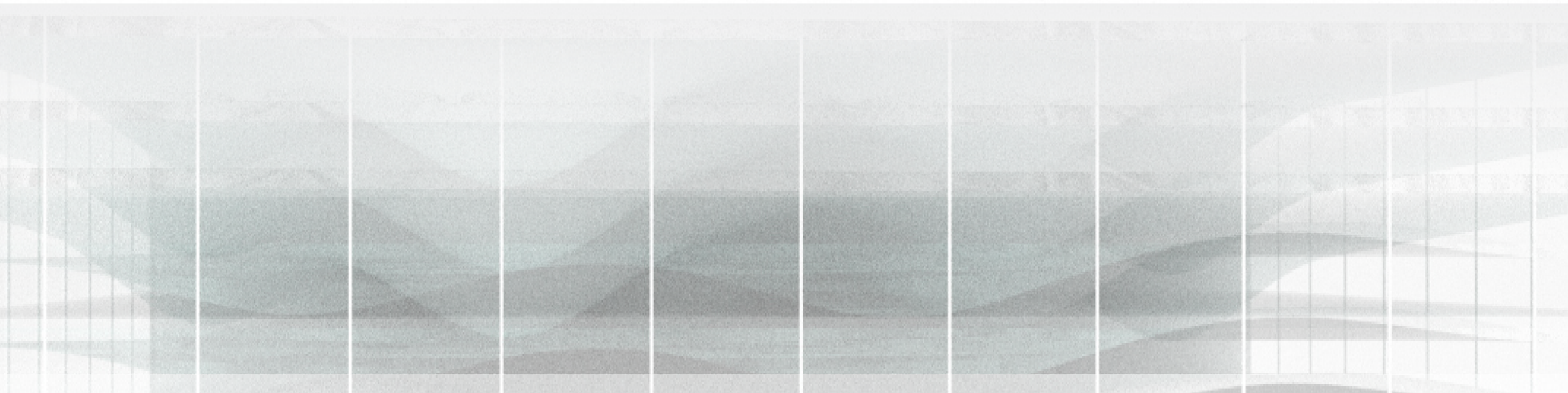


THERMAE

- Exploring the potential of geothermal energy of a hybrid facility in Gothenburg.



CHALMERS
UNIVERSITY OF TECHNOLOGY





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Graduation and publication: Spring 2024



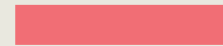
Abstract

Currently, the world is heavily dependent on non-renewable sources of energy such as fossil fuel. This has led to a number of environmental issues such as air pollution, deforestation, and climate change. The need to transition to renewable energy sources has become increasingly urgent, and many countries have set ambitious targets to reduce their carbon footprint and increase their use of clean energy. However, while renewable energy sources such as solar, wind, and hydropower have gained significant momentum in recent years, there are still challenges to their widespread adoption. For example, the intermittency and unpredictability of solar and wind power can make them less reliable for large-scale energy production. There are also environmental concerns surrounding the production and disposal of some renewable technologies, such as solar panels and batteries.

Geothermal energy is an alternative renewable energy source that has several advantages over other forms of renewable energy. It is a reliable and consistent source of energy that can be used for both electricity generation and heating/cooling applications. Additionally, geothermal energy does not rely on weather conditions or the availability of sunlight or wind, making it a more predictable and dependable source of power. Hence architects are called upon to provide creative holistic and sustainable solutions to the growing demand for energy and recreation facilities in urban areas.

The aim of this thesis is to investigate the potential of creating a hybrid facility that combines a geothermal power plant and a thermal bath in Gothenburgh. In doing this, the project also aims to explore how the energy produced from such an environment can be reinterpreted and poetically expressed in architecture, providing unique spatial qualities that enrich the human experience, inspire and educate the mind.

Student Background



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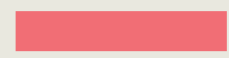
Acknowledgement

First and foremost, I extend my gratitude to my supervisor, Kengo Skorick, whose clarity and curiosity guided me through the intricacies of this thesis. His dedication to exploring even the wildest topics with sincerity has been invaluable. I would also like to express my sincere appreciation to my friend Ilyas Awadh. His guidance has been instrumental throughout my entire educational journey, shaping my perspectives and igniting my intellectual curiosity. Additionally, I am indebted to Eddie Can for his expertise and wisdom, which enriched the discourse of this thesis and provided invaluable insights into its subject matter.

My thanks go to my family. Their unwavering belief in me and steadfast support have been the cornerstone of my academic pursuits. Finally I extend my heartfelt thanks to my wife, her patience, sacrifice, love and support have sustained me through the peaks and lows of this journey. Without her, this endeavor would not have been possible.

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Introduction

Main Questions and Objectives

The aim of this thesis is to investigate the potential of creating a hybrid facility that combines a geothermal power plant and a thermal bath. In doing this, the project also aims to explore how the energy produced from such an environment can be reinterpreted and poetically expressed in architecture, providing unique spatial qualities that enrich the human experience.

The purpose of this project is to provide a holistic and sustainable solution to the growing demand for energy and recreation facilities in urban areas. The combination of a geothermal power plant and thermal bath can provide a unique and innovative approach to energy production and recreational opportunities, while expression of spatial expression can provide inspiration and curiosity for geothermal energy.

Delimitation

This master's thesis in architecture is conceptual and unprecedented in nature. While certain mechanical aspects have been taken into consideration, it is important to note that the actualization of this thesis would require expertise in geology and engineering to solve some of the more complex and technical aspects. As such, this thesis should be seen as a proposal that would require further technical research and development in order to be fully realized. Furthermore, while the idea of combining two programs in one facility may be profitable in theory, it is important to note that no calculations have been made in order to prove this hypothesis. Therefore, the economic viability of such a facility remains hypothetical.

Thesis Question

What are the architectural design possibilities and benefits of creating a hybrid facility that combines a geothermal power plant and a thermal bath in Gothenburg, and how can the energy produced by this facility be poetically and spatially expressed in architecture to enhance the human experience?

Method and Process

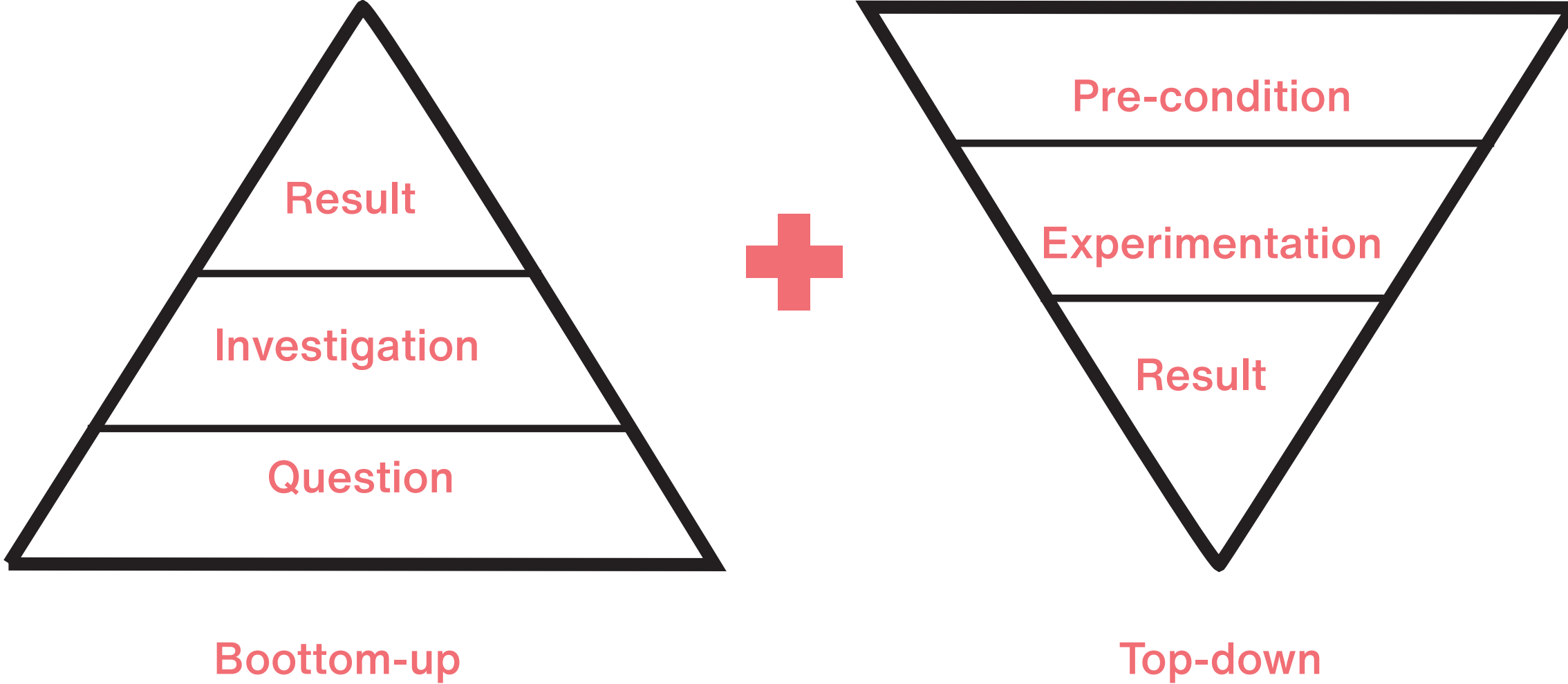
The approach to this master's thesis was based on two bottom-up *questions* and one top-down condition. The first two questions were intended to be answered through research and design exploration, while the *condition* emerged from an aesthetic intuition and was meant to be integrated with the outcome of the resulting from exploration. These are questions that were asked in the early stages and are not to be confused with the thesis question, they should rather be seen as tools that provided context for the project.

- Q1. In which extreme environment will the thesis take place?
- Q2. What type of facility will be integrated with the extreme environment?
- C1. The answer to the first and the second question should, among other things, produce a kinetic spatial effect that evokes wonder.

To answer the questions, different extreme conditions and their environments were studied, the aim was to explore and analyze such environments and identify their characteristics.

The conditions were eventually narrowed down to extreme heat and after some research the earth crust became the final extreme environment of choice due to its global availability and its energy producing potential. The current faculties that are associated with geothermal energy are geothermal powerplants, but there is a far more ancient facility that that has been associated with geothermal energy, being thermal baths, hence the second question were naturally answered.

Finally, the aim of the condition was to integrate the produced energy into the spatial experience of the hybrid facility and create a unique and poetic expression of the energy. This involved exploring the aesthetic and sensory aspects of the energy produced by the extreme environment and translating them into spatial qualities that enhance the user's experience.



=

Background

Geothermal Energy

Geothermal energy is a form of renewable energy that has been gaining attention due to its reliability and low environmental impact. Unlike solar and wind energy, which are dependent on weather conditions, geothermal energy provides a stable and consistent source of power that can be used for various purposes, including heating and cooling buildings, and generating electricity. Geothermal energy is harnessed by drilling wells into the earth's crust and tapping into the heat generated by the planet's core.

