end of the 21st century. (Bjerström, 2021) The effects of a disrupted gulf stream would induce a significant impact on Northern Europe, where Sweden could see a climate more reminiscent to that of Alaska, with short & dry summers, prolonged winters, an increased frequency and strength in winter storms and winter temperatures of -50 degrees celcius.

Larsson family. Midjourney (2023)

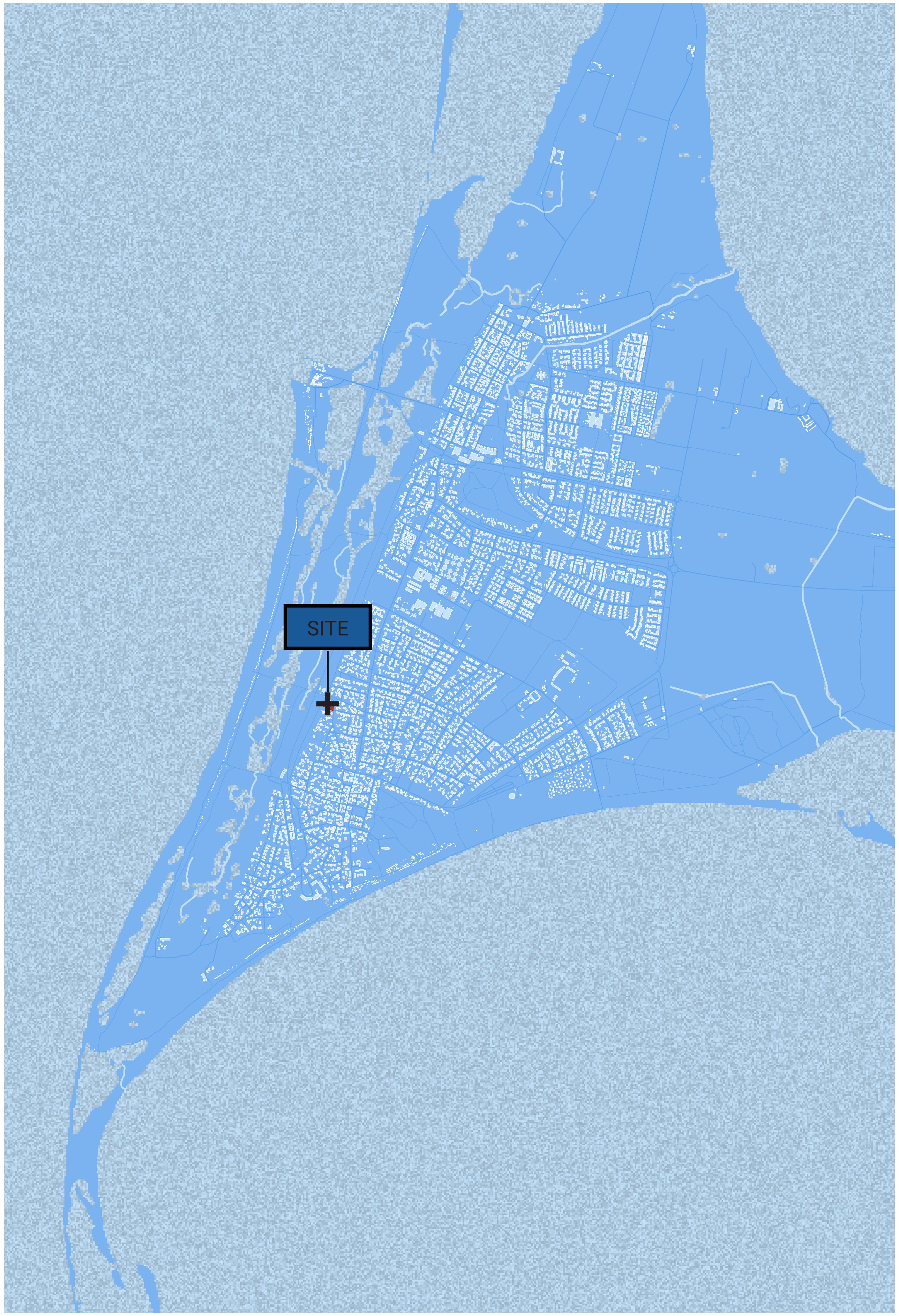
SCENARIO

This fictive, but somewhat probable scenario begins with the news that the Gulf stream has deteriorated in a much higher degree than anticipated. Sweden's climate is expected to face much more dire conditions in the few coming years. With an extreme climate spanning across northern Europe, some who have the financial abilities, decide to migrate to lower latitudes. Many decide to remain in Sweden but have to adapt to the new harsh environment. With an increased pressure on food supply due to the diminished agricultural abilities in Sweden, habitants have to make sure to create a higher level of self-sustainment and protect themselves from the severe weather. Whilst indoor farming is implemented on a larger scale in Sweden, the imported goods, which sees an increase in cost due to the high demand, simply isn't enough for most.

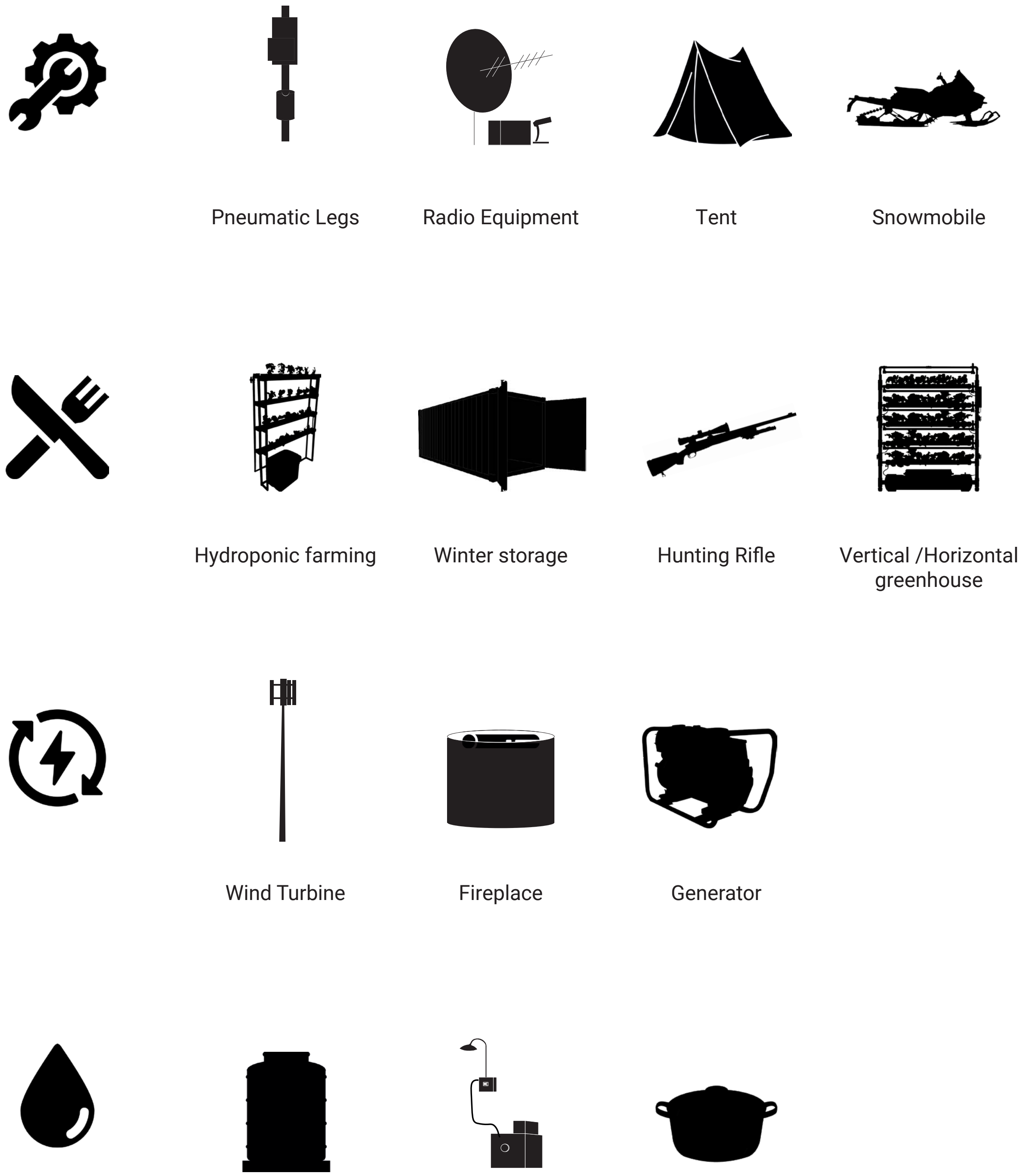
USERS

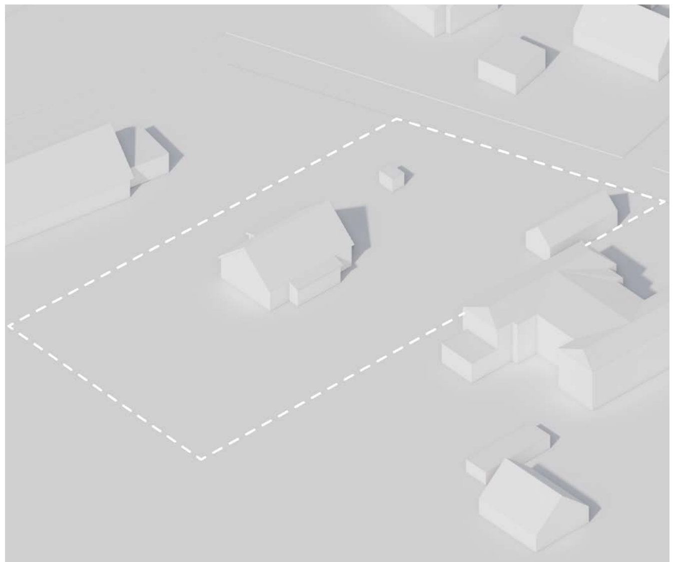
This scenario revolves around the Larsson family, consisting of Joakim and Sigrid. The family, having lived in Skåne for generations moved to Skanör Falsterbo a few years before the event. Skanör Falsterbo is one of the most southern points in Sweden which generates a more favorable situation compared to that of the northern parts of the nation. With its close proximity to the European mainland, during the short summers, cargo holding food and other supplies are shipped from the ports of Germany to Southern Sweden. During winter months, the Danish strait is frozen, which means that a snowmobile can be used to drive across in emergency situations to reach the European continent.

Right: Site plan. 1 : 30 000

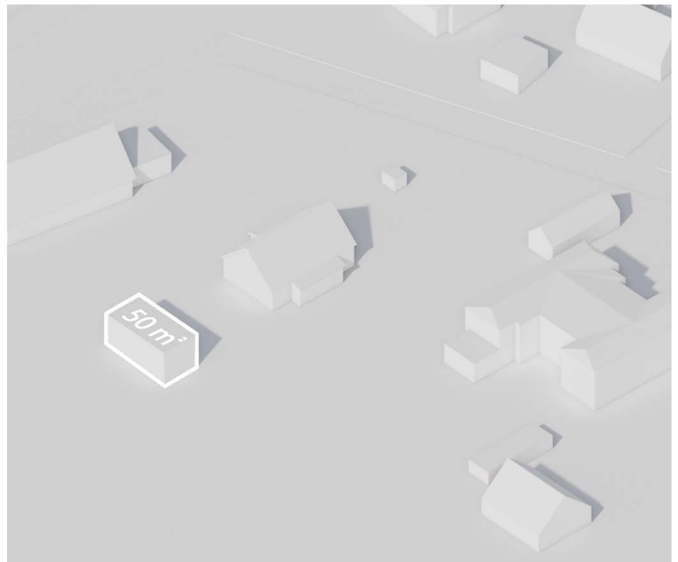


Tools





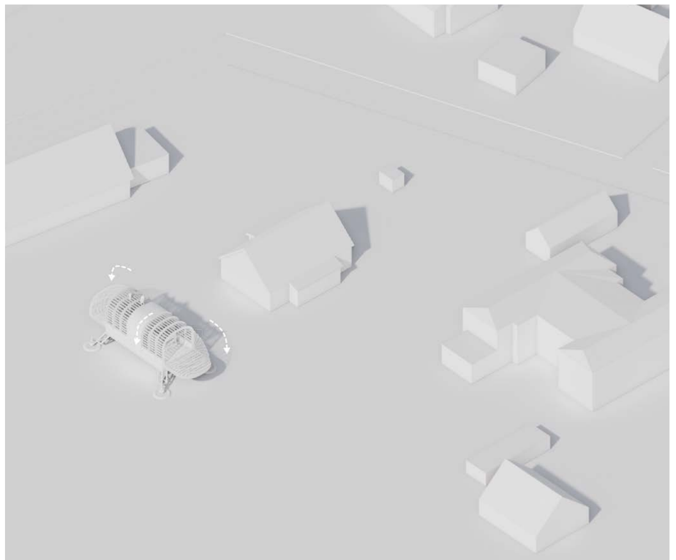
The site is located on Prästaledsvägen 3 in Skanör Falsterbo



With the necessary requirements for 2 inhabitants, a size of approximately 50 sqm was developed

To accommodate for increased frequency and strength of winter storms as well as the precipitation that follows, the module is made aerodynamic

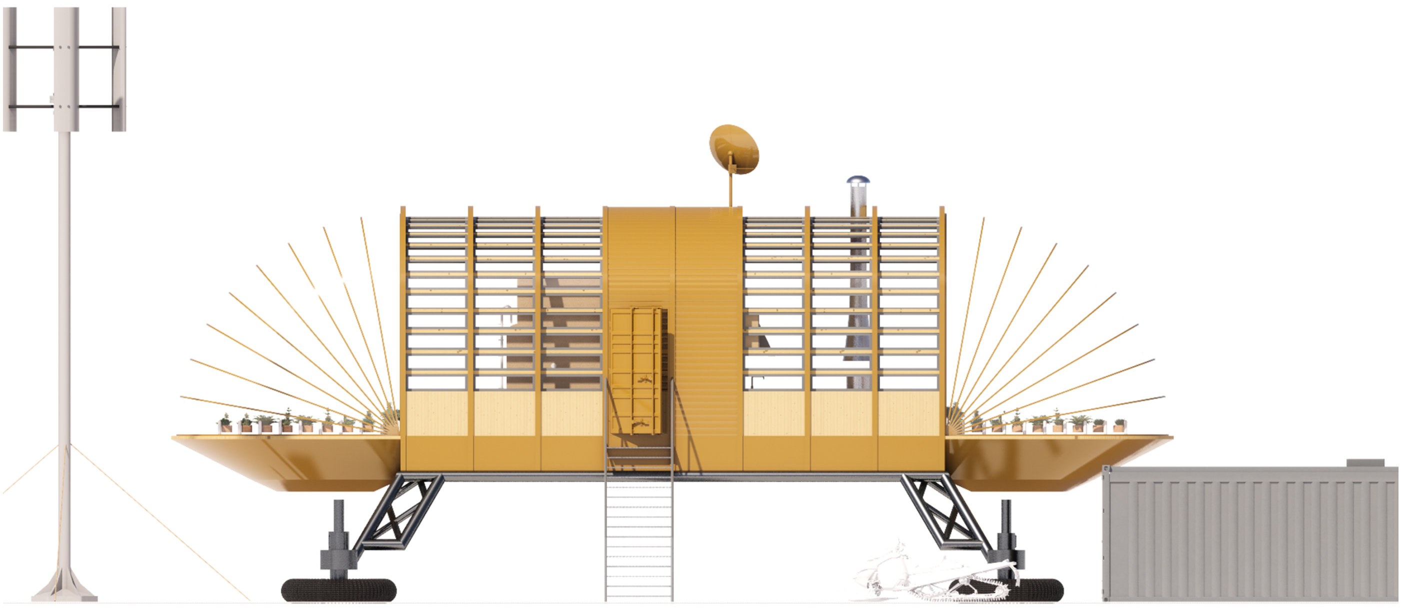
With heavy snowfall and shifting snow, the module is placed on pneumatic legs to elevate structure above.