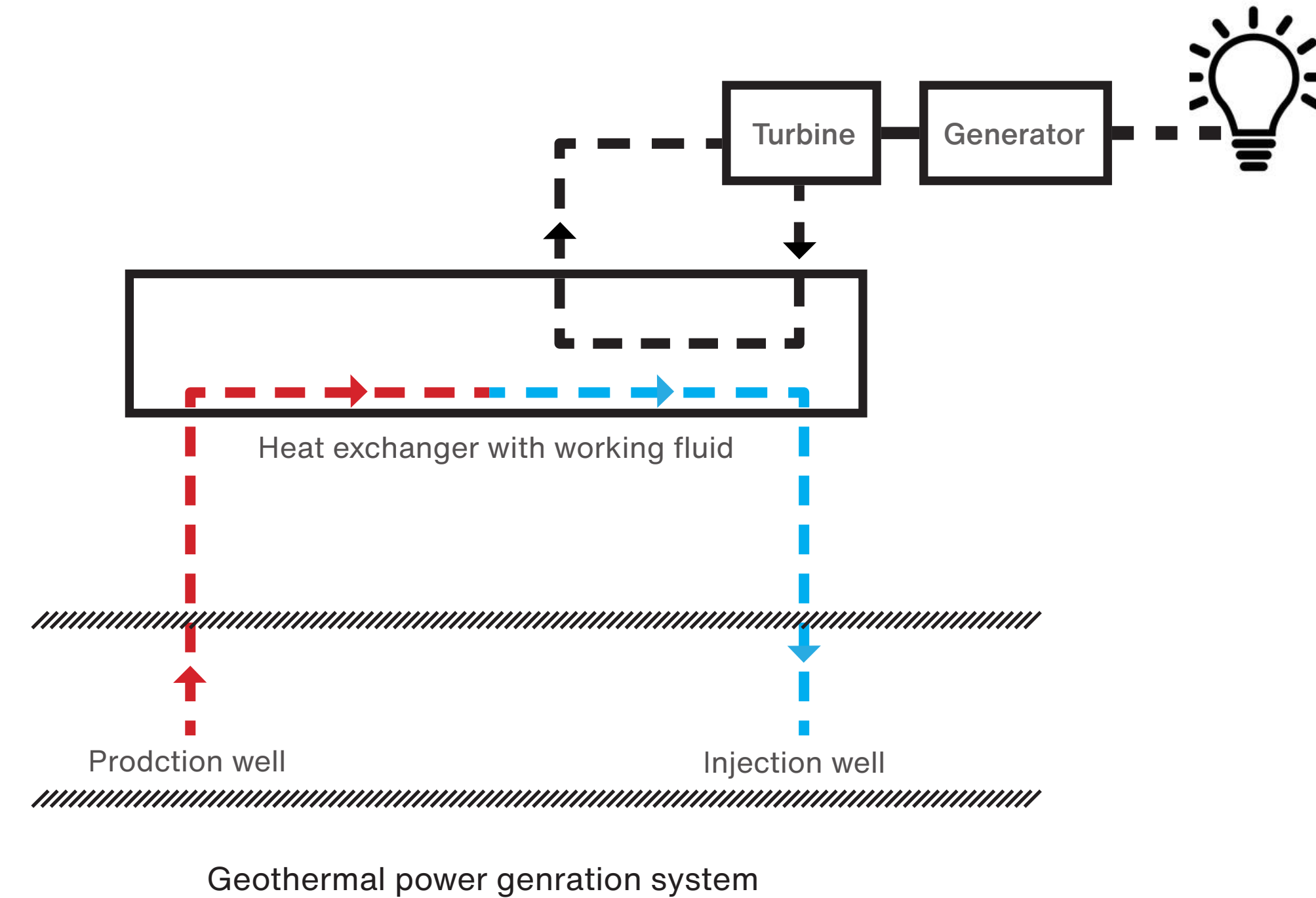
Hot Dry Rock Method

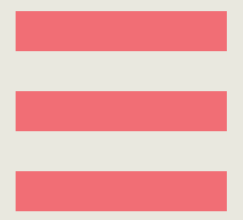
The HDR (Hot Dry Rock) method is a type of enhanced geothermal system (EGS) that involves drilling deep into the earth's crust, fracturing the rocks, and creating a permeable reservoir. The reservoir is filled with water, which is then heated by the hot rocks and pumped back up to the surface to power a turbine and generate electricity.

The Binary Cycle

The Binary cycle is a type of power generation technology that is often used in conjunction with HDR. In a Binary cycle power plant, the hot water that has been pumped up from the HDR reservoir is used to heat a second fluid with a lower boiling point, such as an organic Rankine fluid. The heat from the hot water causes the second fluid to vaporize, which then drives a turbine and generates electricity.

The connection between HDR and the Binary cycle is essential for the efficient generation of geothermal energy. HDR provides the hot water necessary to generate electricity, while the Binary cycle technology allows for the efficient conversion of heat into electricity, even at lower temperatures. By combining these two technologies, geothermal energy can be generated more efficiently and with less environmental impact compared to traditional fossil fuel power generation methods.





References

The Blue Lagoon - Iceland

Unparalleled for its experiential qualities and contrasting material elements it offers the lagoon provides a unique sensory experience. The juxtaposition of the warm, mineral-rich waters against the surrounding cool, volcanic landscape creates a captivating contrast that engages all the senses. By replicating and reinterpreting this contrast in the bath, one is able to create a multi-dimensional experience that heightens the sensations of relaxation and rejuvenation for visitors.

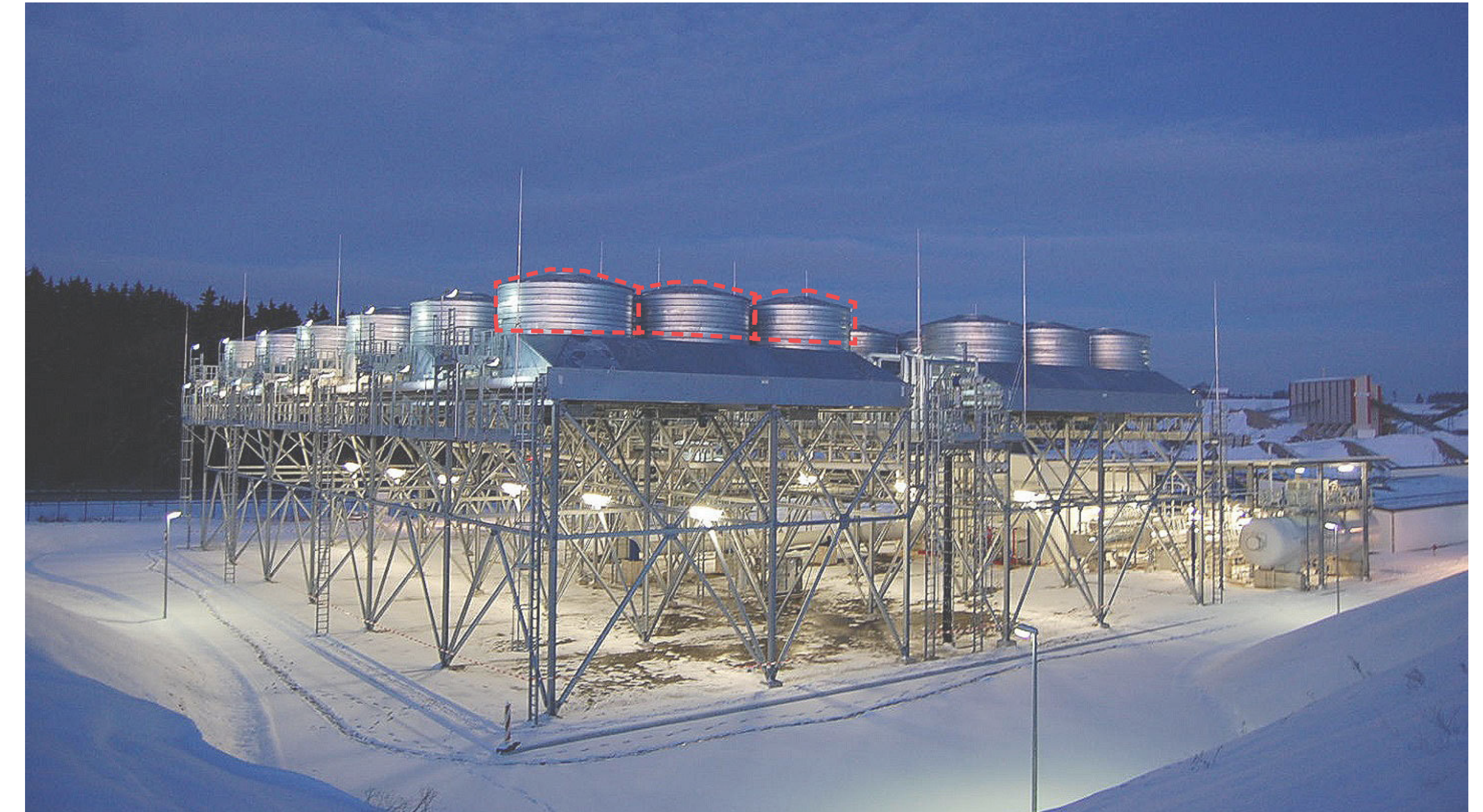


Traunreut: Geothermal Power plant

The Geothermal Power Plant in Traunreut is a small-scale power plant located in Traunreut, Germany. Built in 2013, the plant has a capacity of 3.5 MW and is designed to extract geothermal energy from a depth of 3,500 meters and convert it into electricity. Due to its low impact and small size, it is an excellent candidate for a case study on integrating renewable energy infrastructure in urban environments.

Recostructural Opportunities

The plant footprint covers an area of around 3600 sqm with the cooling fan installation taking up about 2/3 of the total area. Additionally, the fans have been placed on a 12 m high structure in order to draw the pipes more efficiently from below. Hence the shape of the power plant presents spatial opportunities for architectural interventions, since the void below the cooling fans creates space below the structure, which in turn can be utilized for various purposes. Additionally, some of the current functions that are currently outside (due to standard practice) could, with some piping adjustments, consequently, be fitted below the cooling fans.



VI

Design Proposal

Site: Frihamnen - Gothenburg

Sweden has long been at the forefront of renewable energy adoption, and its relationship with geothermal energy is no exception. Geothermal energy, which harnesses the heat stored within the Earth's core, has gained significant attention in Sweden as a reliable and sustainable energy source. While the country primarily relies on hydroelectric power, geothermal energy has emerged as a promising supplement in its renewable energy portfolio.

Frihamnen

Frihamnen, located in Gothenburg, is an iconic area that has undergone significant urban development in recent years. Situated on the city's waterfront, it holds historical significance as a former industrial harbor. However, with changing times and urban planning initiatives, Frihamnen has transformed into a vibrant and sustainable urban district.

One of the key characteristics of Frihamnen is its focus on sustainability and innovation. The area has been developed with a strong emphasis on eco-friendly practices, aiming to create a greener and more livable environment.



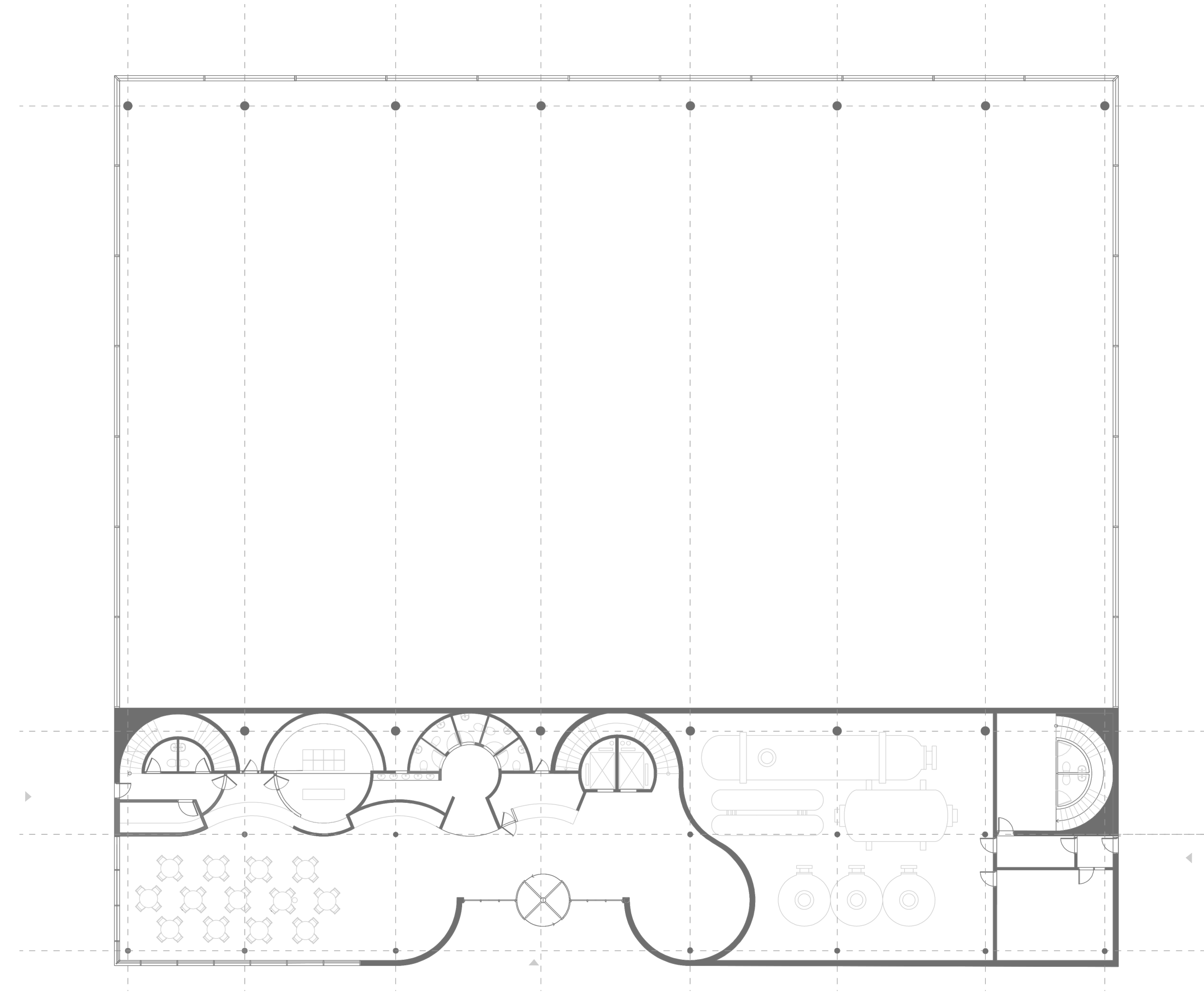
Massing map- Frihamnen



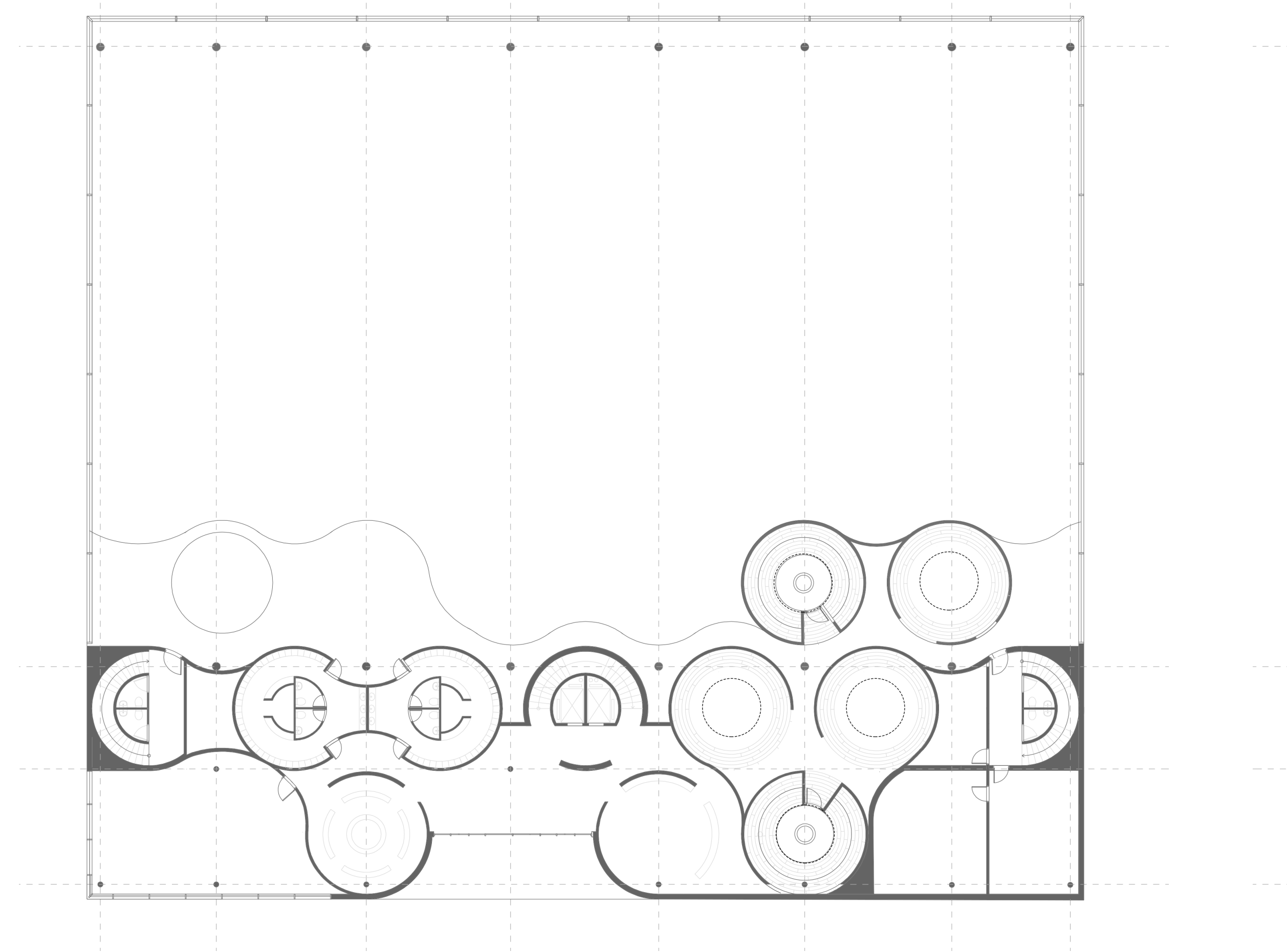
Massing map- Frihamnen



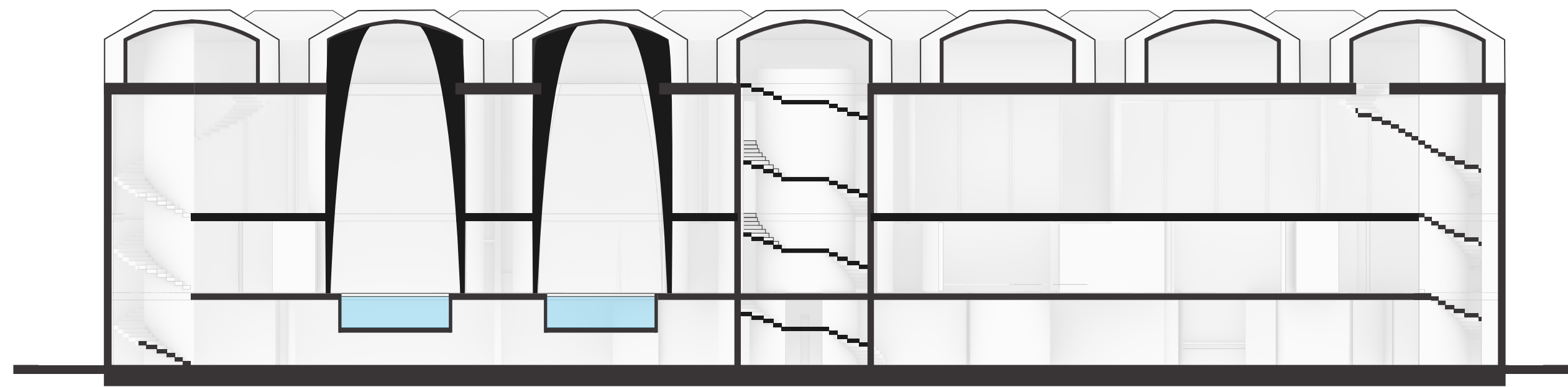
Massing map- Frihamnen



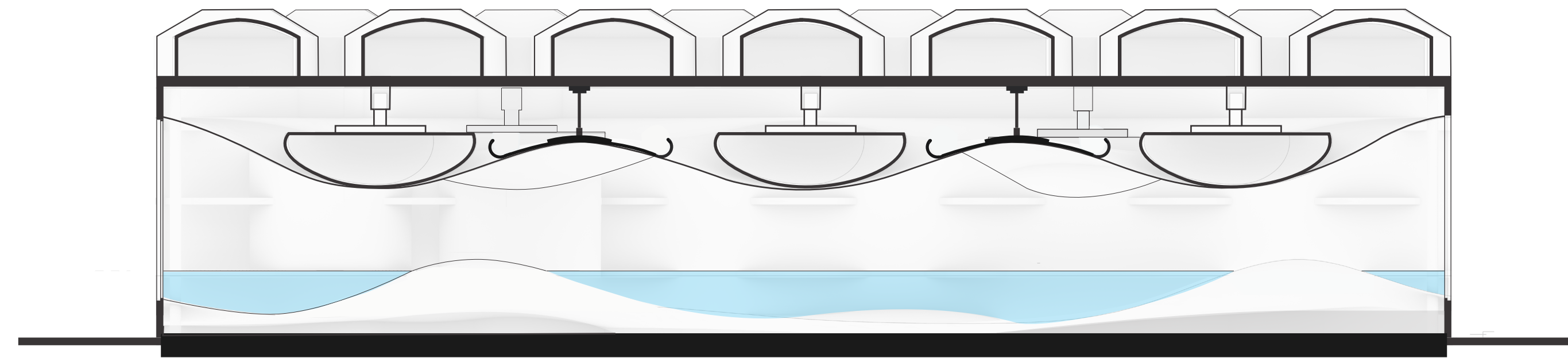
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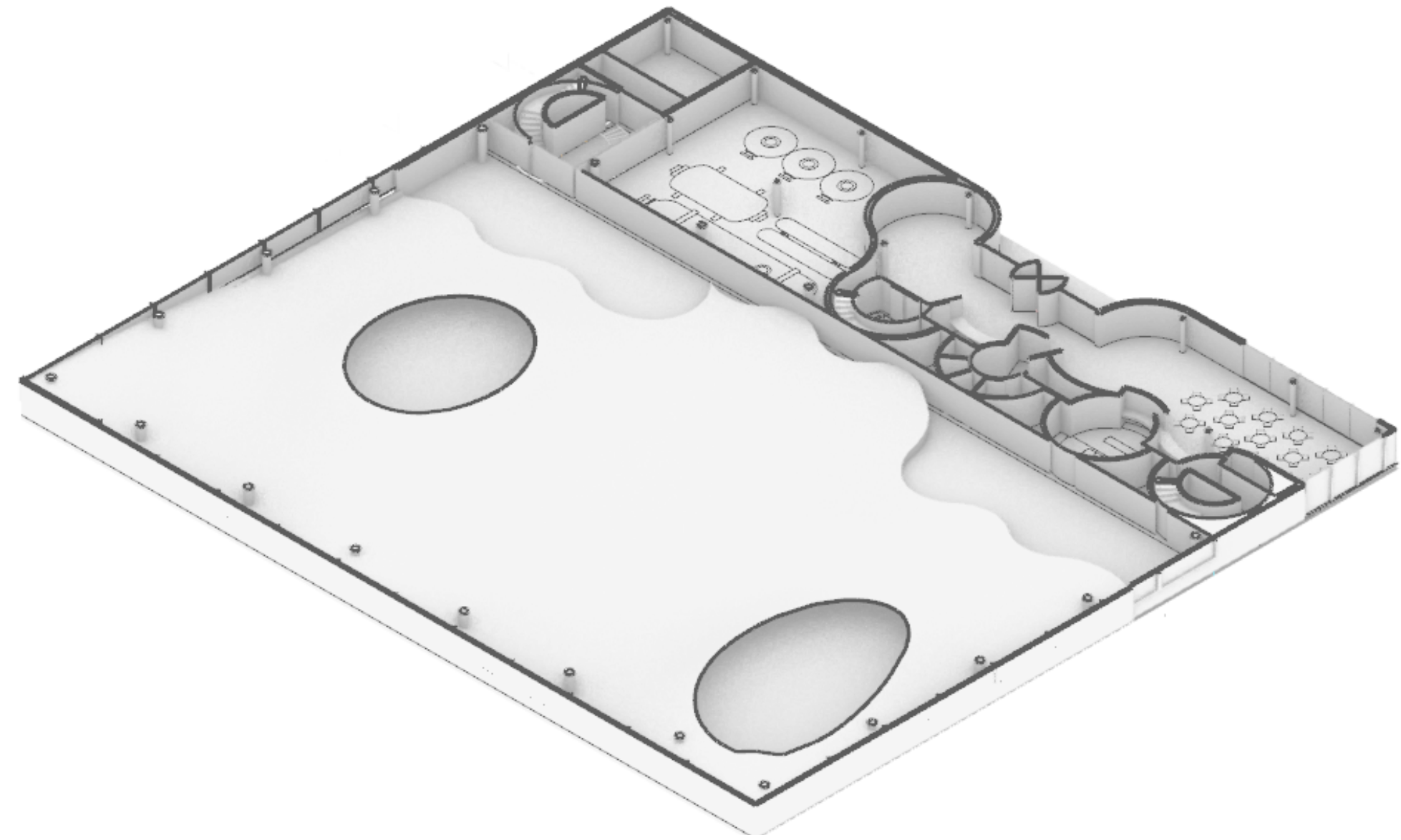
L2