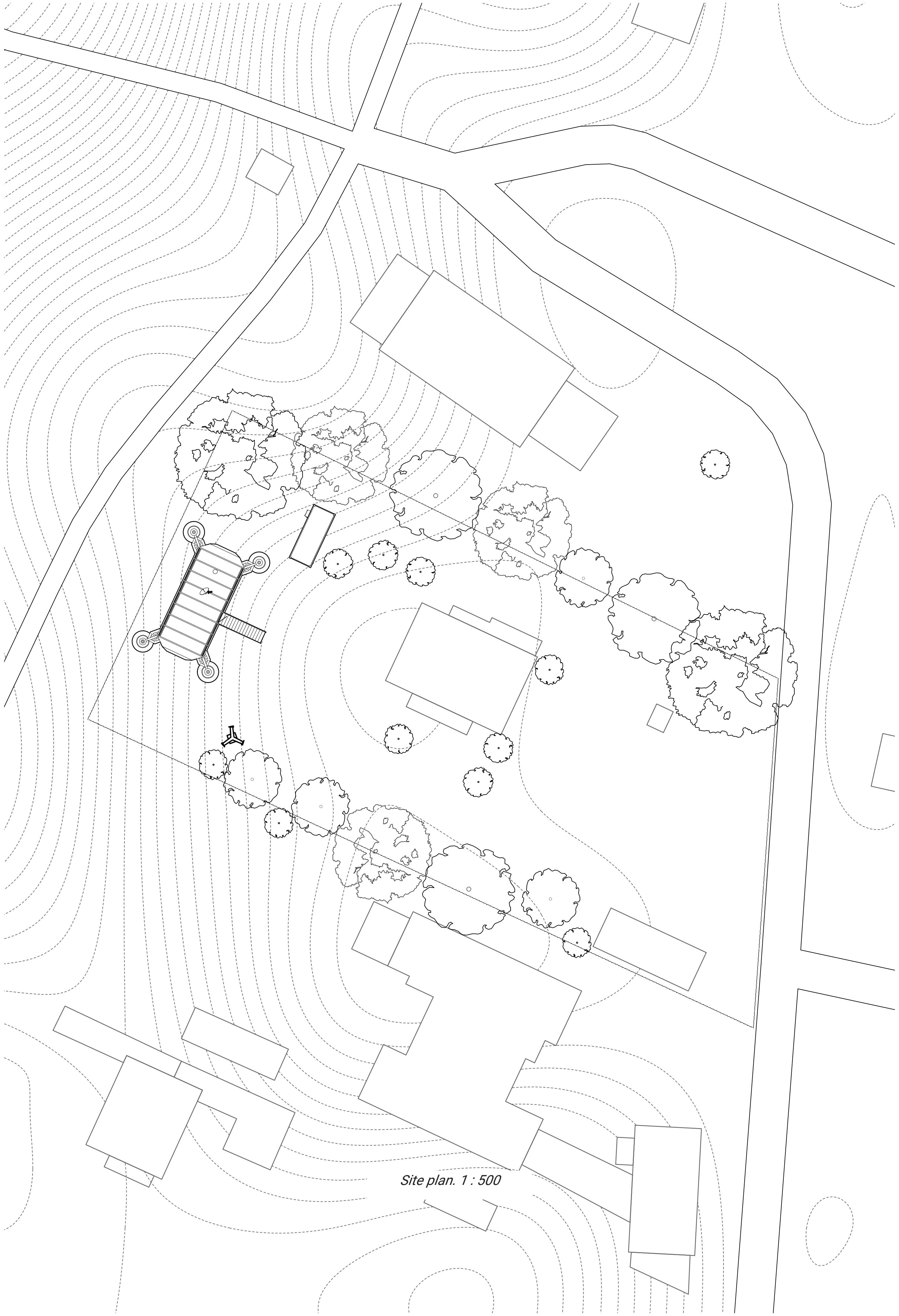
To facilitate crops grown in summer, the module is turned into a greenhouse with the ability to open and close ends as well as opening or closing the window shutters depending on the weather

A container acts as a winter storage for imported goods and harvested grains, whilst an anchored wind turbine provides energy.

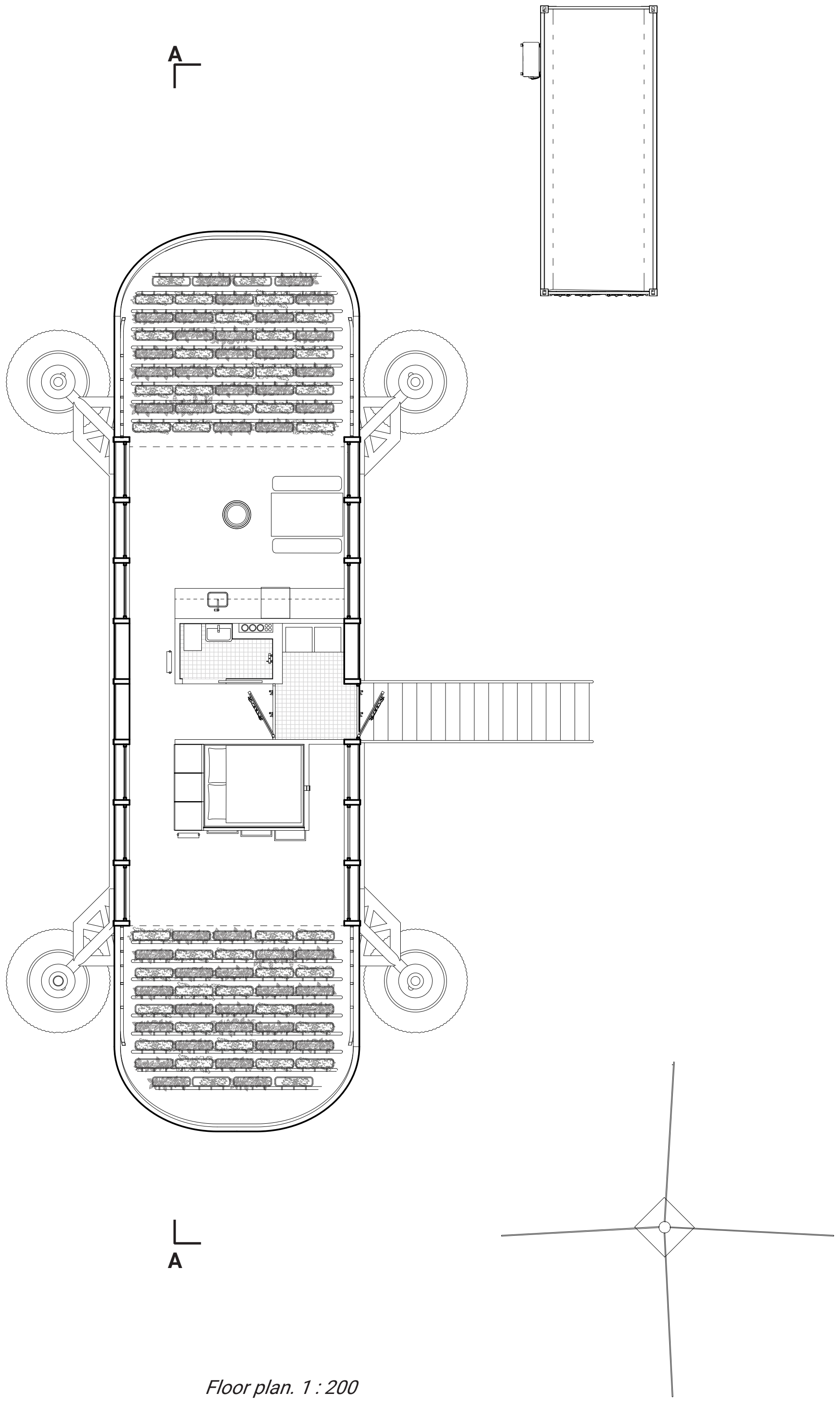
Elevation South-West. 1 : 200



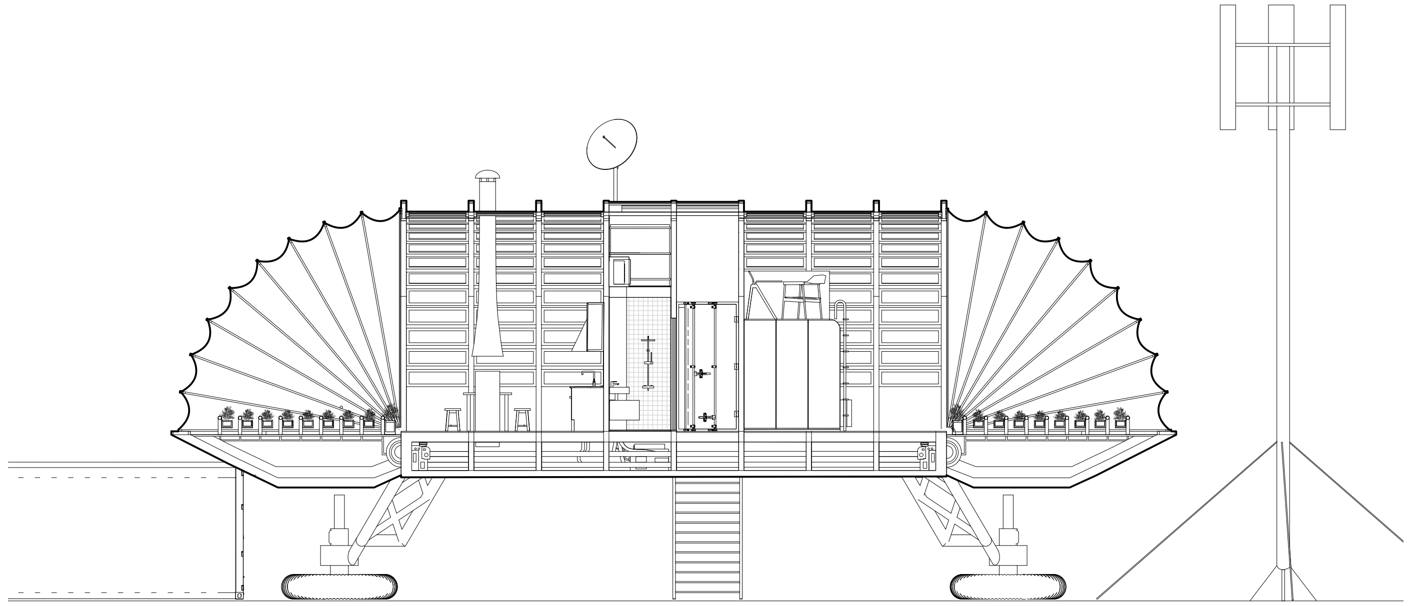
Elevation South-East. 1 : 200



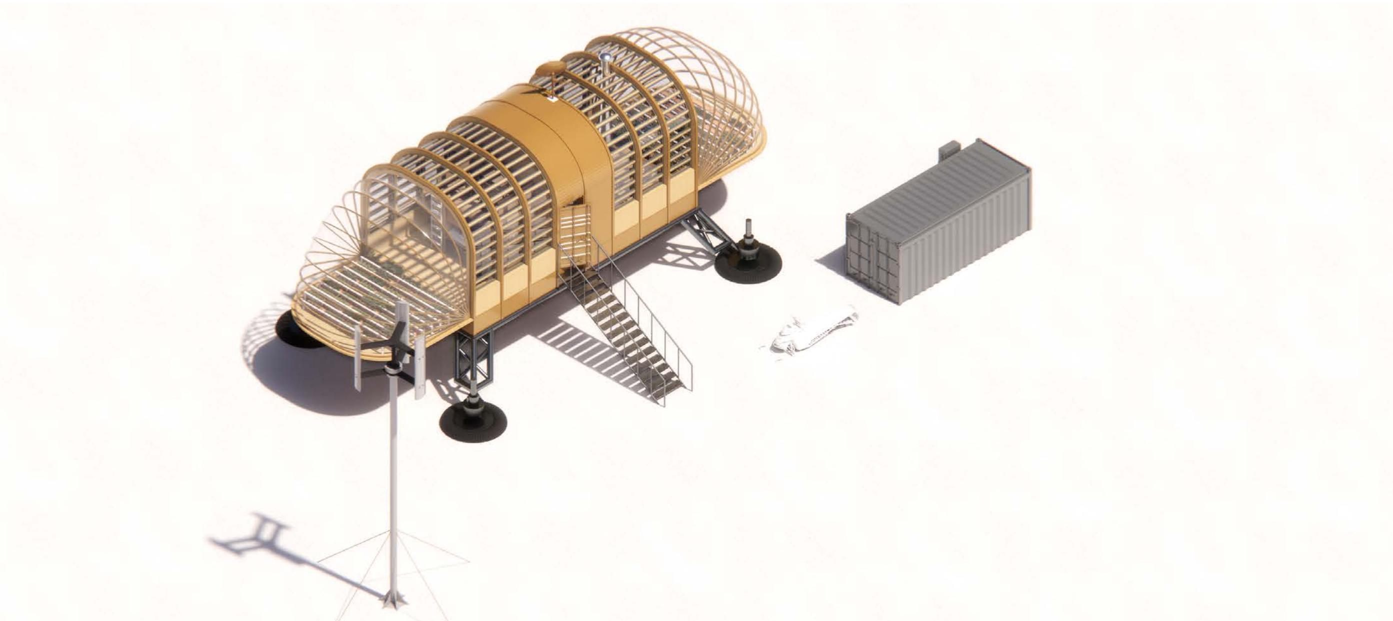
Site plan. 1 : 500



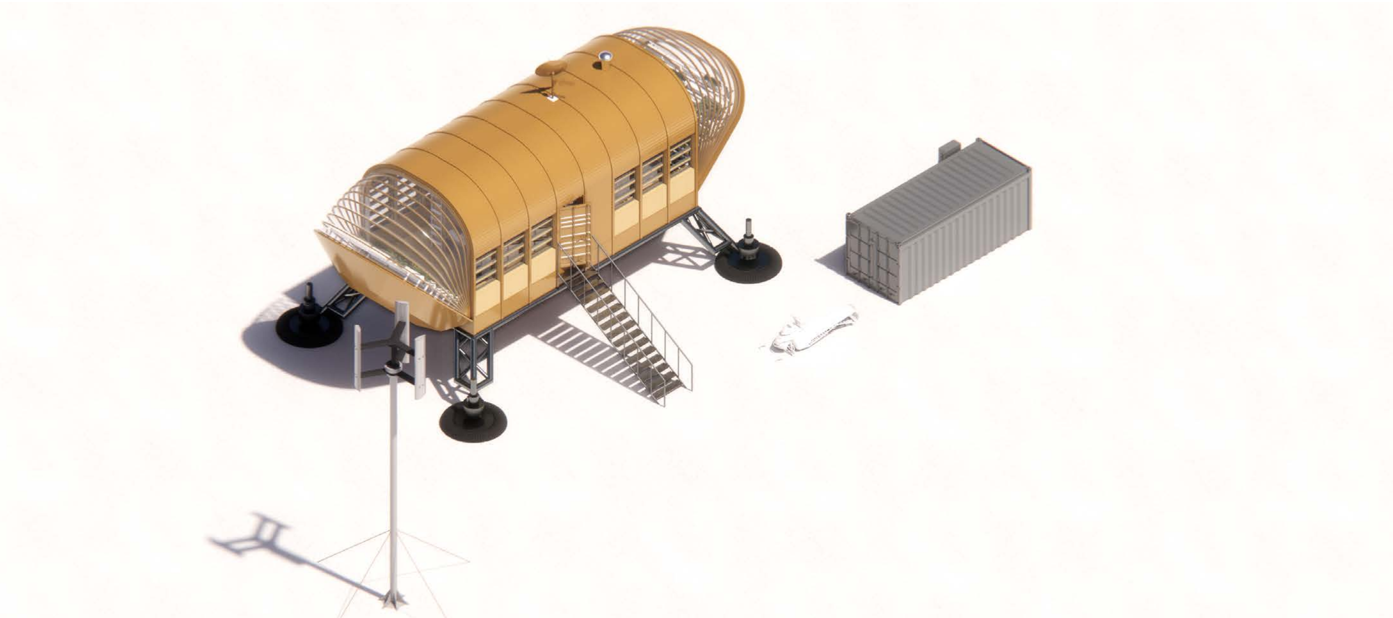
Floor plan. 1 : 200



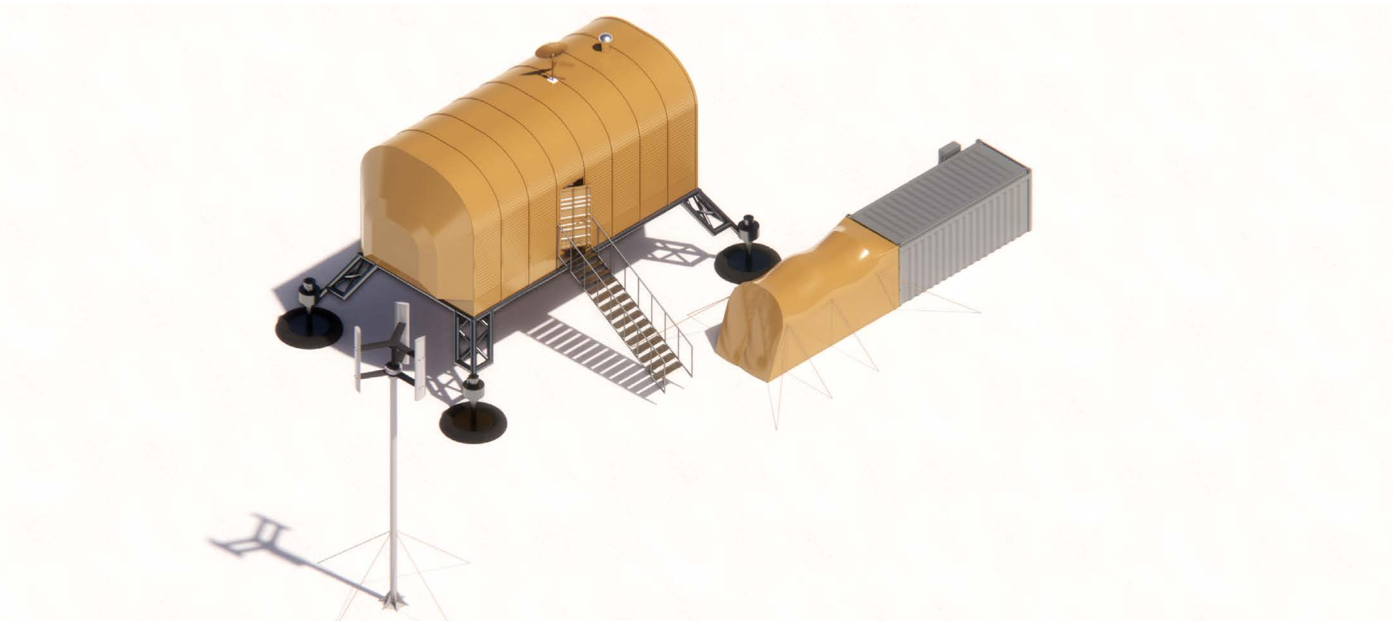
Section A - A. 1 : 200



During favorable conditions, the whole unit can be made into a greenhouse for increased food production



Canopies can fold up and blinds pulled down to shield unit and preserve heat.



Closing and elevated to withstand intensive winter storms.