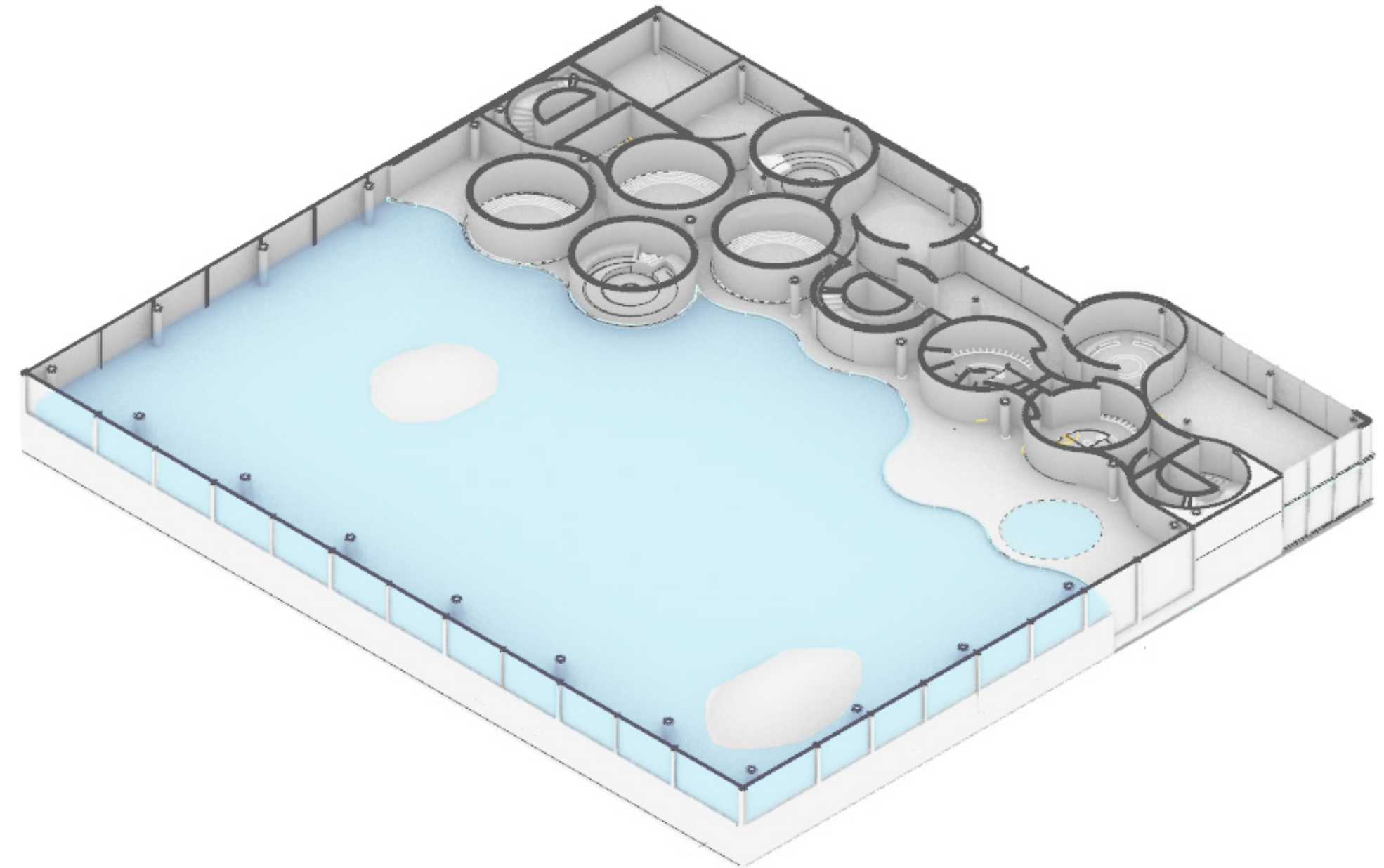
Section 1



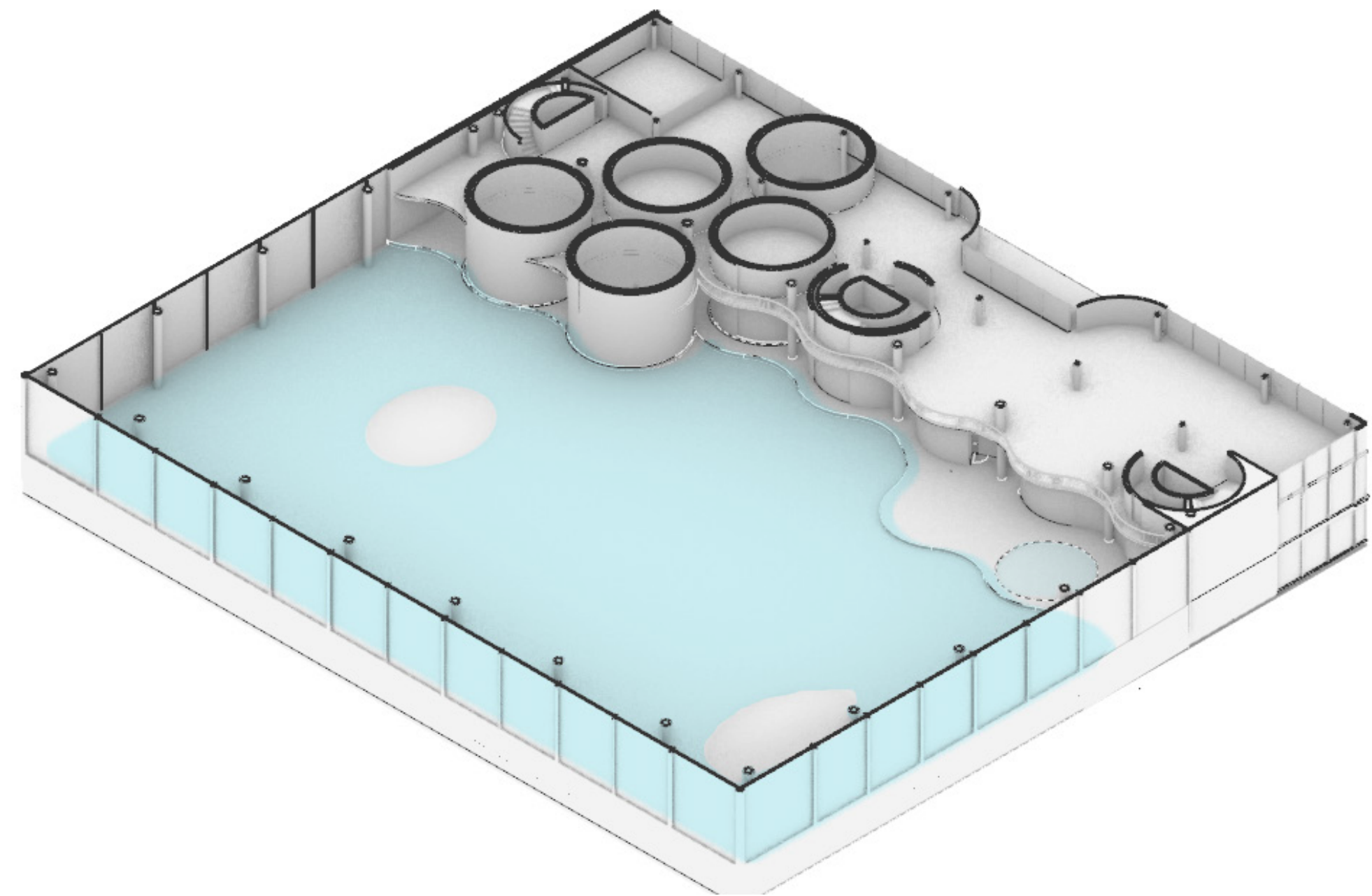
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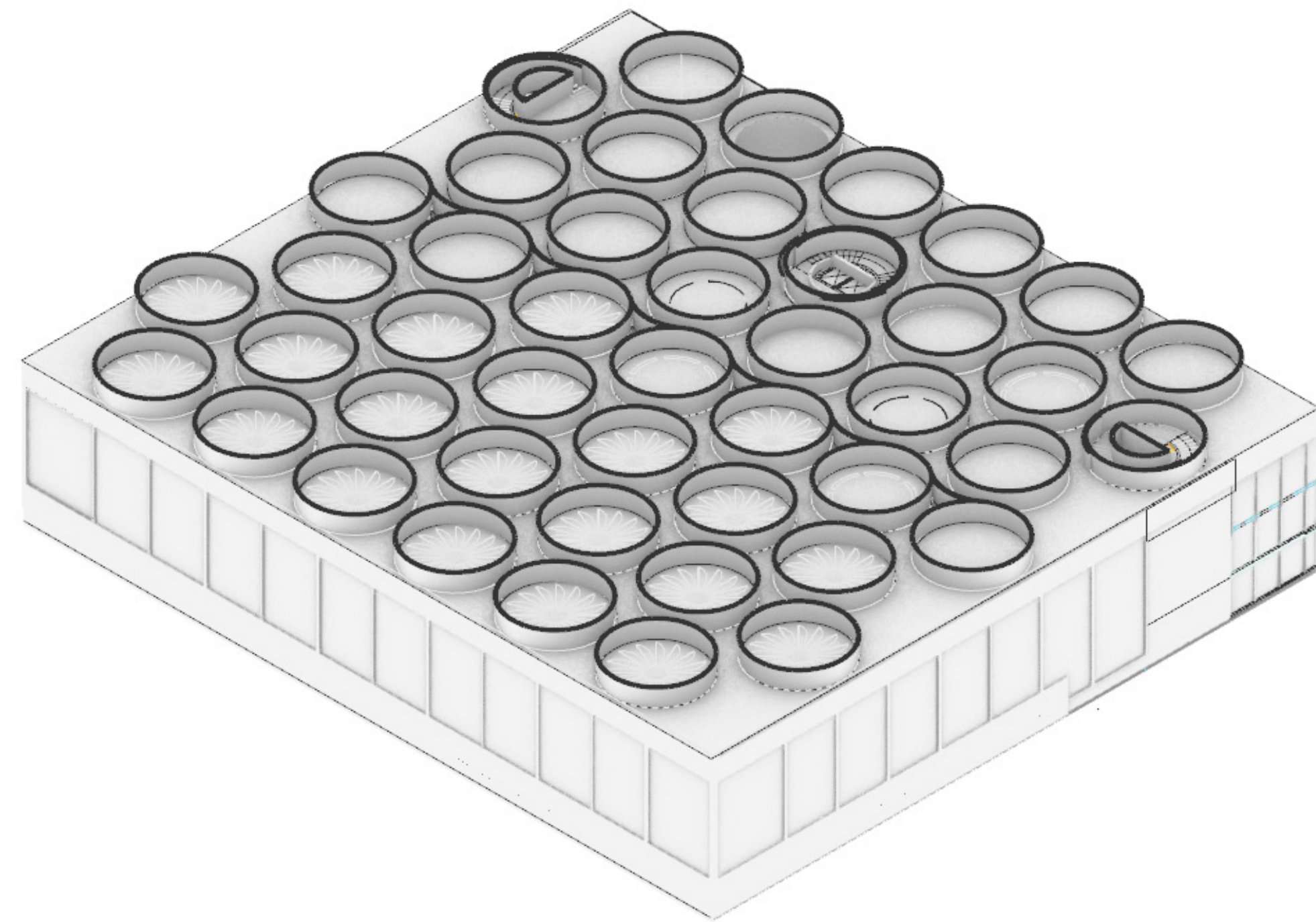
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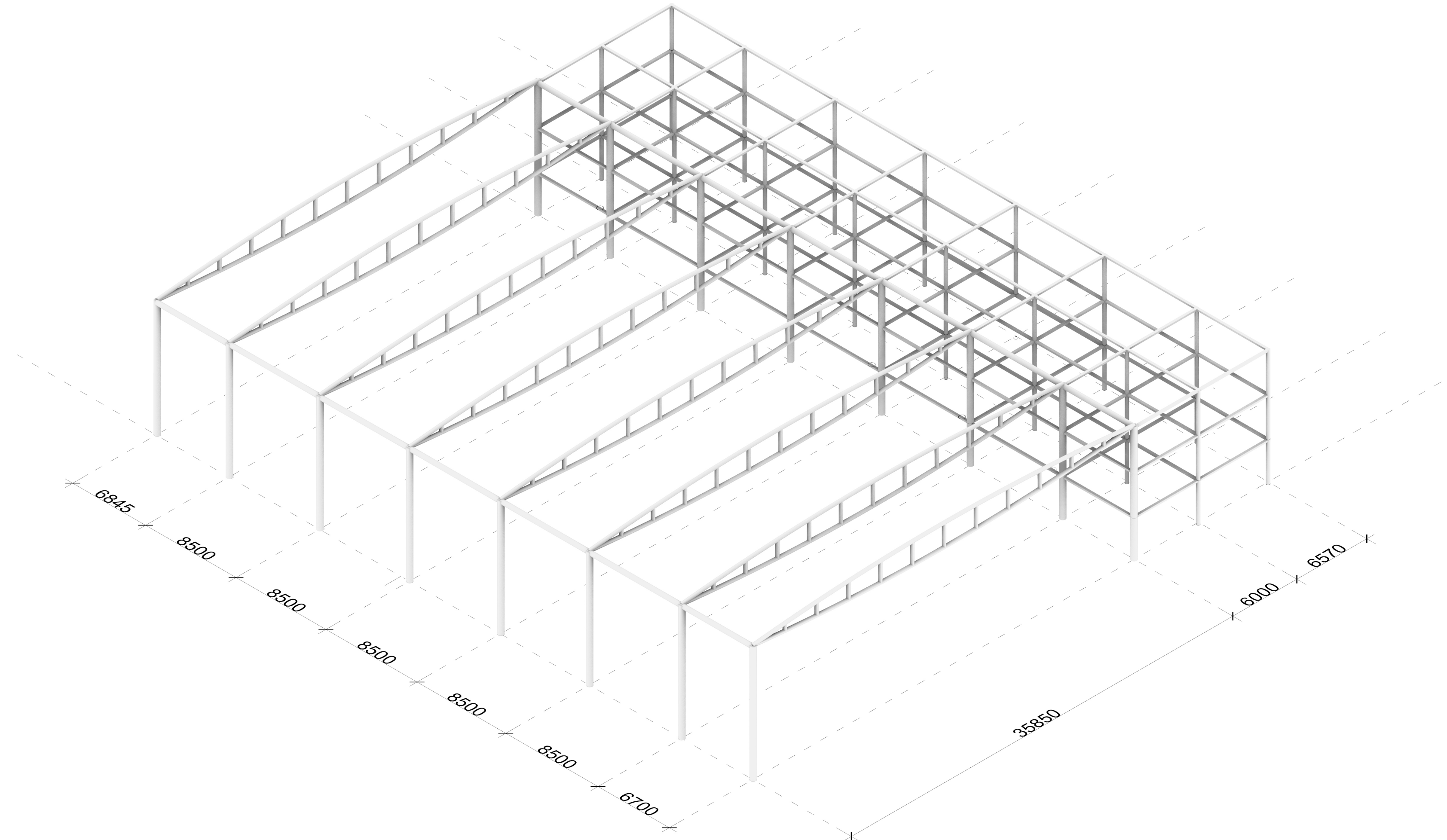
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L3