Interior Perspective - Bedroom

Exterior Perspective.

Scenario 3

BACKGROUND

Apocalyptic events is something mentioned since the dawn of mankind. From religious scriptures to the discovery of dinosaur fossils, there's a fascination for the end of the world as we know it. Levy (2006) argues that there are 5 different main categories of doomsday events. The Frankenstein effect, The third world war, ecocide, climate change and lastly, cataclysmic events. All possessing the possibility of becoming world ending scenarios for our civilization as we know it.
With the development of digital tools for more detailed analysis and continued research of potential threats, the awareness of "doomsday"-events have made the apocalyptic event as relevant today as it was in the dawn of mankind.

Svensson family. Midjourney (2023)

SCENARIO

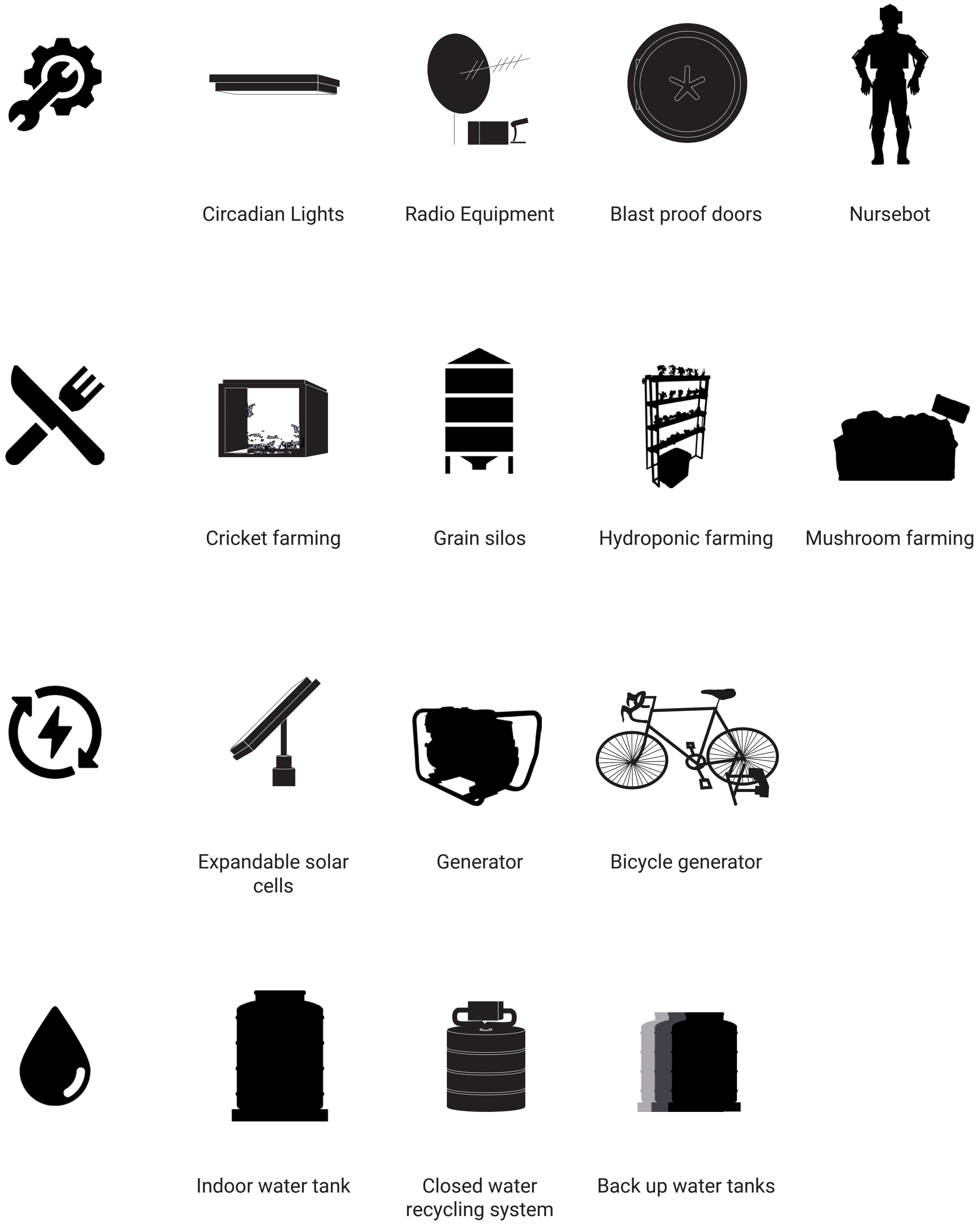
We don't know what happened, we don't know how it played out. There are no radio-transmissions or no evidence of a thriving outside world. Skanör Falsterbo, and likely the rest of the world is silent. What is known is that the surface is uninhabitable for life forms. Resources are non existent apart from what has been planned or stored safely, and the world that we once knew is gone. What survived was what was pre-planned for, and only the extremities of contingency plans made it trough to the post-world.

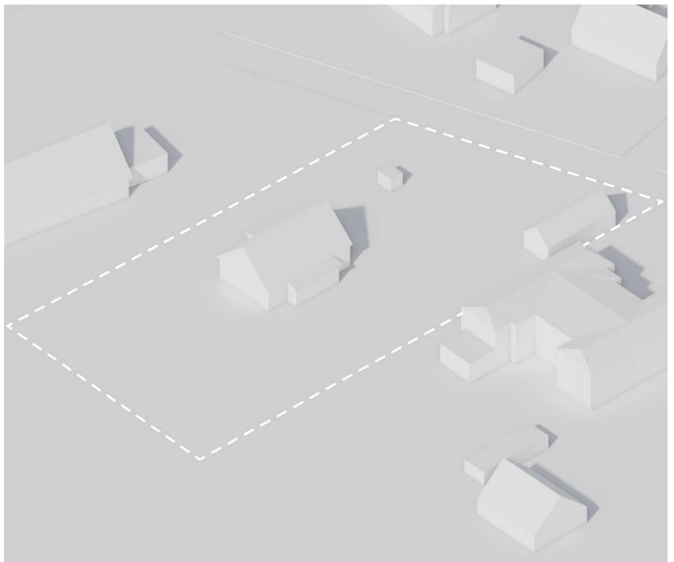
USERS

This scenario revolves around Kevin Svensson and his nursebot XYL-0345. Kevin, a retired former employee of the European Space Agency, ESA, began to find interest in prepping. Enjoying a solitude lifestyle, he began preparing for an apocalyptic scenario. With no family and no need for social interaction, he simply wishes to reside in a secluded space built beneath his old childhood home in Skanör-Falsterbo. Kevin only sees the logic in sealing himself off from the rest of the world as long as his existence is secured for the rest of his expected life.

Right: Site plan. 1 : 30 000

Tools

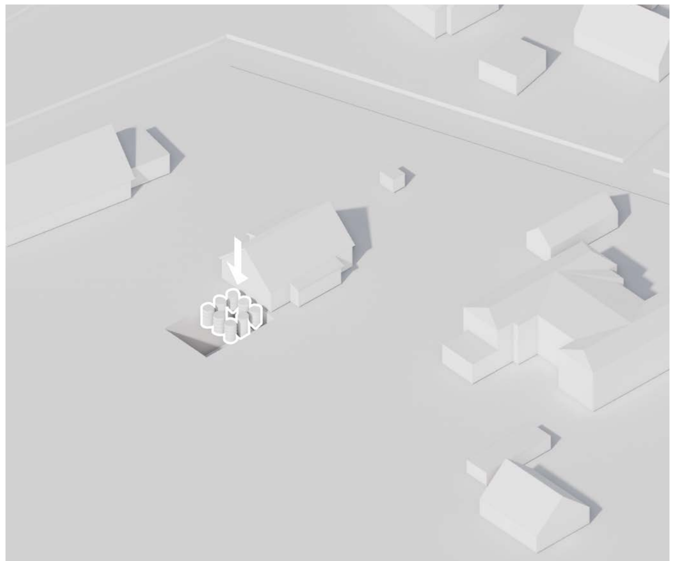




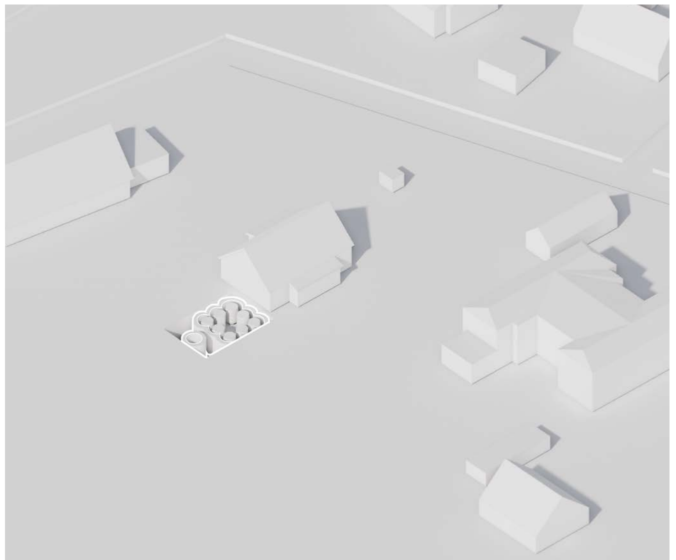
The site is located on Prästaledsvägen 3 in Skanör Falsterbo

For one person to be self sustaining on a vegetarian plant based diet, a field of half an acre is a minimum size without taking into account for redundancy for low yields or unforeseen issues

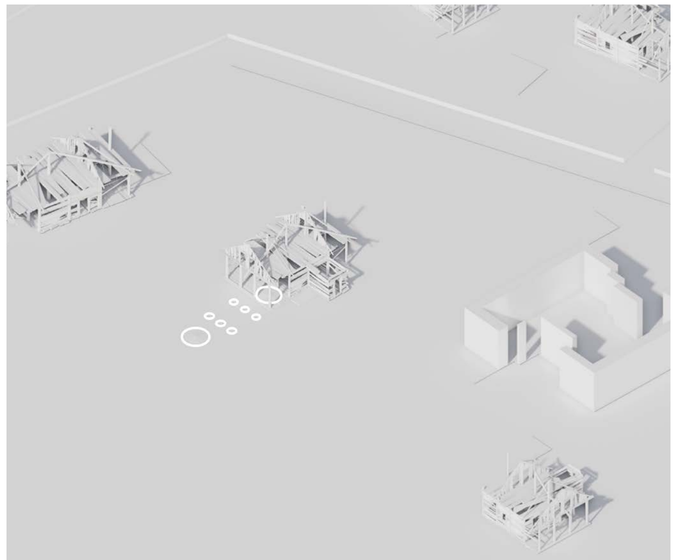
To protect itself from the external environment, the design is placed underground to place mass in the form of soil between itself and the hostile environment



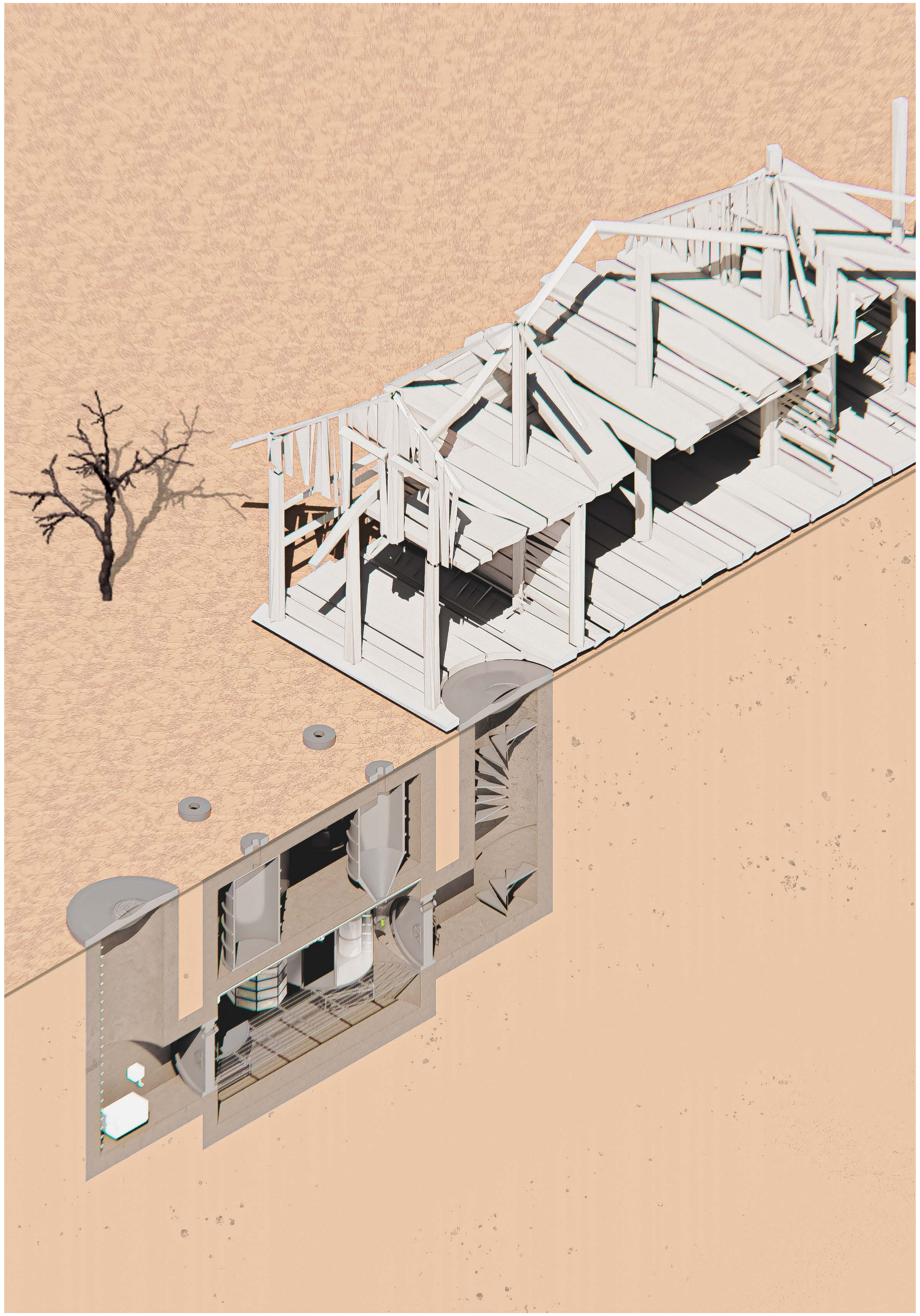
To minimize the size and cost, the design instead hosts silos filled with long lasting grains, water and retractable farming pods



The silos and tanks shape the exterior walls which aids in distributing external forces inflicted on the building

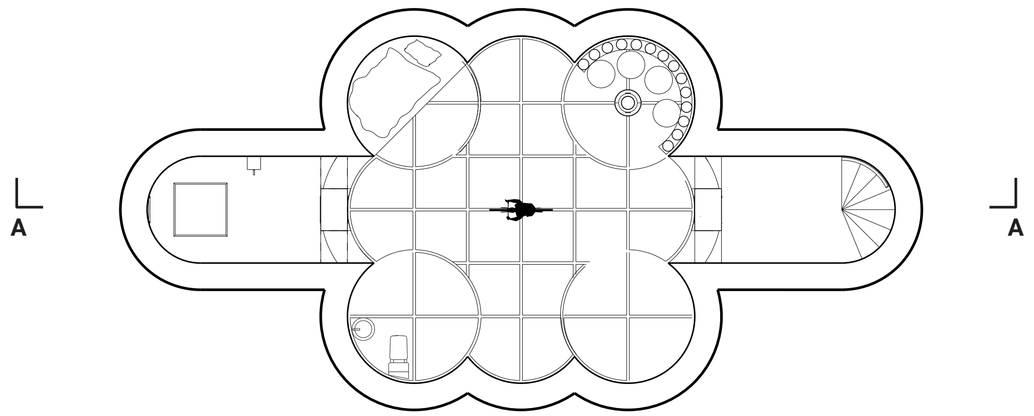


Two escape hatches are distributed in each end of the silo, witch top hatches for the silos so that they can be filled externally. Once the world around perishes, the hatches are the only thing visible.