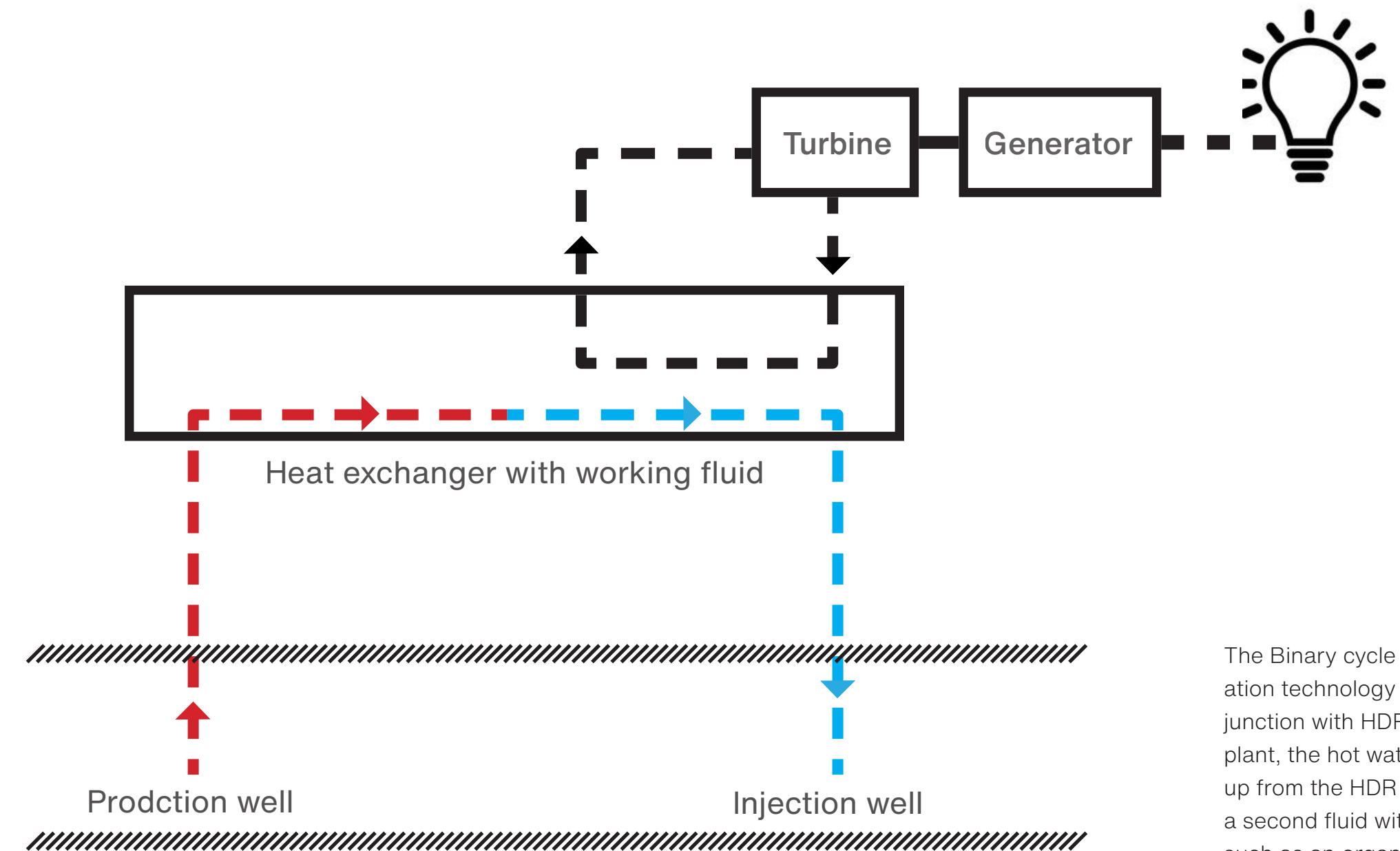
L4



Structural diagram

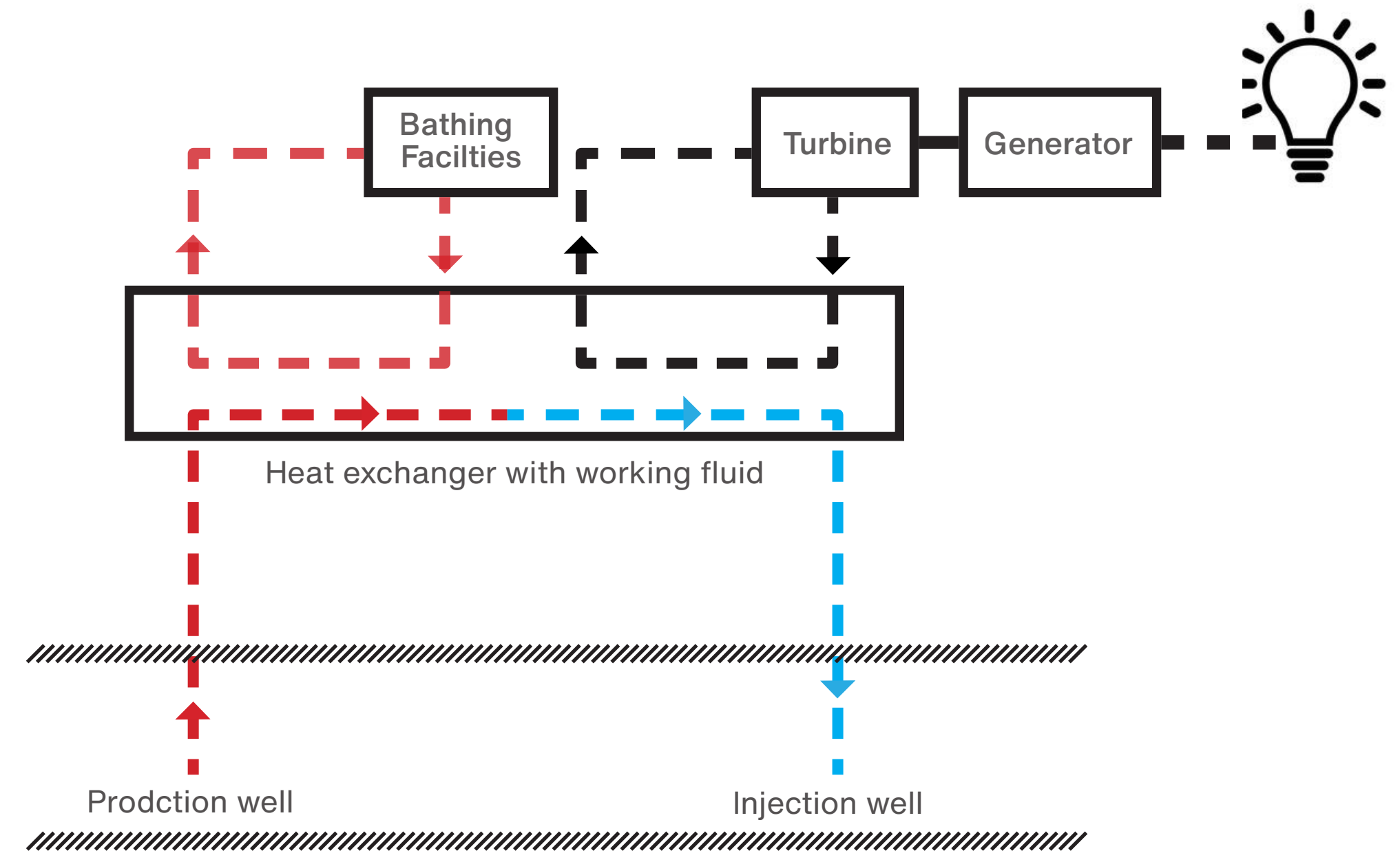
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The Hybrid System

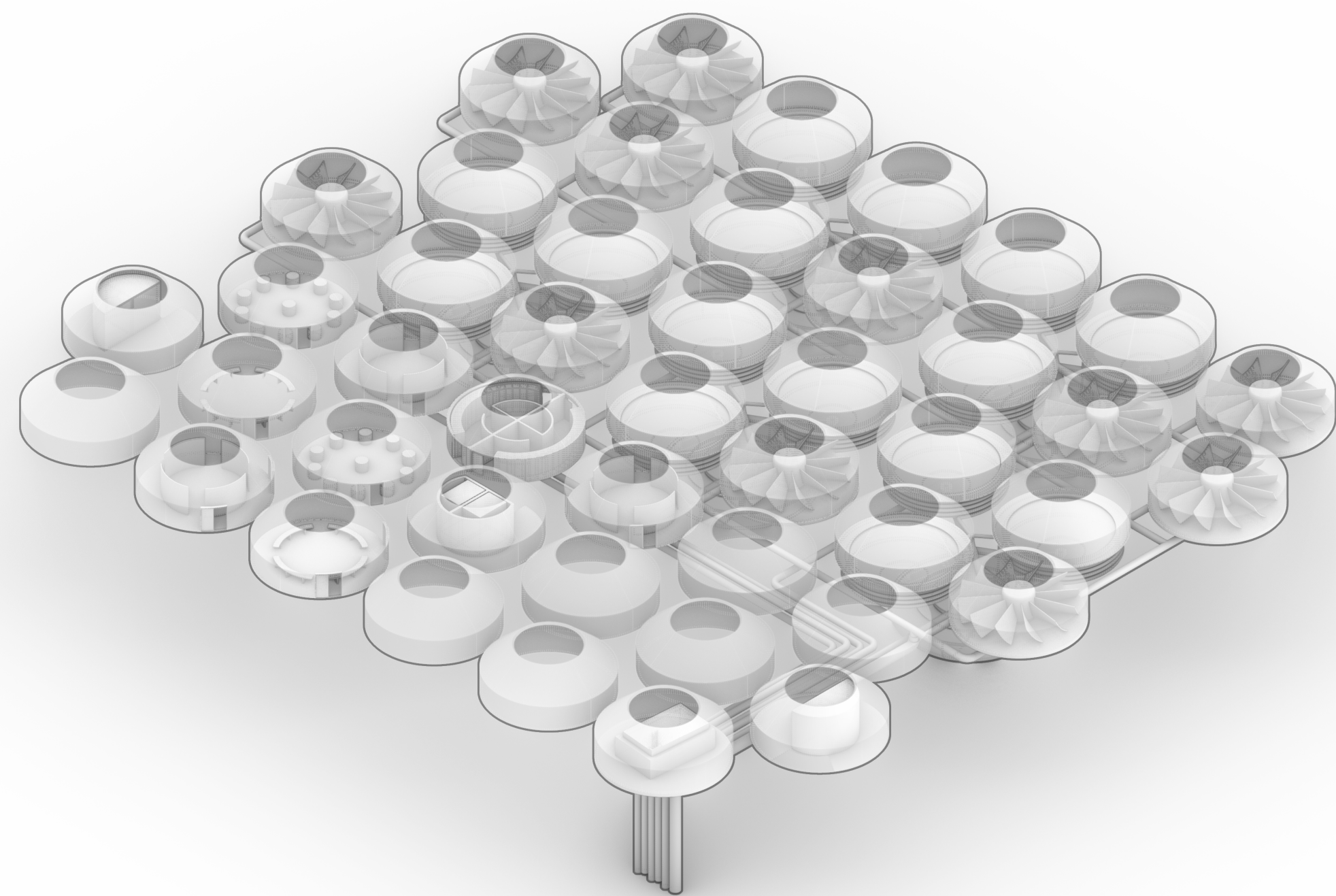


Geothermal power generation system

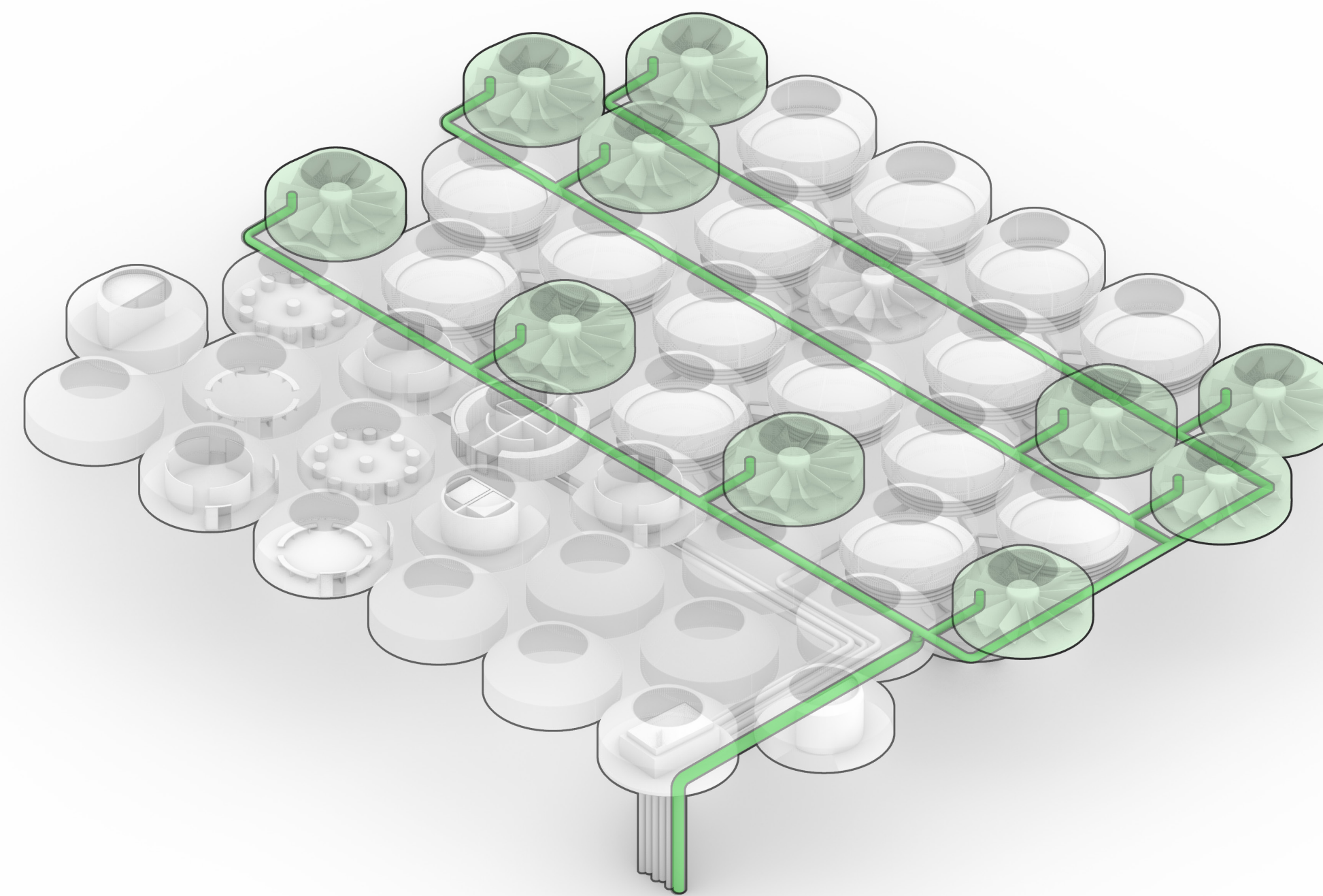
The Binary cycle is a type of power generation technology that is often used in conjunction with HDR. In a Binary cycle power plant, the hot water that has been pumped up from the HDR reservoir is used to heat a second fluid with a lower boiling point, such as an organic Rankine fluid. The heat from the hot water causes the second fluid to vaporize, which then drives a turbine and generates electricity.



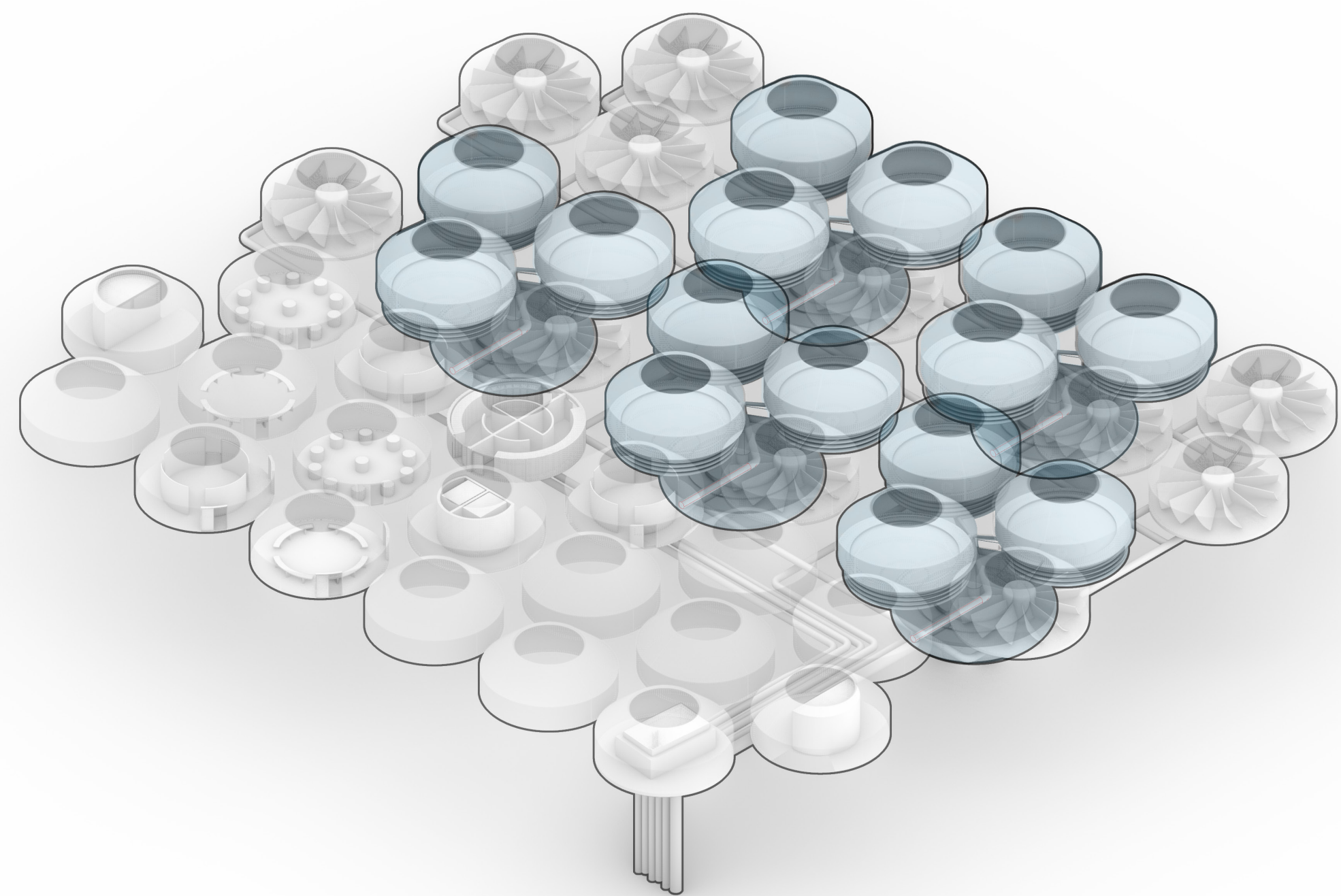
Hybrid Geothermal power generation system