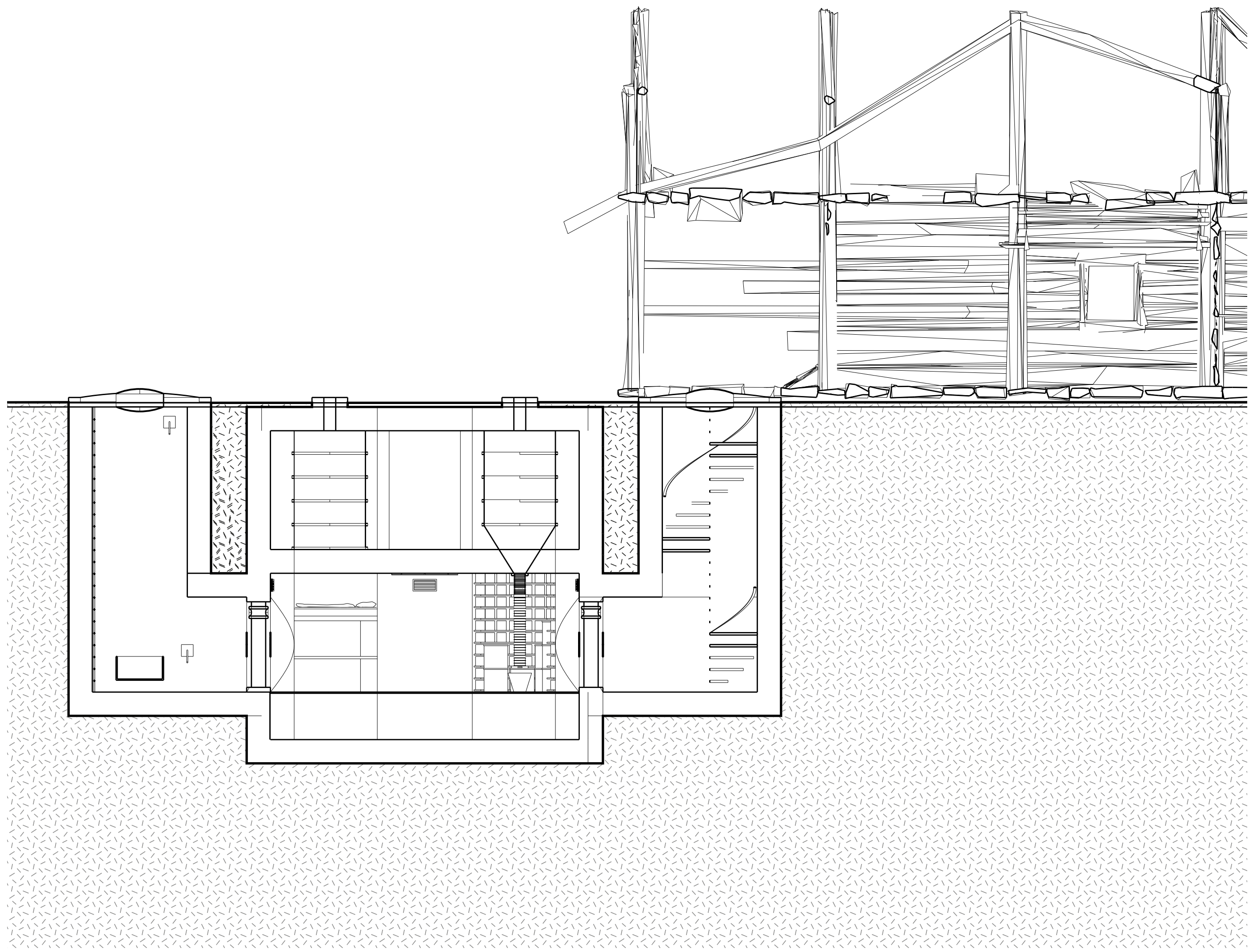


Hidden beneath the ground

Site plan. 1 : 500



Floor plan. 1 : 200



Section A - A. 1 : 200

Exterior Perspective.

Interior Perspective.

Interior Perspective.

CONCLUSION

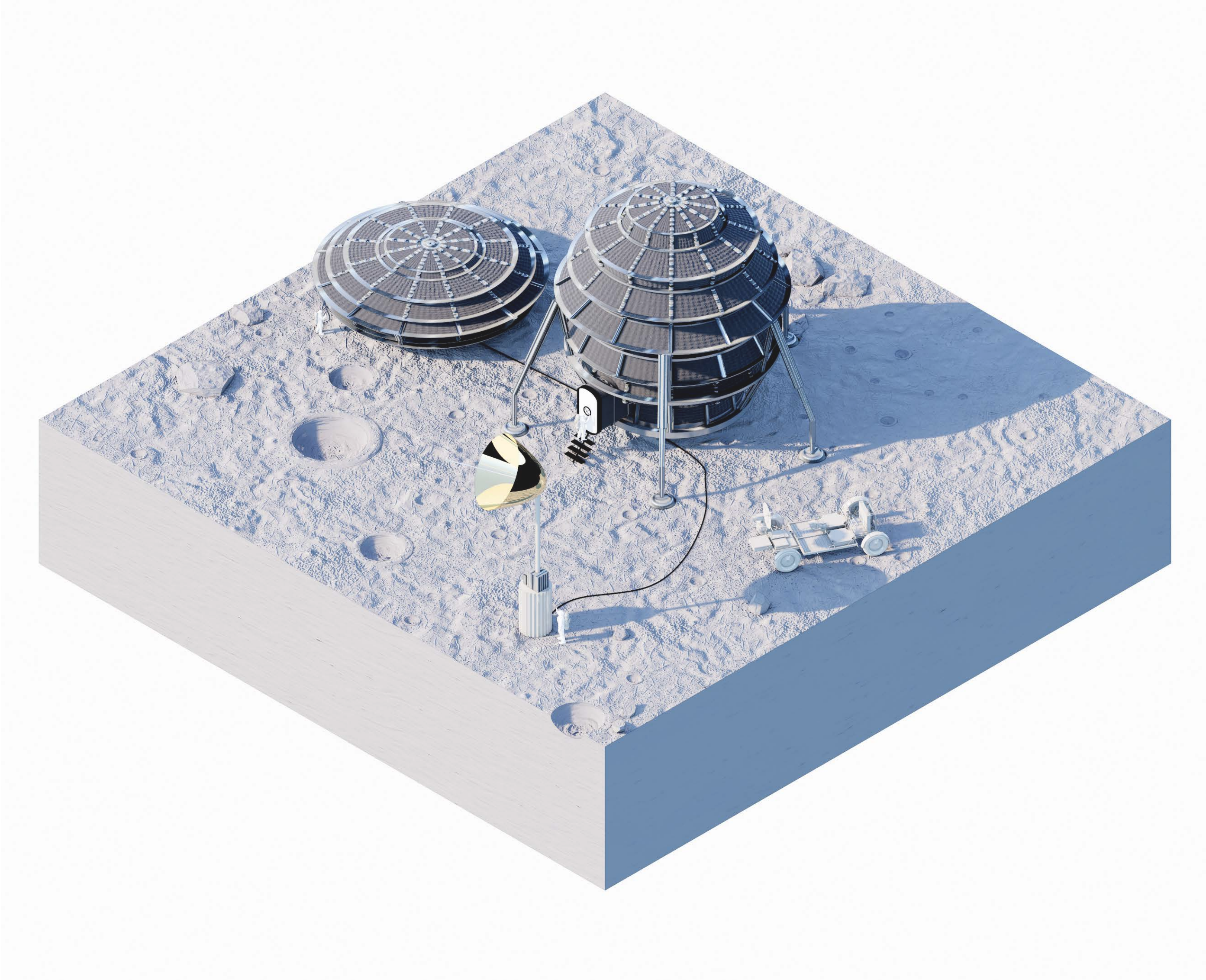
The architectural profession is facing rapid changes in the way that it presently functions. Architects' will, sooner than formerly anticipated, be forced to deal with threats and obstacles previously perceived as fictional. With global emissions on the rise and a lack of rational and political unification in a response to these, extreme climates will become a more common reality in all parts of the world.

Through the investigations of this thesis, we found that as a species, mankind has already developed the ability to design human habitats for some of the most extreme environments imaginable. Current habitats for extreme environments often place a significant impact on resources and finances due to the complexity of the projects. To some degree, many of these projects also further the effects of global emissions and thus, speeding up the process of generating more extreme environments. A catch 22.

For the architectural practice, it's imperative to both understand the challenges that the profession is facing, as well as to plan ahead and to re-imagine what a habitat entails. Current data points in the direction of a rapid and global change, which will effect us in a more significant way than what has been witnessed in previous generations. Whilst the data predicting this points in various directions, we can be certain that we've reached a point where measures has to be taken to take into account an altered future.

Through our research, this thesis have generated designs with a variety in complexity, resources and strategies to indulge in a range of different solutions. By doing so, we have gained an understand of to what extremities the profession has to turn in order to master its ability to withstand an altered climate. To not only survive, but thrive, in these extreme environments, modern architecture has to mutate and adapt. A building has to understand its local context which means not only from a historic and contemporary perspective, but to that of an unforeseen future and special attention has to be given to local resources.

Superimposing scenarios of extreme environments onto Sweden gave us the ability to challenge the perception of what contemporary Swedish architecture implies. Whilst Sweden is typically believed to be able to withstand much of the global challenges linked to increased emissions, there are scenarios where Sweden could face less likely, but more difficult challenges. We would not argue that there is a single solution to this issue, but rather many. Adaptability, and not being afraid of a mutation of the built environment is key to withstanding any potential extreme scenario in a Swedish setting. Whilst an extreme environment in a Swedish context would pose significant impact on our contemporary society and lifestyle, this thesis would argue for Sweden remaining a habitable zone with proper care for its architecture.



BIBLIOGRAPHY

WEBSITE

Cambridge Dictionary. (2023). Definition of the word "Extreme". https://dictionary.cambridge.org/dictionary/english/extreme

Halley VI Research Station. British Antarctic Survey. (2023, March 26). Retrieved April 27, 2023, from https://www.bas.ac.uk/polar-operations/sites-and-facilities/facility/halley/

IPPC. (2023). Definition of Terms Used Within the DDC Pages. https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html

Lantmäteriet. (2023) Postglacial land uplift https://www.lantmateriet.se/en/geodata/gps-geodesi-och-swepos/reference-systems/postglacial-land-uplift/

Life Coast Adapt Skåne (2023) VI TESTAR NYA METODER MOT KUSTEROSIONENS NEGATIVA EFFEKTER https://lifecoastadaptskane.se/

Myndigheten för Samhällsskydd & Beredskap (2023) Om MSB. https://www.msb.se/sv/om-msb/

Naturvårdsverket. (2023) Effekter i Sverige. https://www.naturvardsverket.se/amnesomraden/klimatforandringar/klimatet-i-framtiden/effekter-i-sverige/

Sveriges Meteorologiska och Hydrologiska Institut. (2023). Vad händer med klimatet? https://www.smhi.se/klimat/framtidens-klimat/smhis-samlade-huvudbudskap-om-klimatet-1.189288

Sveriges Meteorologiska och Hydrologiska Institut. (2014 - Updated in 2021). Vad är en klimatmodell? https://www.smhi.se/kunskapsbanken/klimat/klimatmodeller-och-scenarier/vad-ar-en-klimatmodell-1.80272

Sveriges Meteorologiska och Hydrologiska Institut. (2022) 150 år sedan Backafloden – katastrofen som ödelade Skånes kust https://www.smhi.se/bloggar/vaderleken-2-3336/150-ar-sedan-backafloden-katastrofen-som-odelade-skanes-kust-1.189508

Sveriges Meteorologiska och Hydrologiska Institut. (2020) Framtida medelvattenstånd https://www.smhi.se/klimat/stigande-havsnivaer/framtida-medelvattenstand-1.165493

Sweco (2023) Klimatanpassning av Falsterbonäset i Skåne https://www.sweco.se/projekt/falsterbonaset/

Trelleborgs kommun. (2023) Vall som kustskydd planeras vid Västra Sjöstaden. https://www.trelleborg.se/nyheter/vall-som-kustskydd-planeras-vid-vastra-sjostaden/

United Nations. (2023). Climate change - united nations sustainable development. United Nations. https://www.un.org/sustainabledevelopment/climate-change/

United Nations. (2022, May 1). Climate change - united nations sustainable development. United Nations. https://www.un.org/sustainabledevelopment/climate-change/

United Nations. (2023). THE 17 GOALS https://sdgs.un.org/goals

U.S Department of Argiculture. (2023) Climate Hubs, Extreme Weather. https://www.climatehubs.usda.gov/content/extreme-weather

Visit Sweden. (2023) Swedish weather and climate. https://visitsweden.com/about-sweden/weather-and-climate/

Ystad Kommun (2020) Strandfodring i Ystad Sandskog https://www.ystad.se/bygg-miljo/miljo-och-avfall/natur-miljo-och-klimat/erosionsskadecentrum/projekt/strandfodring-i-ystad-sandskog/

LITERATURE

Boukhchim, N. (1), Fraj, T. B. (2,3), & Reynard, E. (4). (2018). Lateral and "Vertico-Lateral" Cave Dwellings in Haddej and Guermessa: Characteristic Geocultural Heritage of Southeast Tunisia. Geoheritage, 10(4), 575-590–590. https://doi.org/10.1007/s12371-017-0251-2

Levy, J. (2006). The doomsday book: Scenarios for the end of the world. Vision Paperbacks.

Sheppard, L., & White, M. (2017). Many Norths: Spatial practice in a polar territory. Lateral office.

REPORTS AND ARTICLES

Bjerström, E. (2021, February 22). Ny Forskning: Golfströmmen Har Mattats av UPP emot 20 procent. SVT Nyheter. https://www.svt.se/nyheter/utrikes/varningen-golfstrommen-kan-stanna-helt-1

Caesar, L., McCarthy, G. D., Thornalley, D. J., Cahill, N., & Rahmstorf, S. (2021). Current Atlantic Meridional Overturning Circulation Weakest in last millennium. Nature Geoscience, 14(3), 118–120. https://doi.org/10.1038/s41561-021-00699-z

Choi, J. (2017). Extreme Environment Architecture. Honolulu: University of Hawaii at Manoa

Farooqi, S. (2020, December 24). Rose island: The building of a utopia. Engineering.com. https://www.engineering.com/story/rose-island-the-building-of-a-utopia

Feldmann, J., & Levermann, A. (2015). (rep.). (M. Oppenheimer, Ed.)Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin. Princeton, NJ: Princeton University.

Gualandris, D. (2021, May 26). The Matmata pit dwellings keeping the Tunisian indigenous past alive. IGNANT. https://www.ignant.com/2020/08/21/the-matmata-pit-dwellings-keeping-the-tunisian-indigenous-past-alive/

Länsstyrelsen i Skåne län (2011). Klimatanpassningsatlas för Skåne. https://www.lansstyrelsen.se/download/18.2e0f9f621636c84402730ead/1528811177641/LSTM_2011_Klimatanpassningsatlas_for_Skane.pdf

Hieronymus, M., Dieterich, C., Andersson, H. & Hordoir, R. (2018) The effects of mean sea level rise and strengthened winds on extreme sea levels in the Baltic Sea. Elsevier Ltd on behalf of The Chinese Society of Theoretical and Applied Mechanics. http://dx.doi.org/10.1016/j.taml.2018.06.008

Montali, S. (2022, August 18). The floating homes of Lake Titicaca. BBC Travel. https://www.bbc.com/travel/article/20220814-the-floating-homes-of-lake-titicaca

NASA and Jamestown Education Module. (2007). Exploration: Then and Now -- NASA and Jamestown Education Module. Human Needs. 1-17.

National Research Council (US). Committee on Diet and Health. (1989). Diet and Health: Implications for Reducing Chronic Disease Risk. Washington DC: National Academies Press

Ringqvist, A., & Eriksson, U. (2020). 'Havsnivån är inget som oroar oss' : En fallstudie av bostadsägares perspektiv på översvämningsrisken i Skanör-Falsterbo (Dissertation). http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-414011

Robbins, O. (2021, February - Updated March 2021) Hydroponics: How It Works, Benefits and Downsides, & How to Get Started. https://foodrevolution.org/blog/hydroponics/

Rothschild, L., Mancinelli, R. (2001). Life in extreme environments. Nature 409, 1092–1101. https://doi.org/10.1038/35059215

SAGA Space Architects. (2021, January 6). Lunark. SAGA Space Architects. https://saga.dk/projects/lunark

Seneviratne, S.I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M. Wehner, and B. Zhou, (2021). Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1513–1766, doi: 10.1017/9781009157896.013.

Statens Geotekniska Institut and Myndigheten för Samhällsskydd & Beredskap. (2021) Riskområden för ras, skred, erosion och översvämning. https://www.msb.se/siteassets/dokument/om-msb/vart-uppdrag/regeringsuppdrag/2021/ru-riskomraden.pdf

Swedish Governemt (2018). Nationell Strategi för Klimatanpassning. https://www.regeringen.se/contentassets/8c1f4fe980ec4fcb8448251acde6bd08/171816300_webb.pdf

United Nations Environment Programme (2022). 2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi.

United Nations High Commissioner for Refugees (UNHCR). (2022). Climate Change, Displacement and Human Rights https://www.refworld.org/docid/6241c27d4.html

Qian, Yun, Jackson, Charles, Giorgi, Filippo, Booth, Ben, Duan, Qingyun, Forest, Chris, Higdon, Dave, Hou, Z. Jason, & Huerta, Gabriel. (2016). Uncertainty Quantification in Climate Modeling and Projection. Bulletin of the American Meteorological Society. https://doi.org/10.1175/BAMS-D-15-00297.1

IMAGE

Alder, J., Hostetler, S. & Williams, D. (2013). An interactive web application for visualizing climate data. EOS 94, 197–198.

Morris, J. (2017). The Halley VI British Antarctic Research Station. Halley VI British Antarctic Research Station A pioneering relocatable polar science research station. Retrieved December 10, 2021, from https://hbarchitects.co.uk/halley-vi-british-antarctic-research-station/.

Murray, S. (2016). Berber Hôtel Sidi Driss,. Creative commons. Retrieved March 6, 2023, from creativecommons.com.

NASA. (2022). A view of BEAM and other modules from a space station window. Retrieved 2023, from https://www.flickr.com/photos/nasa2explore/52276818358.

Pino, G. (2017). Rose Island 1968. mondadori portfolio. Retrieved 2023, from https://www.gettyimages.co.uk/photos/mondadori-portfolio.

Ruddiman, W.F. (2000). Concept Diagram of Climate Modeling. Earth's climate: Past and Future.

SMHI. (2014 -accessed in 2023) Vad är en global klimatmodell? https://www.smhi.se/kunskapsbanken/klimat/klimatmodeller-och-scenarier/vad-ar-en-global-klimatmodell-1.80273

SAGA Space Architects. (2021, January 6). Lunark. SAGA Space Architects. https://saga.dk/projects/lunark

Titicaca Uros. (2017). Bolivia Travel Site. Retrieved February 2, 2023, from https://boliviatravelsite.com/Images/ArticlePhotos/titicaca-uros.jpg.