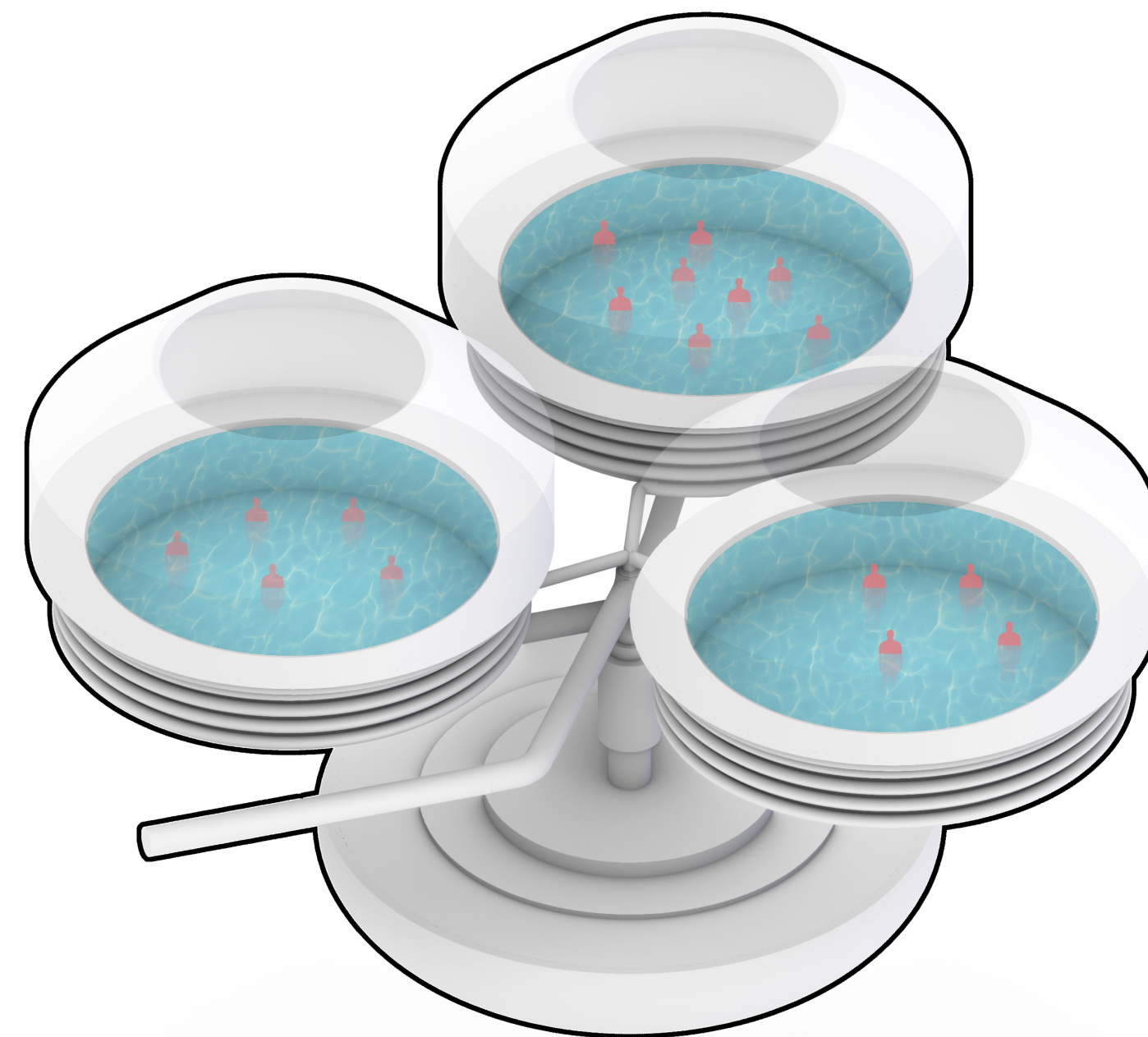
Roof Diagram



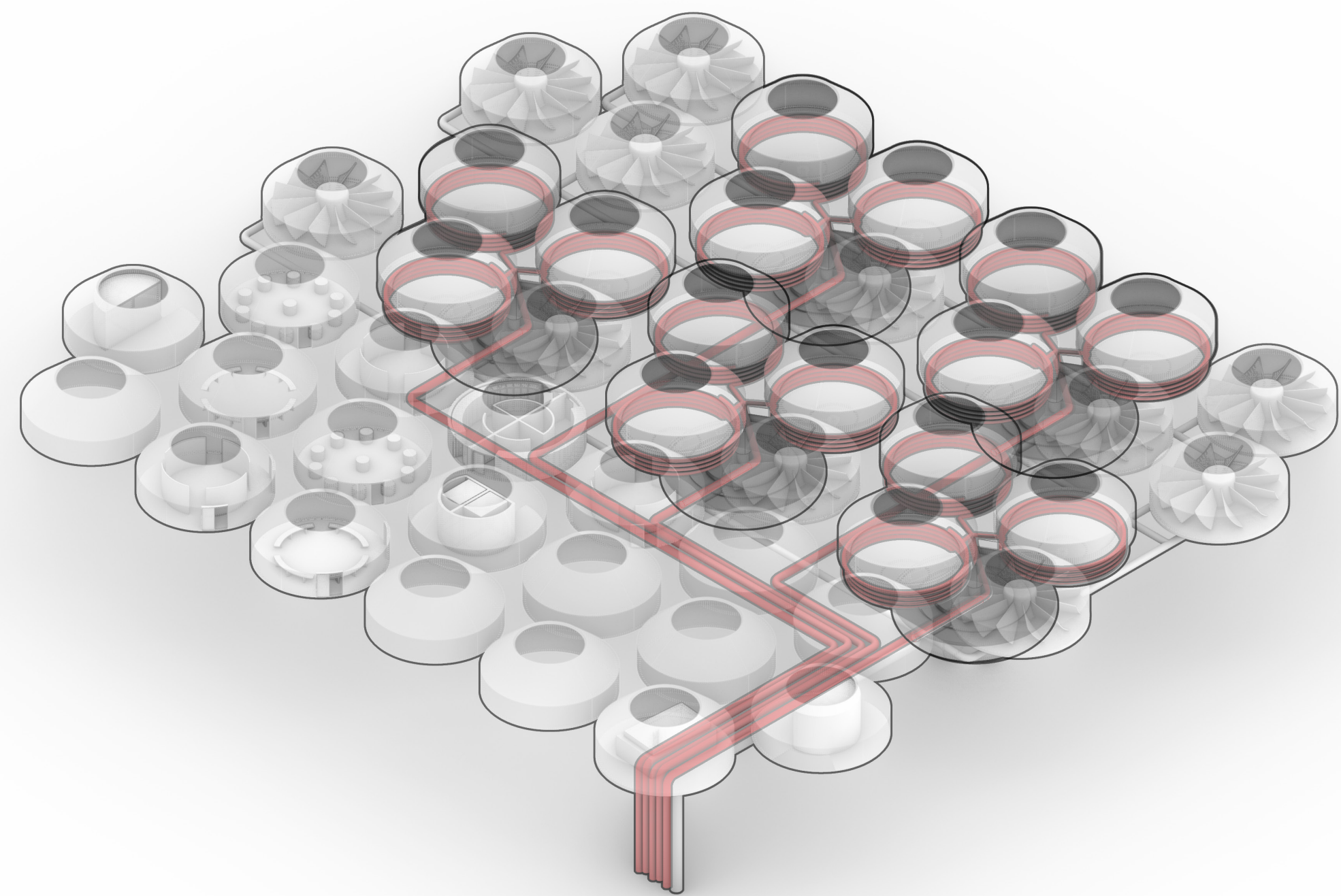
Cooling system



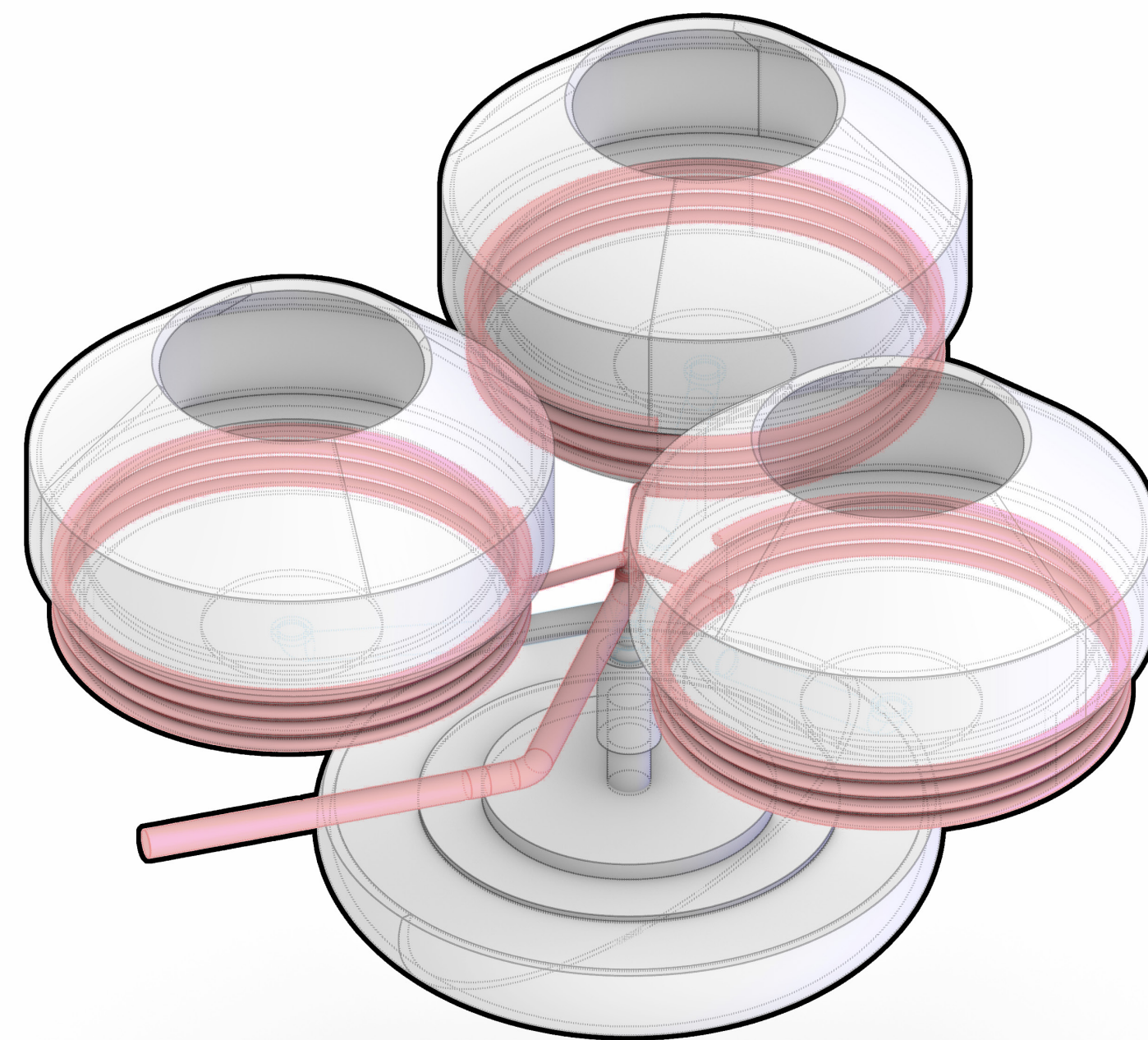
Pool location



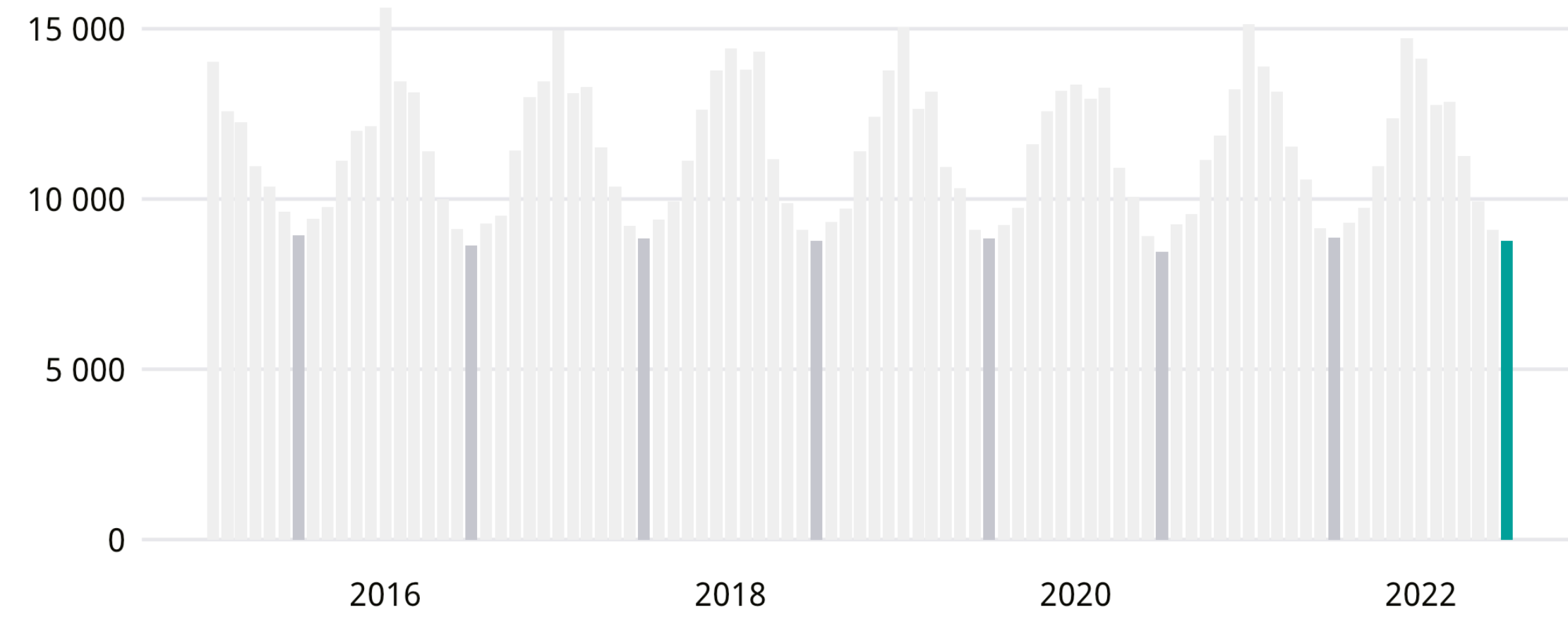
Pools



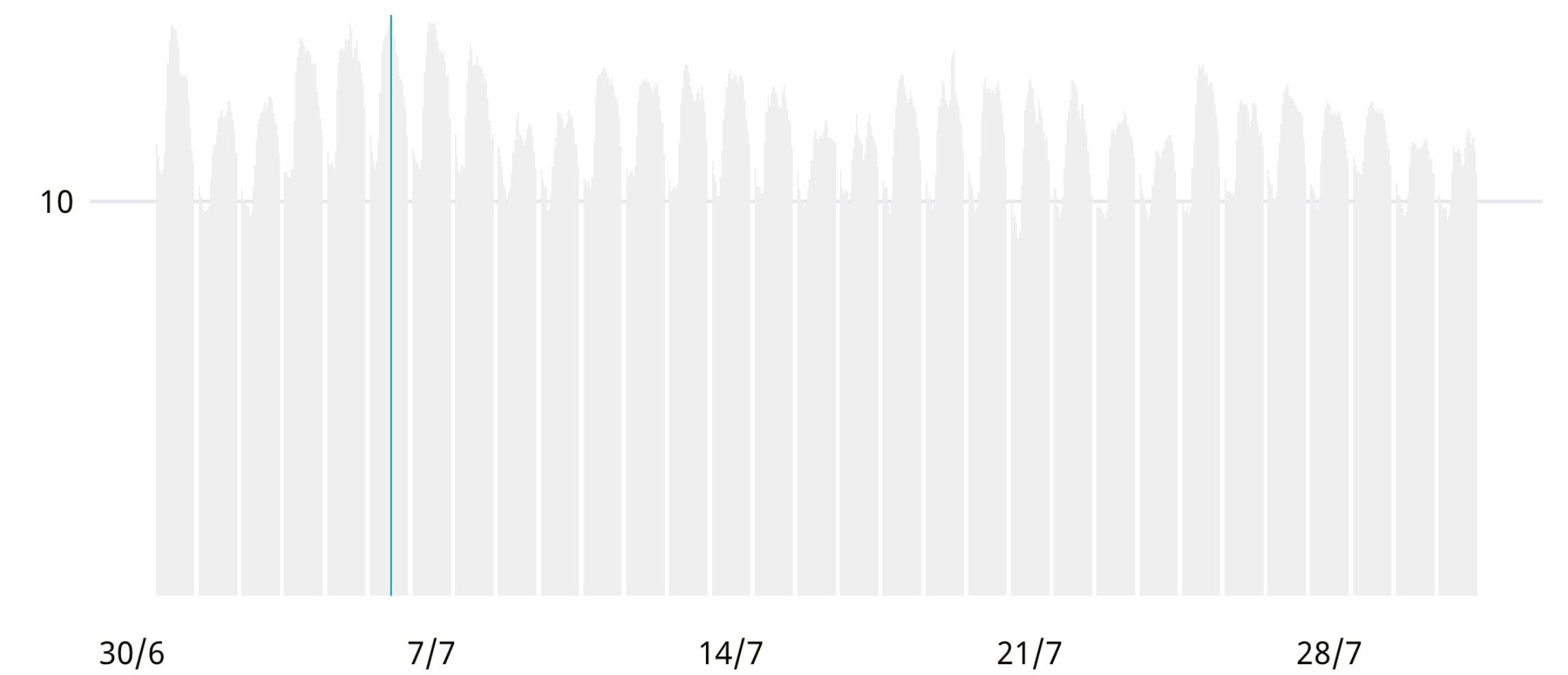
Heating system



Heating mechanism