United Nations. (2015 - accessed in 2023). Take Action for the Sustainable Development Goalshttps://www.un.org/sustainabledevelopment/sustainable-development-goals/

World Bank Group. (2016). Model-simulated global temperature anomalies for the Last Glacial Maximum (21,000 years ago), the mid-Holocene (6,000 years ago), and projection for 2071–2095, under RCP8.5. https://climateknowledgeportal.worldbank.org//sites/default/files/inline-images/Fig2.jpg. Retrieved February 4, 2023,.

Climate Mutants
The rise of the extremophiles

Casper Klarén & Johannes Welander

Examiner: Kengo Skorick
Supervisor: Jonas Lundberg

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Master's Programme of Architecture and Urban Design (MPARC)
Spring 2023

Page Count : 91
Main Booklet 91
Appendix 1: Toolkit 6
Appendix 2: Prototypes 20

Apendix 1

Climate Mutants

The rise of the extremophiles

Casper Klarén & Johannes Welander

Examiner: Kengo Skorick
Supervisor: Jonas Lundberg

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Spring 2023

TOOLKIT

The toolkit consists of findings extracted from the research which we believe could be useful in a further design project development. The toolkit acts as a complementary aid, and the combination of several tools could assist in further development of additional tools and strategies in the process of designing for extreme environments.

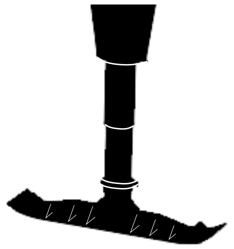
The toolkit is based on contemporary and existing technology but its scope ranges from practical and historical solutions to cutting edge modern applications. By having a wide scope of tools, the idea is to create a resilience of architectural utilities that can be implemented and used for a wide range of purposes and users.

Forming this array of tools, this thesis aims to develop a guideline for others to discuss, use and continue on expanding as a way to deal with changing environments. By setting up a framework of tools for the architectural practice this project aspire to help share knowledge and make more human habitats permitted to adapt to global climate changes.

TOTORA REEDS

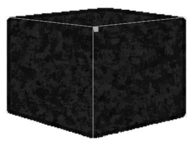
Totora is a type of reed that grows in wetland areas of South America, particularly in Peru and Bolivia. This plant has been used by the indigenous people of the Andean region for thousands of years for a variety of purposes, including food, medicine, and building materials.

SKI FEET



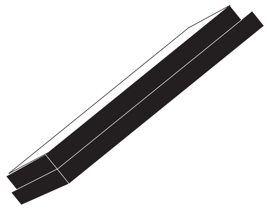
The ski feet found on Halley VI allows the structure to be moved across the ice and snow. They were designed to keep the structure level and stable while being towed across the icy landscape and provides a solid foundation for the structure in the extreme arctic conditions.

AEROGEL



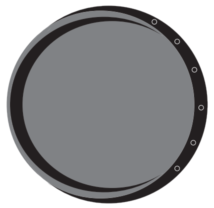
Aerogel is a material that is made up out of 99.8% air and is one of the lightest solids in the world. Despite its density, it acts as an excellent insulator and has a high surface area, making it useful for a wide range of applications in not only space but also as building insulation and electronics.

SKI FEET



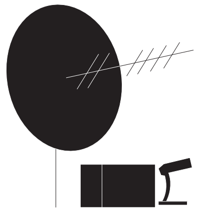
A lighting system designed to regulate the circadian rhythm of humans in space habitats. A combination of LED lights and sensors creates a replica of the cycle of the sun, giving a sense of day and night while in space. It aims to improve sleep quality and overall well-being during long-duration extra terrestrial travel.

PORTHOLE WINDOW



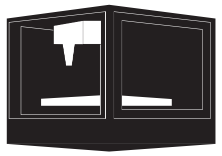
The porthole window distributes pressure omni-directionally which gives it great protection against high or low pressure environments whilst give us humans the opportunity to see outwards.

VHF RADIO SYSTEM



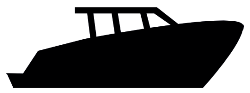
For communication in isolated areas, a communication tool in the form of a VHF dish and FM / SSB broadcasting and receiving systems.

3D PRINTER



The 3D-printer offers advantages of producing complex geometry and replicating parts in whatever material is provided.

BOAT

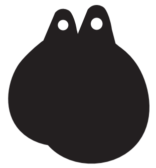


An electrically powered boat enables relatively short durations at sea, but provides the ability to replenish and ferry rides between mainland and other floating structures at sea.

OYSTER FARMING

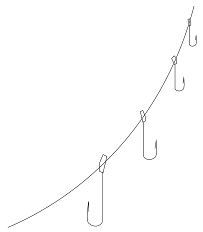
Oysters and clams have been designated as a very effective means of ocean based protein farming. They produce in high numbers, and compared to wild mollusk breeds, they often yield higher nutritional value and carries a lower number of deceases.

UPCYCLED OCEAN PLASTIC



Ocean plastic already exists in an abundance, and with expected increases in water levels around the globe, the amount of ocean plastic is expected to rise. Instead of seeing the plastics as an issue, it could be used as a prominent resource.

FISHING LINE



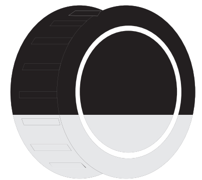
A fishing line can be used to capture fish and mollusks which are sourced locally, providing fats and proteins in coastal or ocean areas

---

KELP FARMING

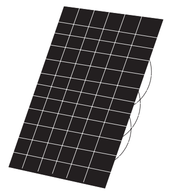
Kelp and other sea weed form a great plant aquatic plant base for a diet. They offer anti-oxidants and nutrients while at the same time offer the ability to be used as a resource material.

WAVE TURBINE



These turbines utilities the energy absorbed from waves. Ranging from a number of different designs, its origins comes from the simple mill-wheel. With the almost constant production of waves, it could be considered as a low yield but reliable energy source.

SOLAR CELLS

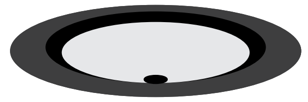


Energy efficient way of harvesting energy during sunny days and day time. Perhaps not utilized as effectively in northern Europe, it still offers a redundancy in supply.

WATER TANK

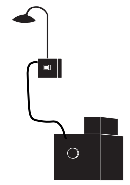
Used for storing fresh water for drinking and sanitary duties. Typically made from PVC plastic.

RAINWATER COLLECTOR



A funnel collects rainwater which is then filtered and purified before stored in a water tank beneath. The freshwater can be used advantageously on open waters.

GREY WATER RECYCLING



By recycling the gray water internally within, a significant amount of water usage can be saved, by reusing the water in showers and basins.

SALTWATER PURIFIER

Using the vast amount of saltwater in an oceanic setting allows for a continuous supply of freshwater. By distilling away the salts and bacteria, salt water can then be used for all purposes.

TENT

The simple combination of fabrics and supports provide a rugged shelter able to protect from various extreme environments. The tent emphasizes on keeping precipitation out from what's beneath.

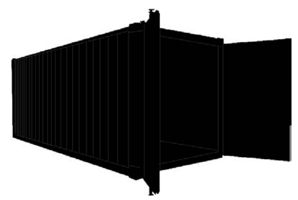
SNOWMOBILE

The snowmobile offers a simple and easy transportation in arctic environments. The speed gives advantage of covering large distances quickly in emergencies. The size makes it easy to stow.

HYDROPONIC FARMING

A lighting system designed to regulate the circadian rhythm of humans in space habitats. A combination of LED lights and sensors creates a replica of the cycle of the sun, giving a sense of day and night while in space. It aims to improve sleep quality and overall well-being during long-duration extra terrestrial travel.

SHIPPING CONTAINER



Used for cold storage of food during winter and shed in summer. The transportability of the shipping container means it can easily be swapped, and its standardization means for easier logistics.

HUNTING RIFLE

Remington 700 chambered in .308. Used for hunting and scaring away predators.

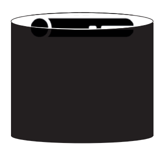
VERTICAL GARDENING

With a small footprint, the vertical gardening method generates a larger yield of harvest in small spaces.

WIND TURBINE

An omni-directional wind turbine produces electricity more often, but at a lower yield compared to a fixed turbine.

FIREPLACE



Used for keeping warm.

GENERATOR

Used to produce electricity in emergencies as a redundancy system

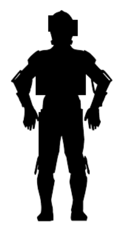
MELTING SNOW

In cold climates snow and ice can be melted and boiled to produce large quantities of clean water.
Is dependent on external energy source.

BLAST-PROOF DOORS

Commonly seen in vaults and bunkers, the blast-proof doors can withstand an immense amount of exterior pressure. They are used to seal themselves from external environments

NURSEBOT



XYL-0345 comes from the XY-NURSE series from MediBot industries. They are designed with the trademark MediBot AI. They offer the abilities of social interactions, medical surveillance, emergency surgery and daily assistance.

INSECT FARMING

Crickets and larvae produce 500% efficiency in protein production compared to beef. They require little need for attention and reproduce with few resources.

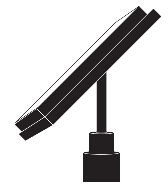
SILO

Steel silos are used for storing grains. They are modified with a double sealing system and a blast proof nozzle hatch to prevent foreign objects to enter them from the top.

MUSHROOM FARMING

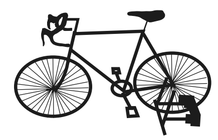
Mushrooms require little to no light to grow and offers the ability to produce large yields with little resources.

EXPANDABLE SOLAR CELLS



Protected from events, the solar cells can then expand out and catch rays of light. Within the tube, they are cleaned with water.

BICYCLE GENERATOR



Used to produce small amounts of electricity with the benefit of creating exercise that is easy on joints.

CLOSED WATER RECYCLING

Used to retain all water within a closed system that is purified from bacteria.

BACKUP WATER TANKS

Used as a redundancy system in case of any catastrophic failure in other water tanks with development of bacteria or radiation.

Apendix 2

Climate Mutants

The rise of the extremophiles

Casper Klarén & Johannes Welander

Examiner: Kengo Skorick
Supervisor: Jonas Lundberg

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Spring 2023

PROTOTYPES

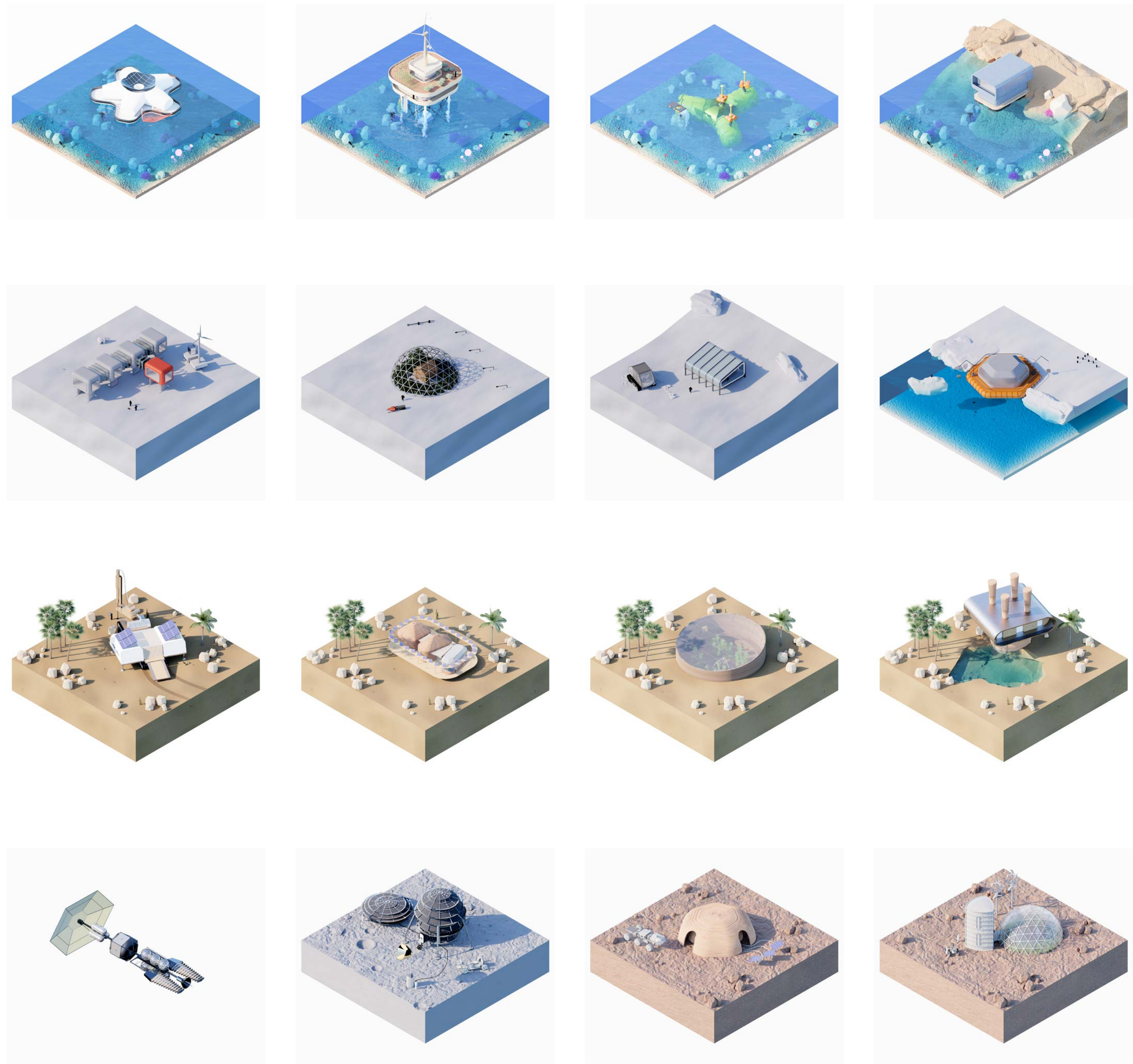
As an introductory crash course in designing for- and constructing in various extreme climates, we challenged ourselves to develop a series of prototypical habitats and shelters by looking at traditional, emerging and future building technologies from said climates.

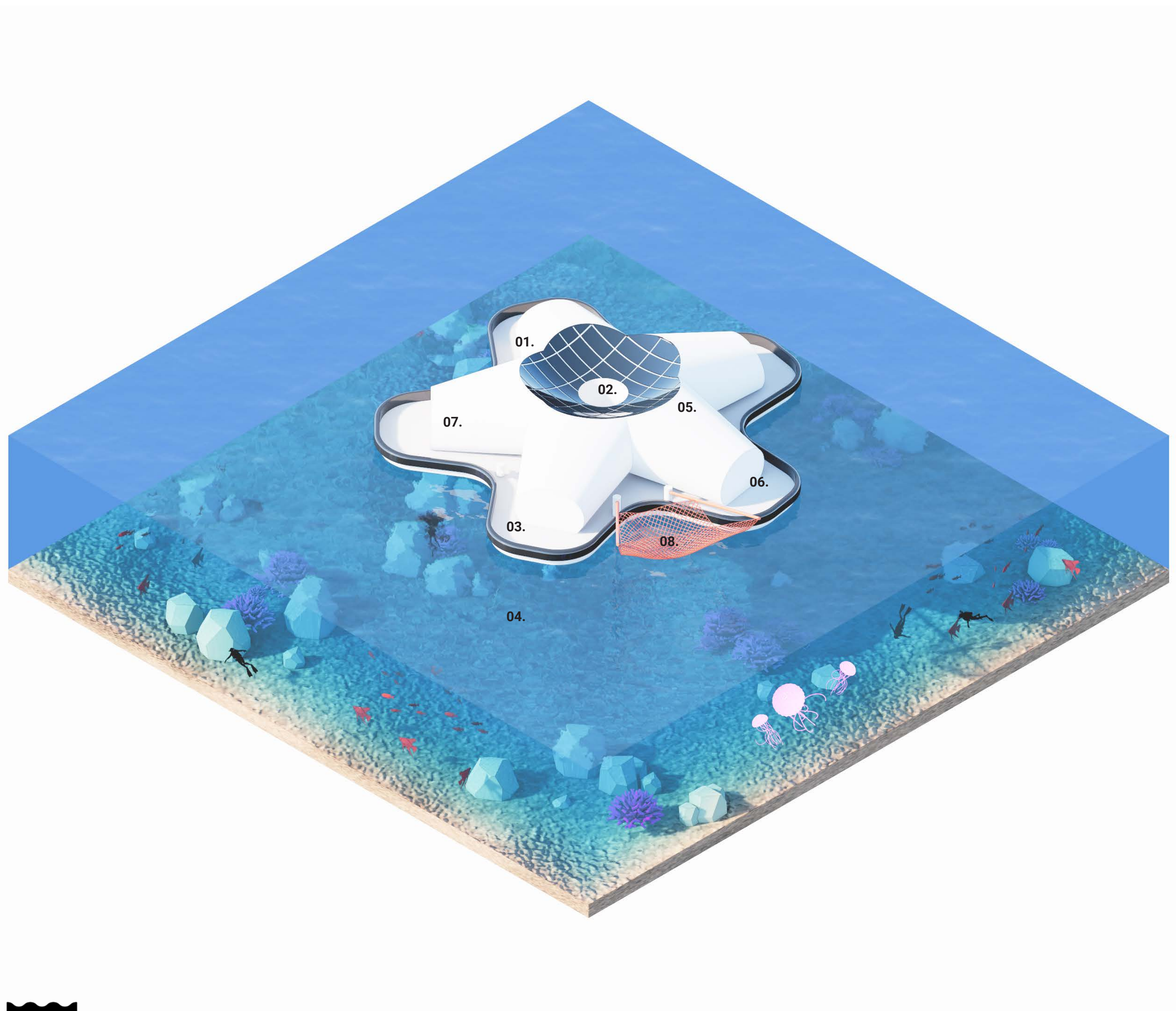
A notional but climate wise defined site was constructed and acted as an early test bed for digital three dimensional exploring using the results and findings from our research and case study investigations.

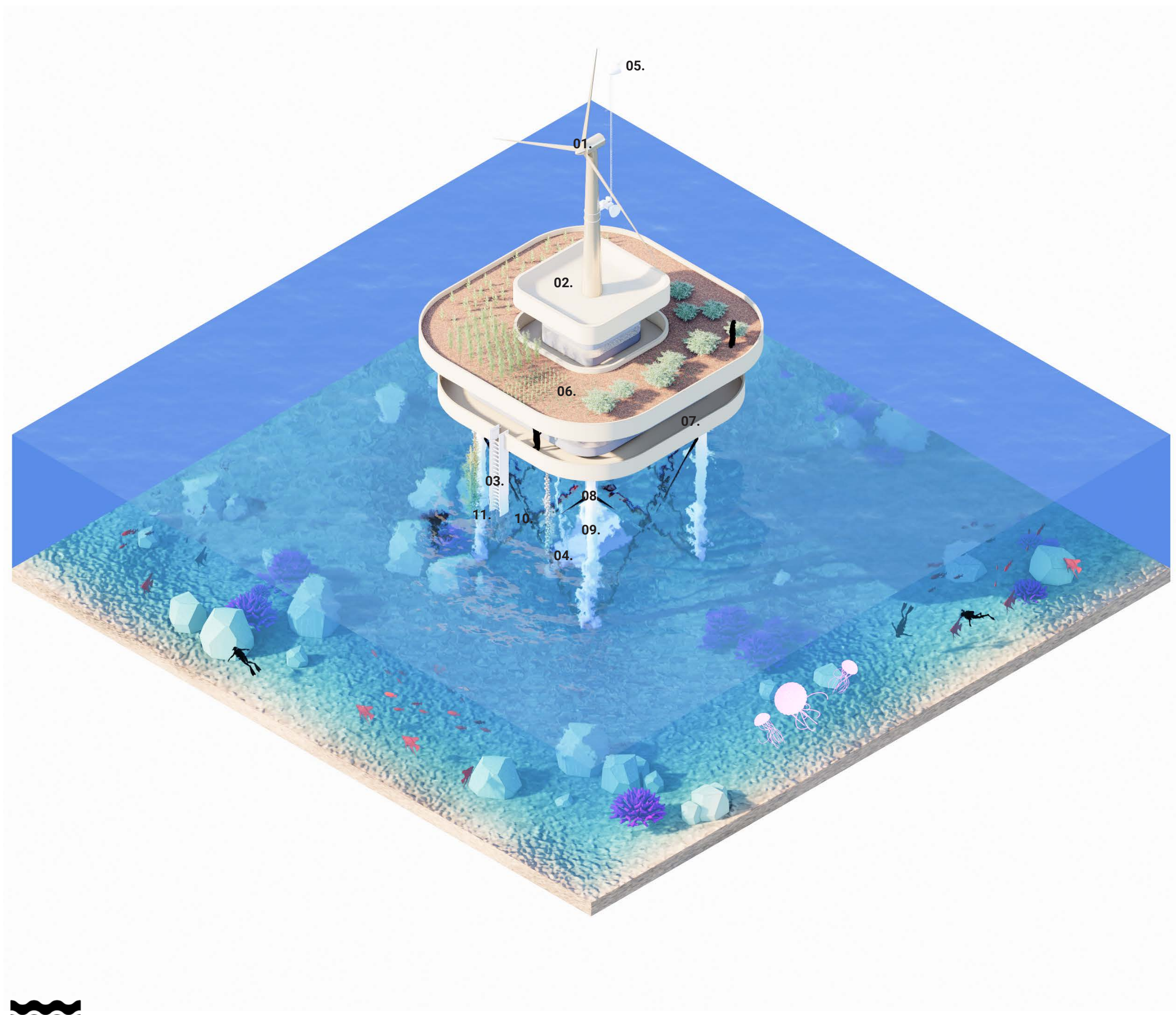
We set out a base framework for what the architectural prototypes would need in order to be not always self sufficient but at least self supportive. The main focal point of the units are on the materiality and functionality of the structures and less development was put into the internal spatial qualities.

The prototype units are designed with the main idea that they should be resilient to the various harsh weather conditions exposed to. The units are different levels of self-sustainable and the materials and functions are to be responsive in a sense that they are chosen site specifically. Further the units aim to have minimal environmental impact, given their specific site constraints.

The 16 prototypes are divided equally on for four different extreme environments:
Arctic, Deep Sea, Desert, and Outer Space. Each of these environments were then defined as four different typologies that we thought could be good ways to respond to the given site.





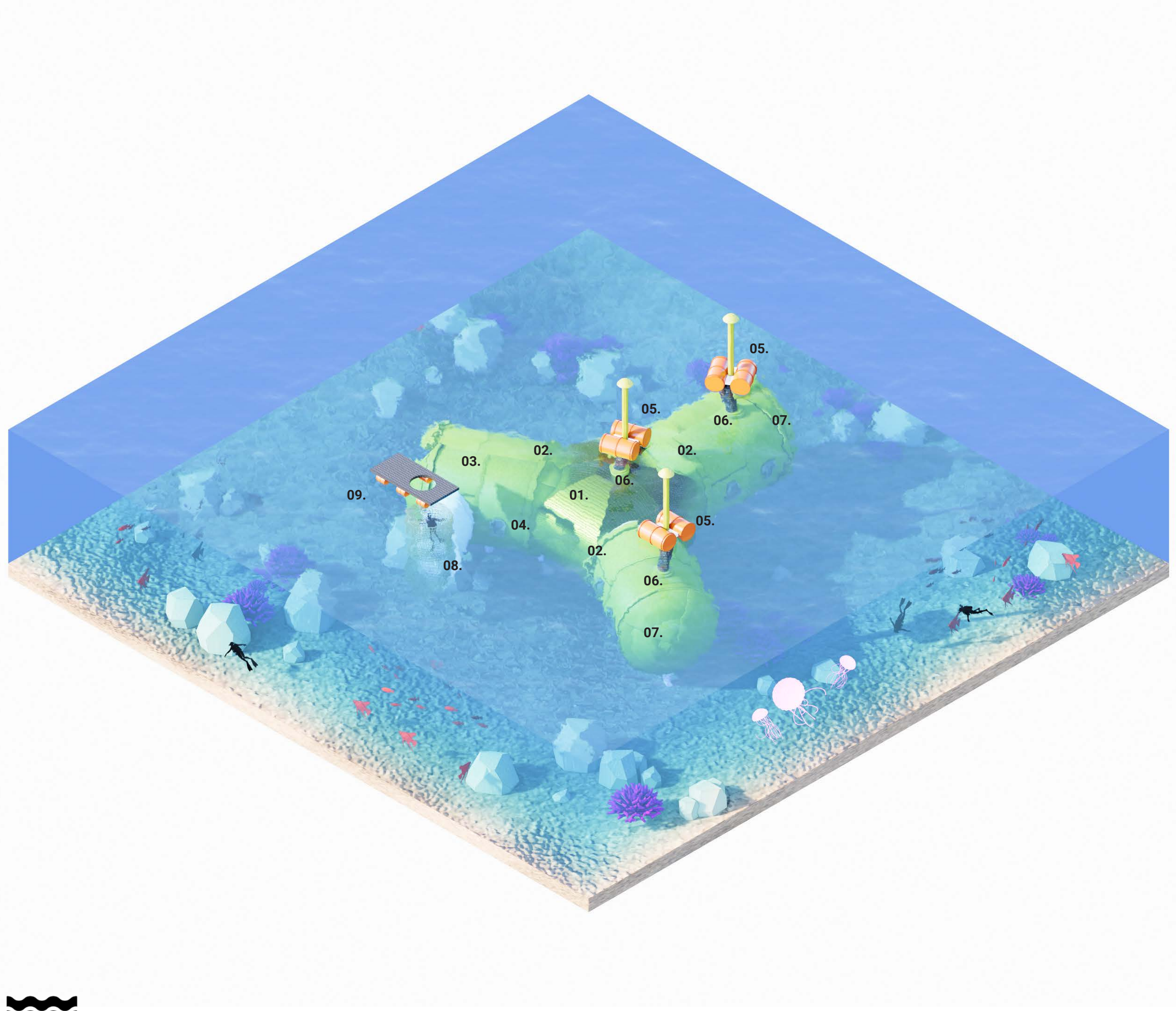


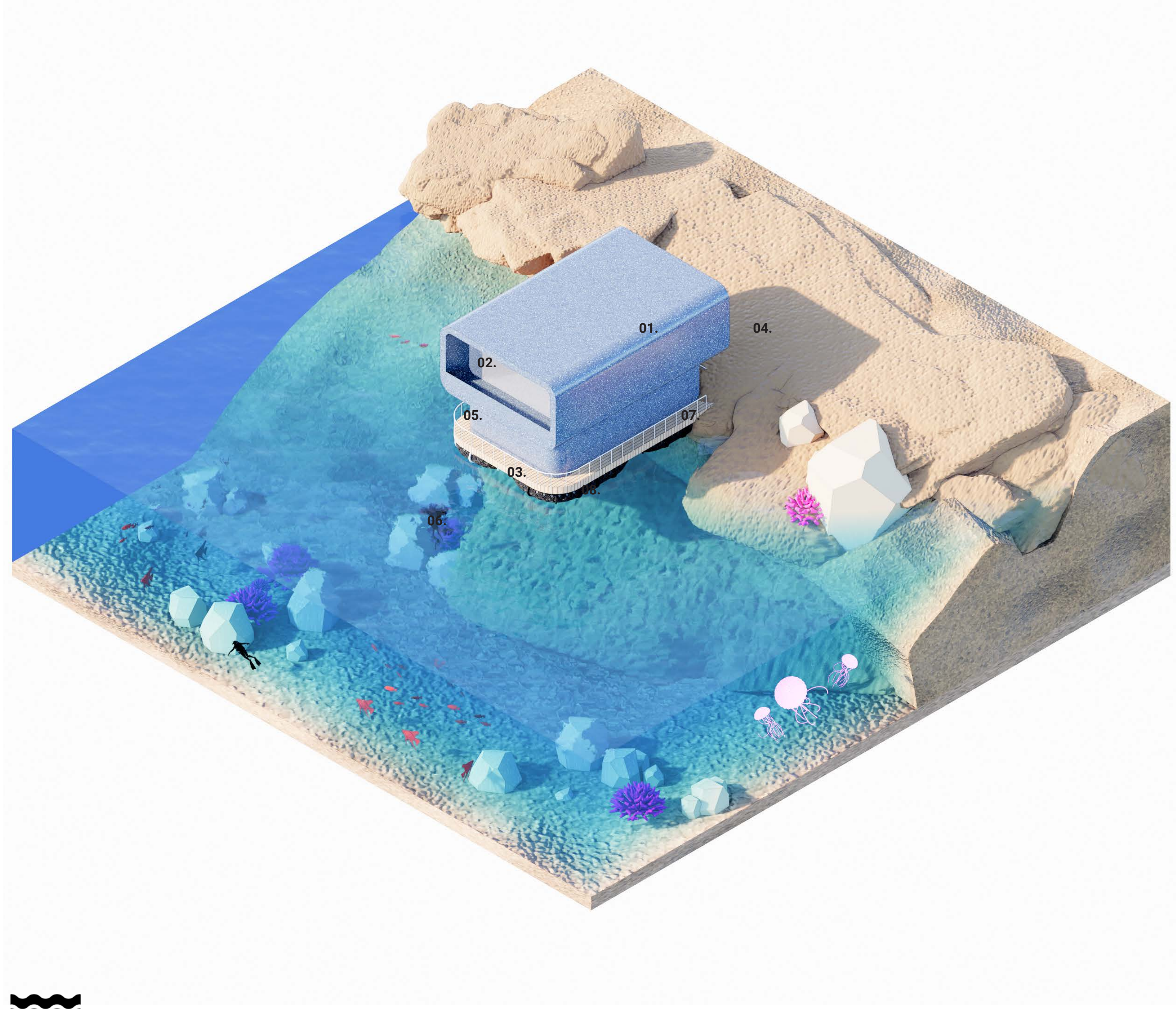
01. FLOATING

01. Solar Panels for energy supply
02. Rainwater collection
03. Rubber to allow for docking with boats and other units
04. Retractable Anchor
05. Low Center of Gravity induces protection against flipping over by waves
06. Wide base for low surface tension
07. Hull made from Aluminum for ease of Maintenance
08. Fishing net / Hammock
09. Oyster farming chain
10. Kelp farming chain

02. FIXED

01. Wind turbine
02. Rainwater collection
03. Multiple long ladders for access in all types of scenarios
04. Ocean floor wave turbine
05. Communication tools elevated for greater
06. range
Farming on roof top, with a wider platform to
07. catch more rainwater
Wider platform provides more shading in
08. living unit
09. Pneumatic legs to keep platform above water
10. Oyster farming chain
11. Kelp farming chain



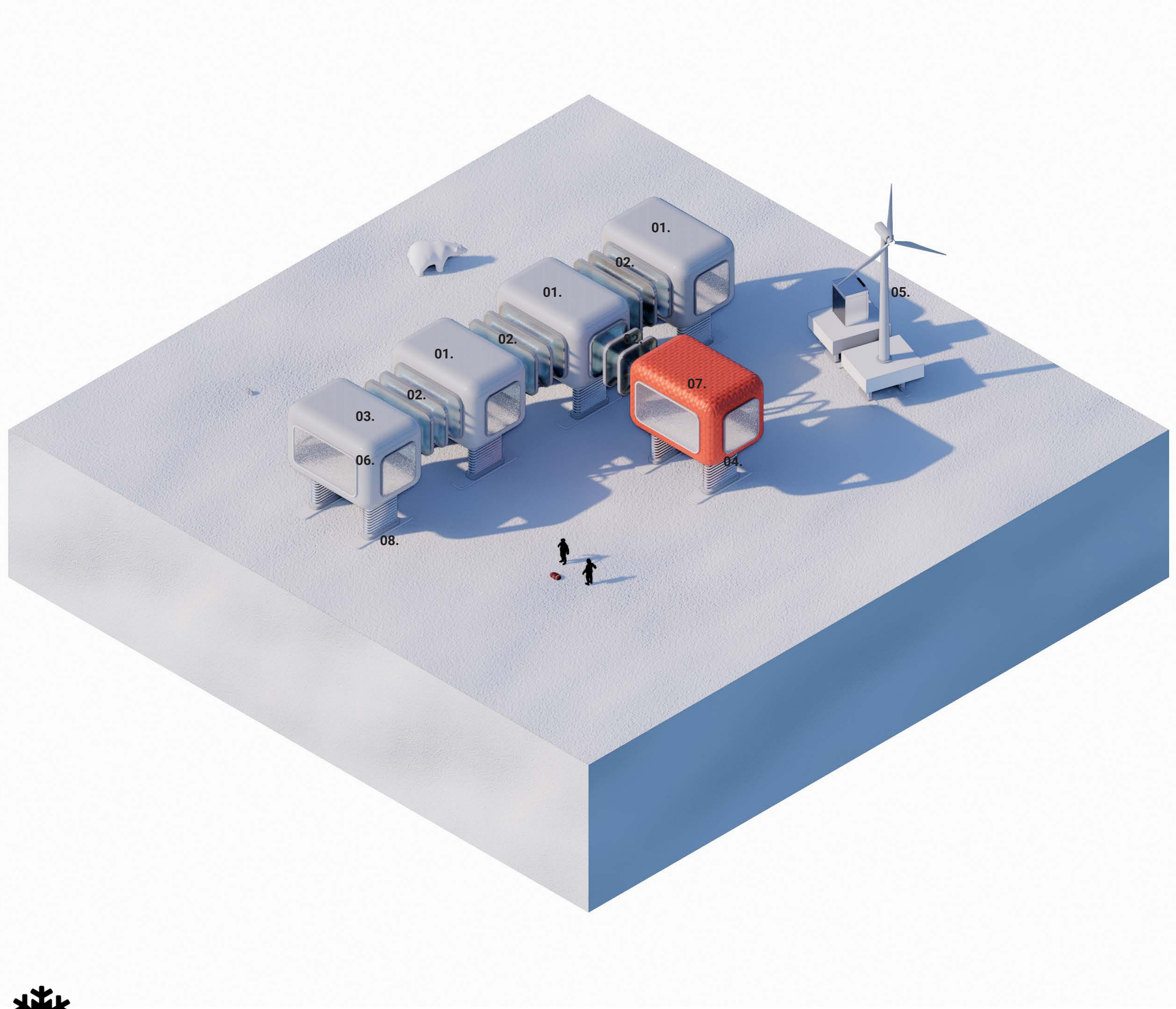


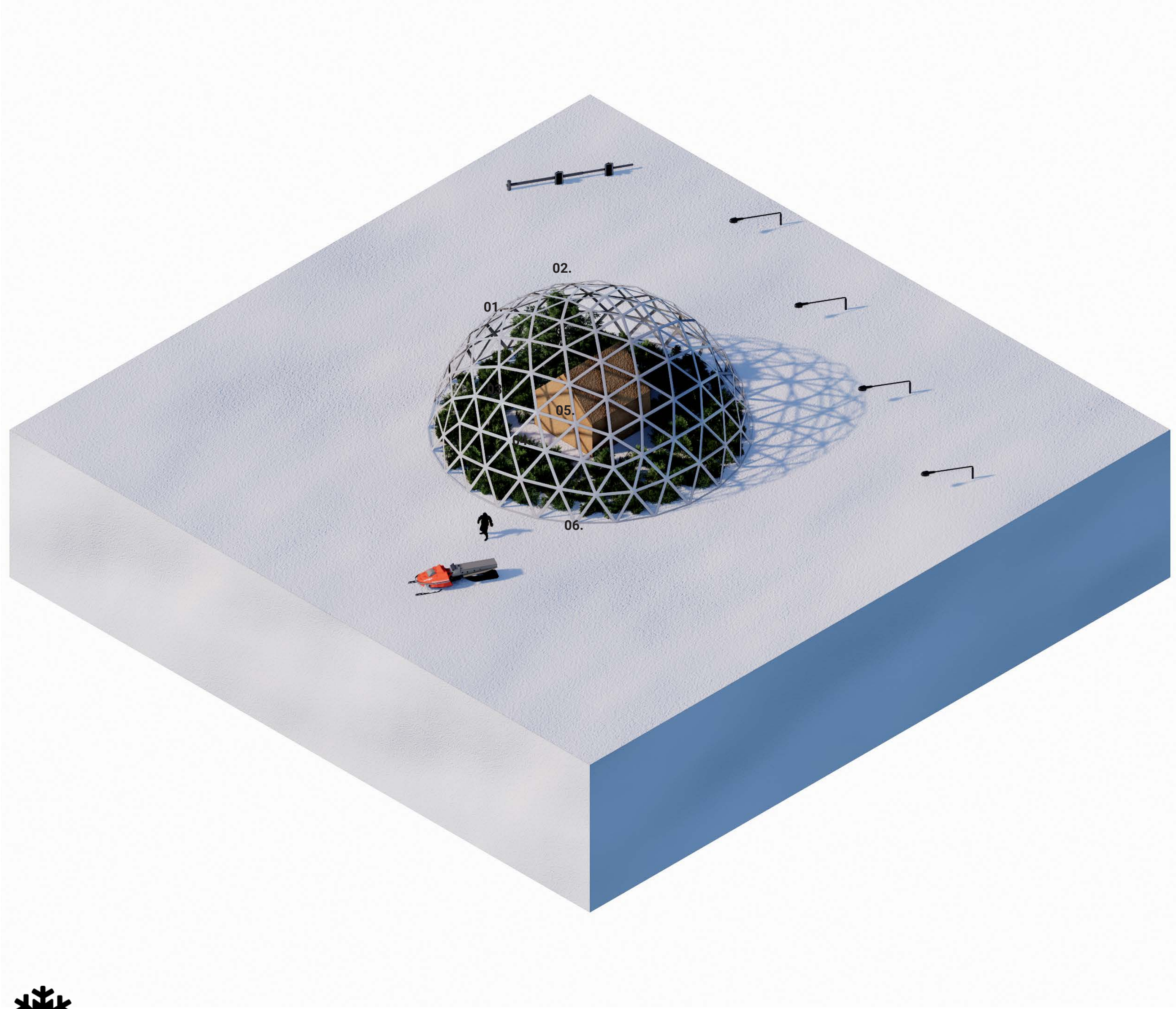
03. SUBMERGED

01. Social and kitchen unit
02. Compartment water seals
03. Access compartment & storage
Floating Dock
04. Oval windows for increased strength against pressure
05. Independent floating oxygen system to keep intakes above water with position light
06. Expandable oxygen pipe to adapt to changing water heights
07. Living Units
08. Oyster farming & protective entrance cage
09. Floating dock

04. LAND + SEA

01. Composite material matrix with recycled plastic and bio resin
02. Deep balcony for solar and wind protection
03. Flotation devices
04. Retractable and expandable landing dock
05. Wooden deck
06. Ocean floor wave turbine



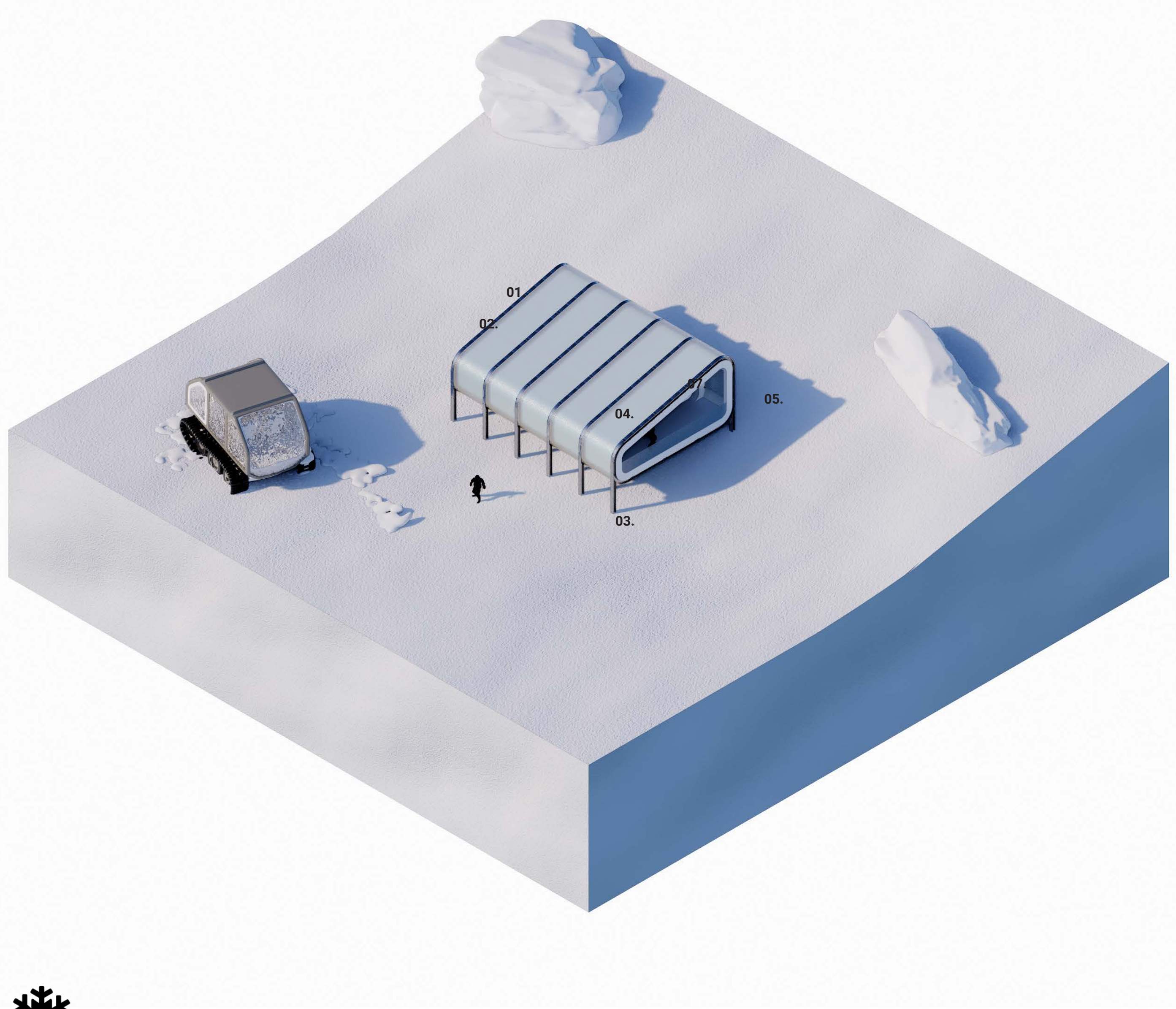


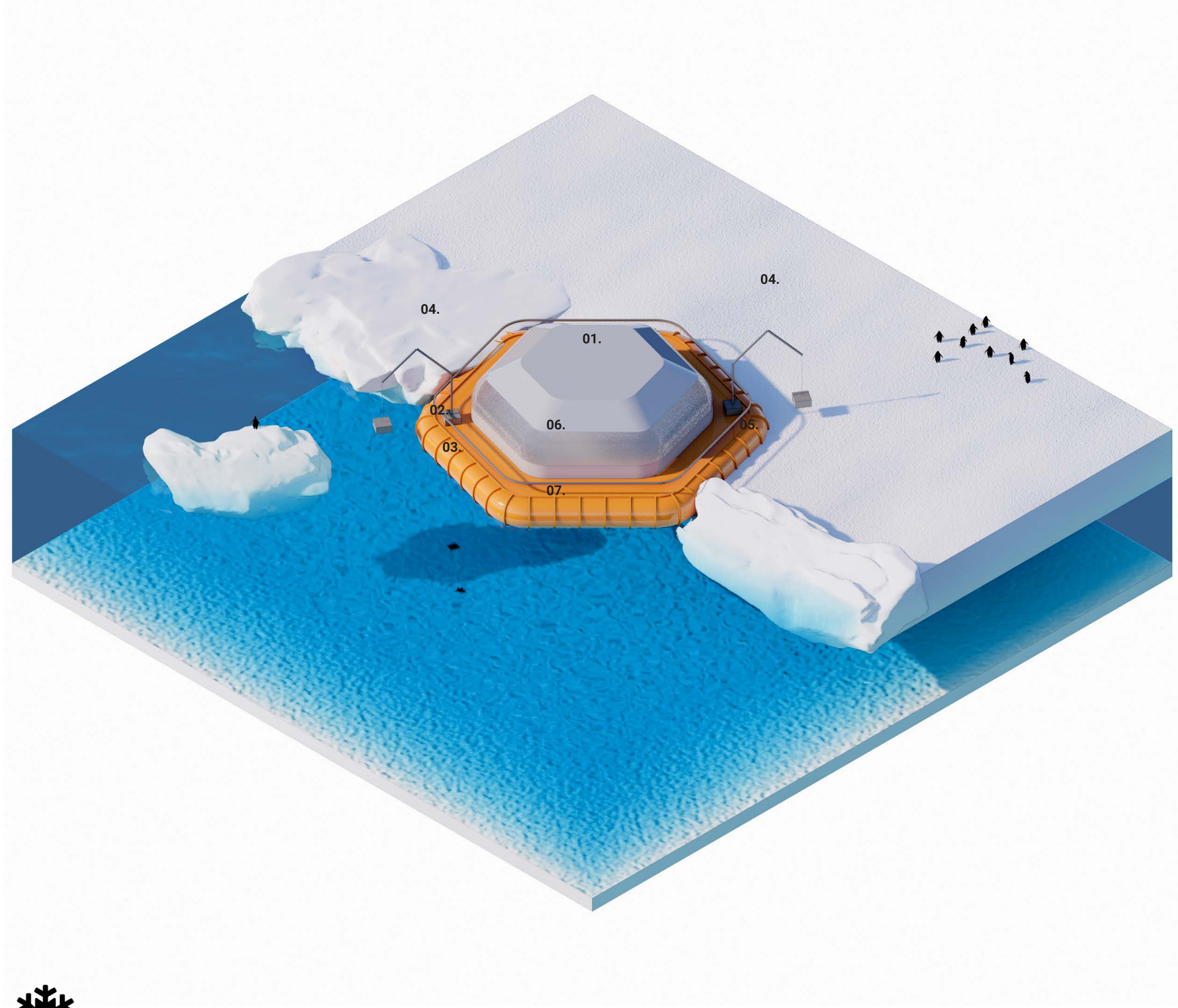
01. PORTABLE

01. Living Pods
02. Variable and disconnected connection tubes to be able to transport each pod individually
03. Farming pod
04. Hydraulic legs to elevate unit to account for Extreme winds and shifting snow height
05. Wind turbine
06. Pods made from GRP, Glass Reinforced Plastic
07. Social and dining pod
08. Metal skis for ease of transportation in snow

02. FIXED

01. Translucent solar panel film
02. Geodesic dome structure
03. Plantation for food supply
04. windows with ballooning capability to remove build up of ice
05. Housing unit with cork
06. Inflatable bottom to keep it elevated above snow



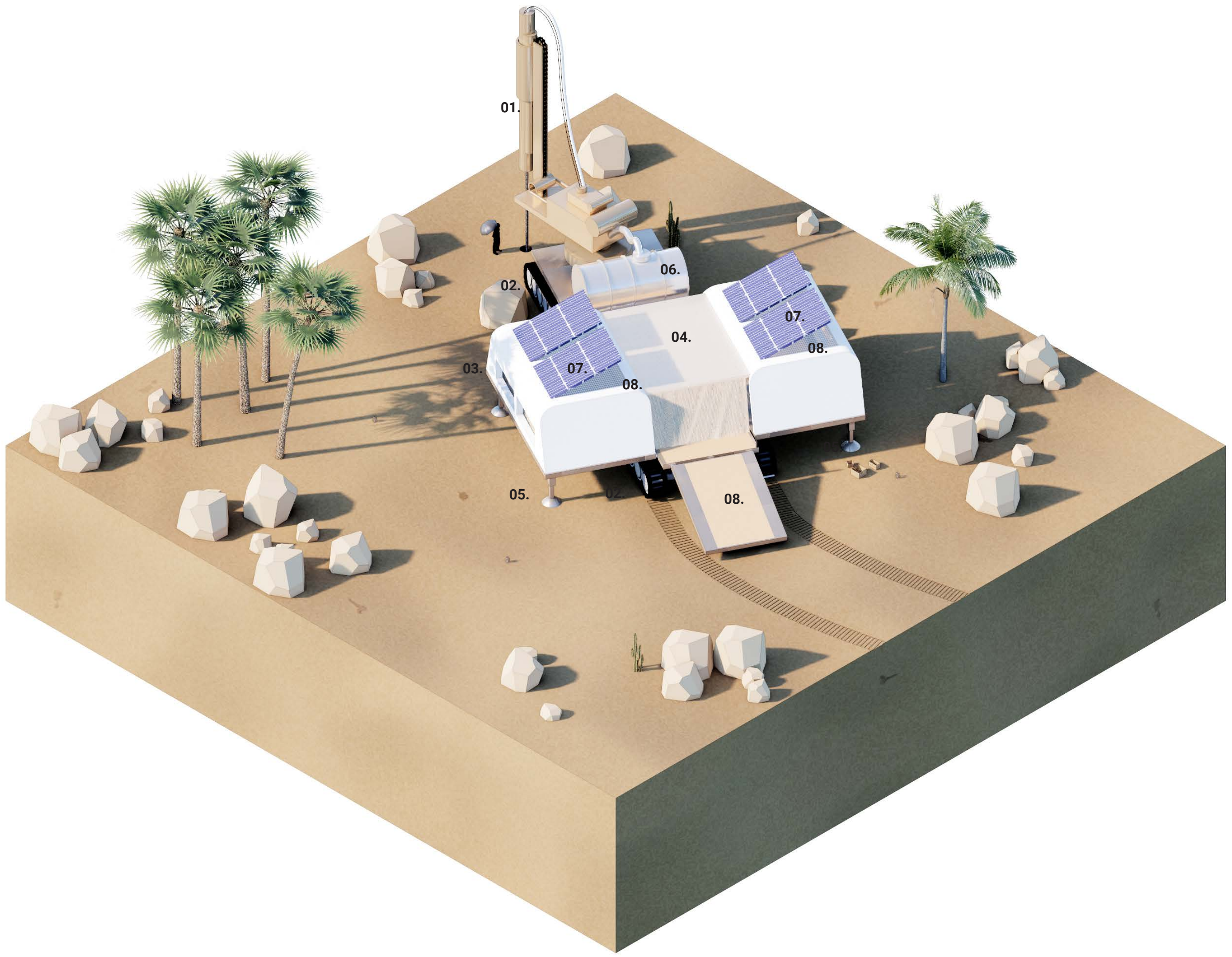


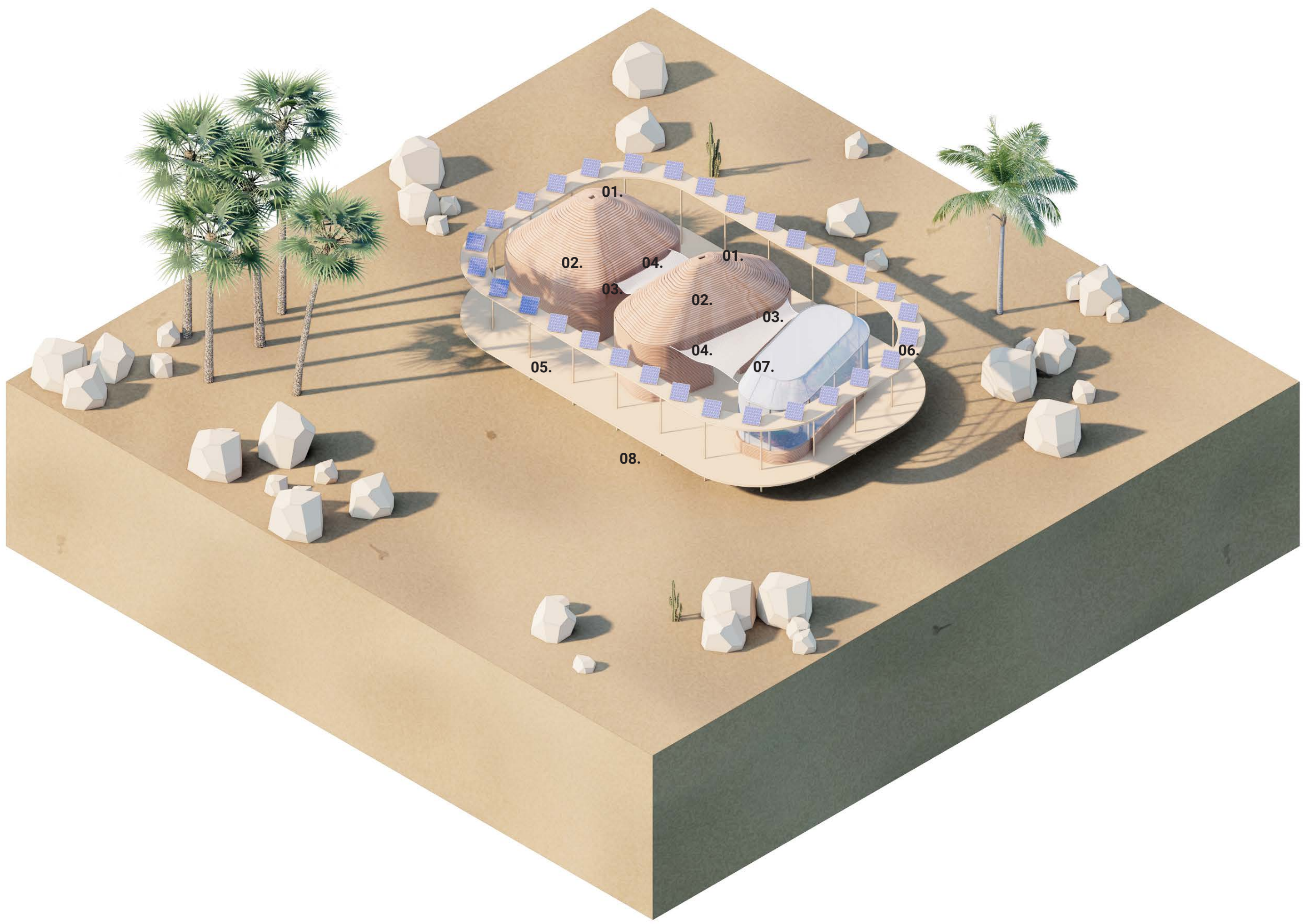
03. ELEVATED

01. Aerodynamic shape to aid against arctic
02. winds
Reinforced rib cage to deal with extreme
03. winds and avalanches
04. Hydraulic legs to keep it elevated from snow
05. GRP, glass reinforced plastic
Retractable ramp

04. ICE + SEA

01. Permeable solar panels for energy supply
02. Aluminum hull for durability and strength in cold environments
03. Rubber fenders as sacrificial layer against floating ice
04. Cranes for loading/unloading equipment
05. Hydraulic drills to lock onto ice sheet
06. Hull made from aluminum for ease of maintenance
07. Wide base for low surface tension



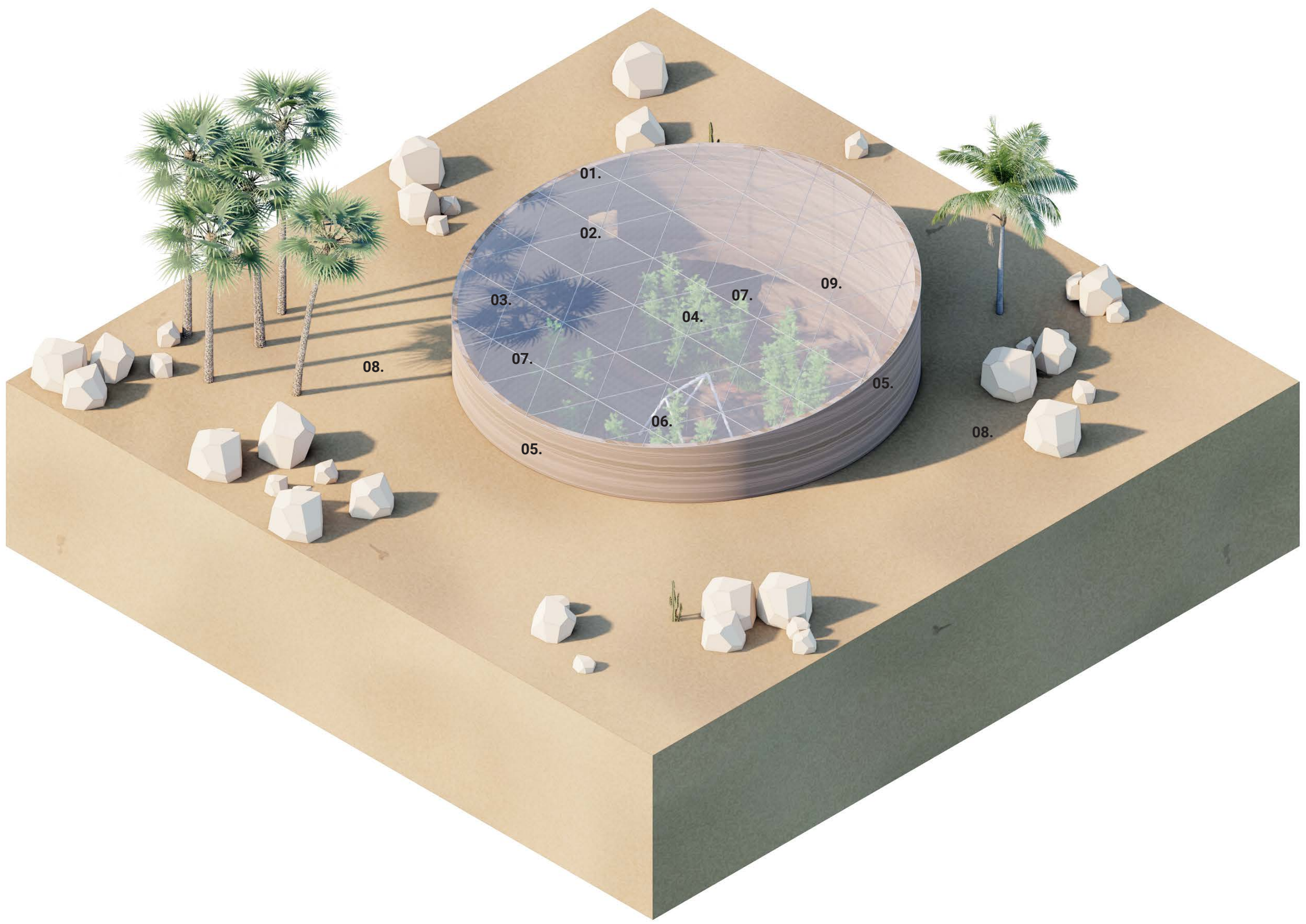


01. PORTABLE

01. Water drill
02. Tracked platform
03. Windows for cross circulation of air
04. Tent-based social area
05. Hydraulic legs for optimal support
06. Water tank in highly reflective material
07. Folding solar cells
08. Windows with weave for escape of warm air and shielding from sunlight
09. Ramp Coated with cork for heat dissipation

02. FIXED

01. Hot air escape zone
02. 3D-printed soil
03. Rotated buildings to induce venturi effect between building for cooling
04. Fabric shading
05. Platform coated with cork for step comfort against heat
06. Rotatable solar panels for optimal efficiency
07. Sealed green house with self irrigating watering and semi-closed system
08. Elevated platform to account for shifting sand and to minimize risk of dangerous wildlife in proximity to living unit.

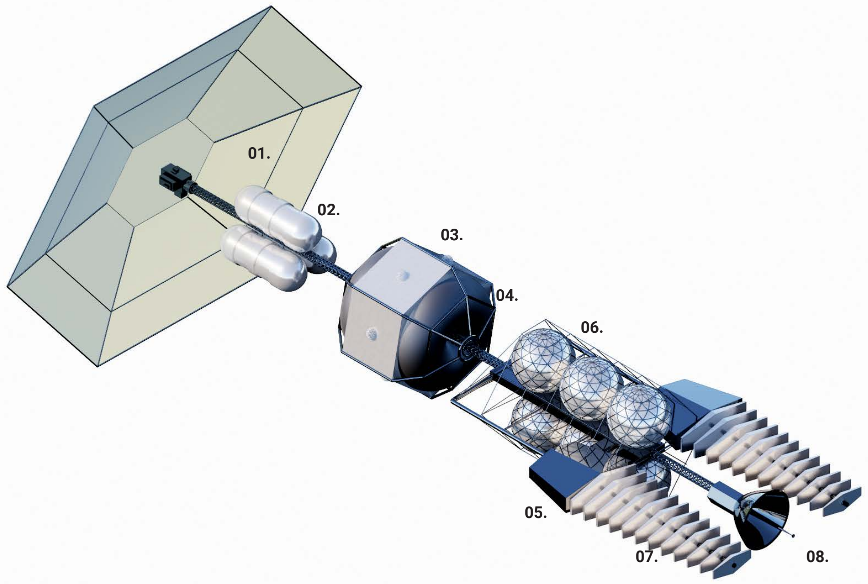


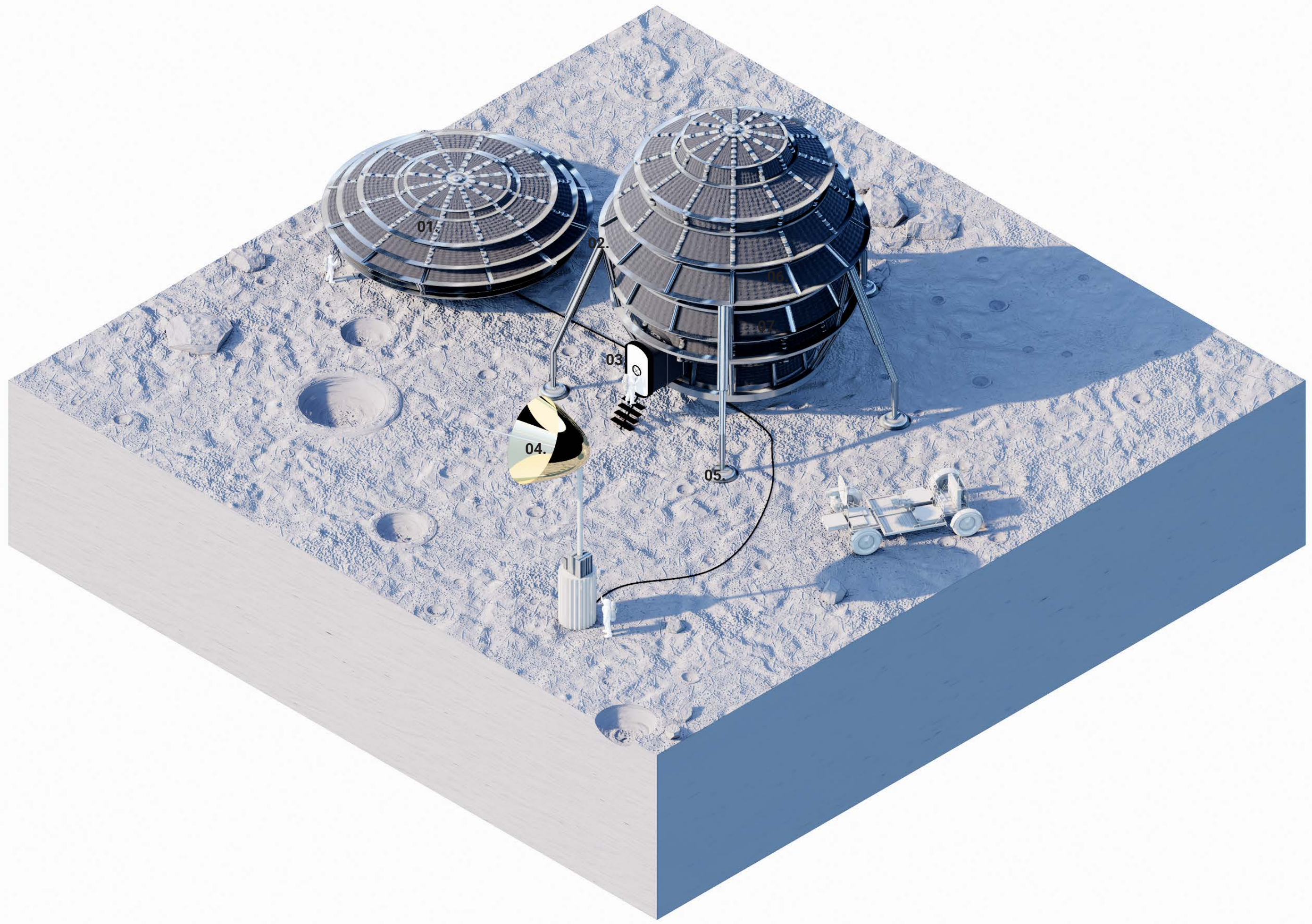
03. UNDERGROUND

01. Sloping glass window for self-removal of sand build up
02. Elevated Closed entrance
03. Retractable solar curtain
04. Crops with natural water irrigation from dome windows
05. Rammed earth wall
06. Water well
07. Subterranean living units
08. Wind Turbine
09. Ramp coated with cork for heat

04. OASIS

01. Wind towers catching colder winds and directing them downwards into living compartment and water basin
02. Reflective metal panels
03. Water basin for collection and storage of water
04. Water basin shaded by living unit keeping it cold
05. Wind turbines within wind towers
06. Windows only under covered balcony for shading
07. Walls made of weaved straw





01. TRANSIT

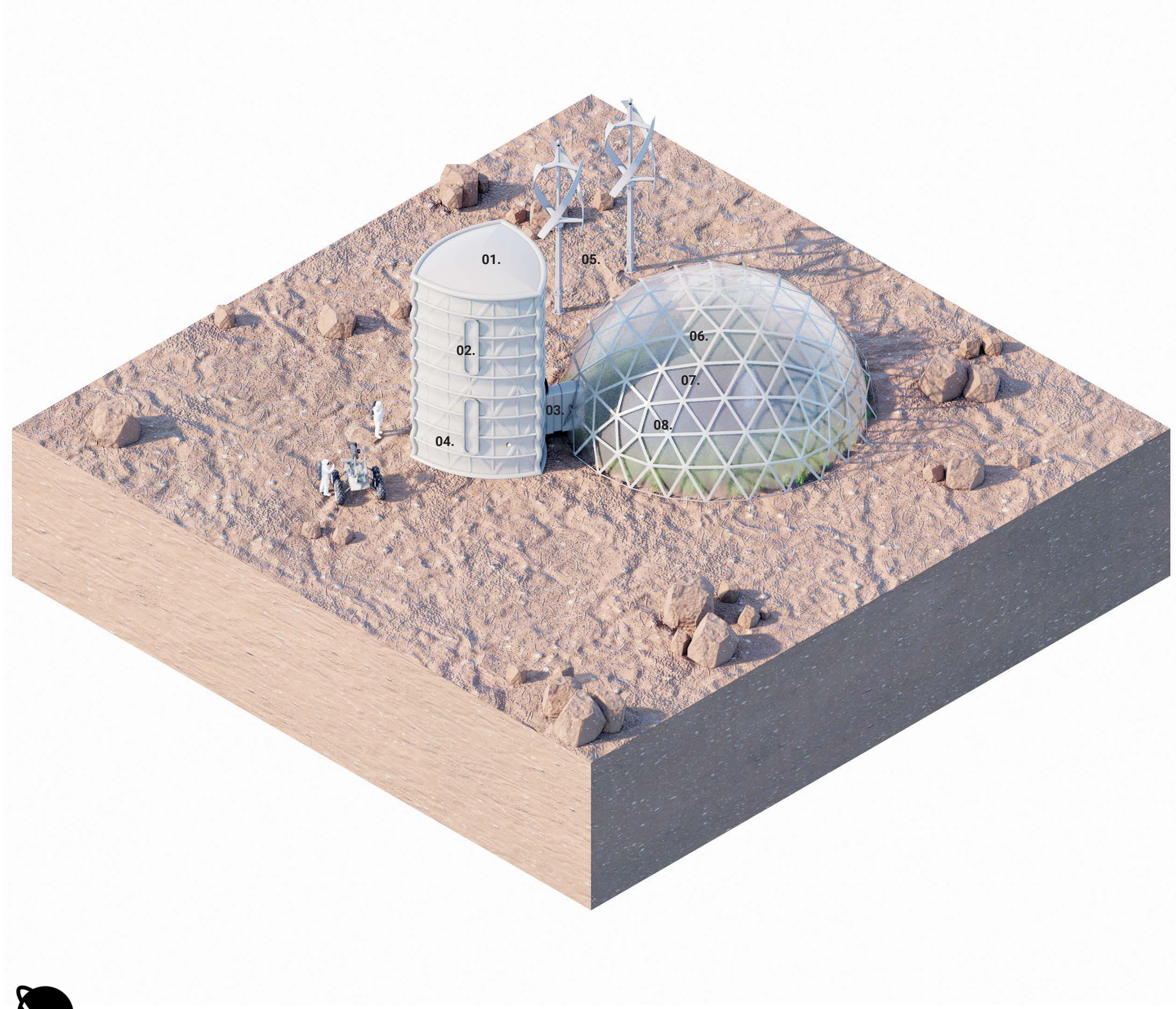
01. Solar cells & debris shield
02. Cargo containers
03. Habitat pod
04. Expandable living pod
05. Engines
06. Propellant
07. Radiators for dissipation of heat
08. Communication array

02. EXPANDABLE

01. Foldable for efficient transportation
02. Aluminum frame
03. Air lock, also provides ability of docking Multiple units together
04. Communication array
05. Stabilizing joint feet
06. 3D-printed space fabric that regulates heat
07. Layers of flexible fabric and closed-cell vinyl Polymer foam for radiation protection

03. ADDITIVE MANUFACTURING

01. 3D Printed sacrificial shell made from surface dust to protect from debris and storms
02. Inner 3D Printed & protected living compartment
03. Airlock
04. Portable solar cells



04. PREFABRICATED

01. Optimal shape for transportation in falcon rockets while retaining best structural strength
02. Oval windows for increased protection against pressure
03. T-shaped air lock with 3 pressure seals
04. 3D-printed composite shell
05. Wind turbine
06. Inflatable geodesic dome for crops and recreation
07. Extra inflatable layer to deal with build up of dust
08. Self sealing material to deal with debris