Avarage monthly electrical consumption in Sweden

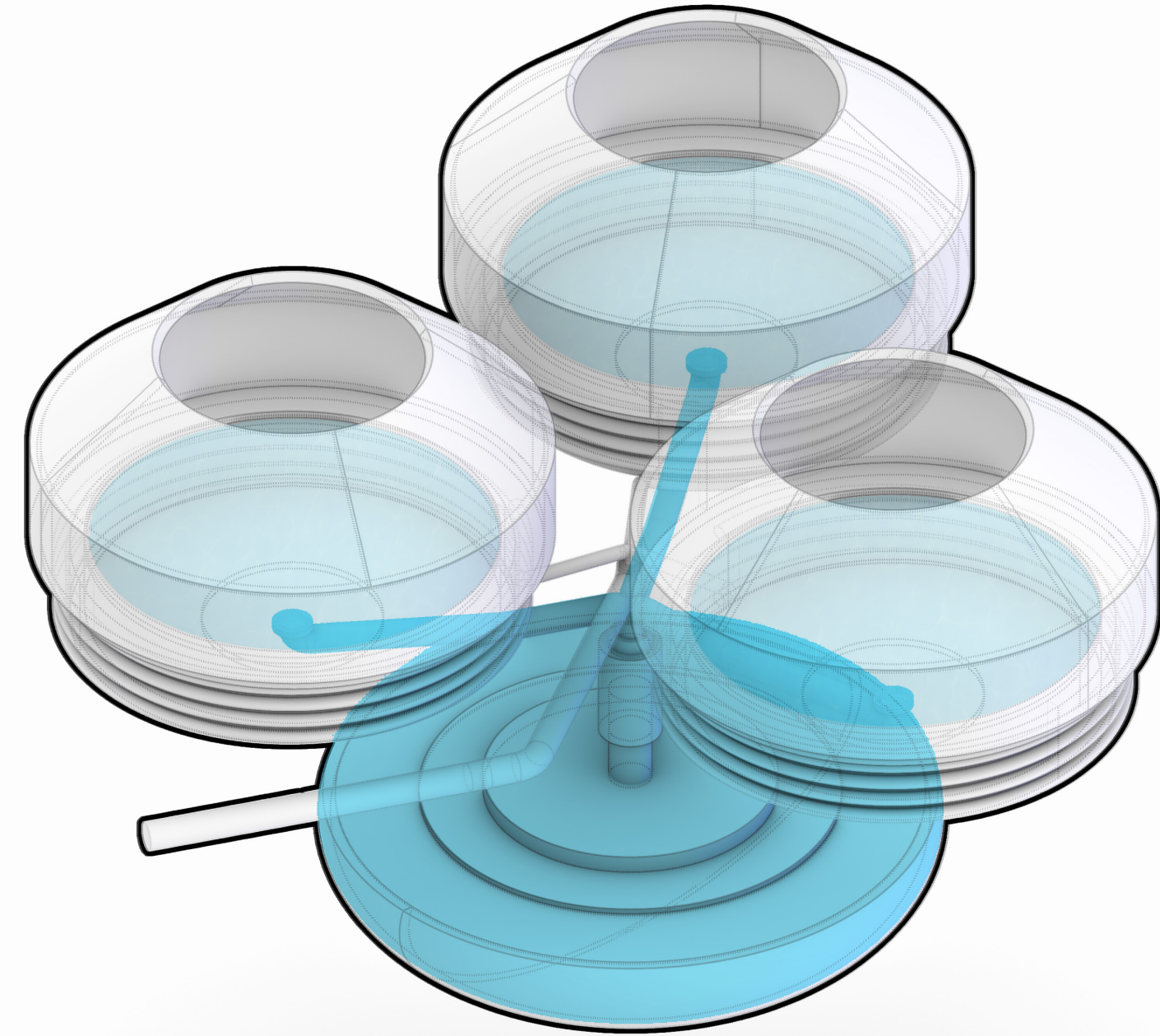


Avarage daily electrical consumption in Sweden

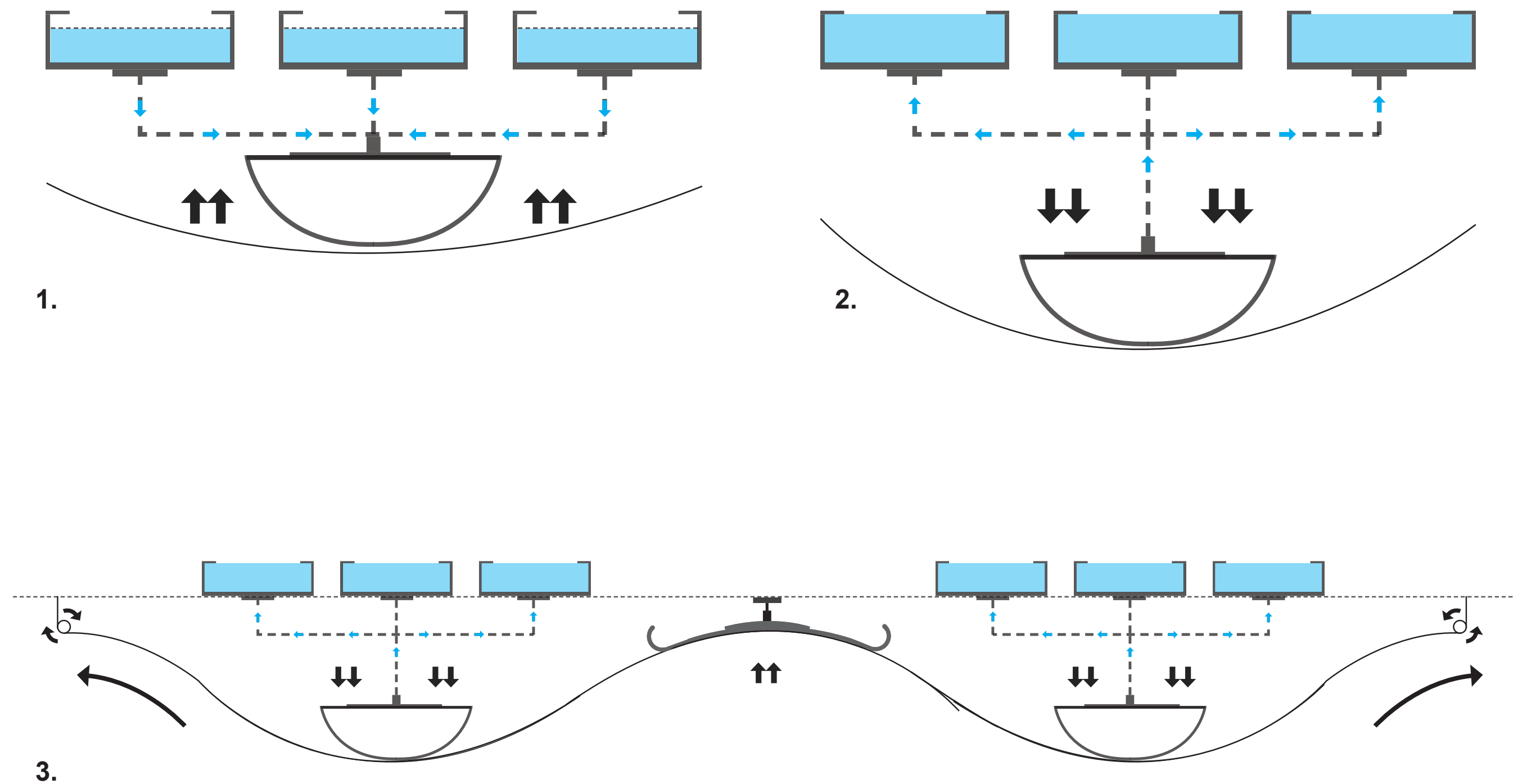
The three pools is strategically positioned on the top of the roof, forming the hydraulic backbone of the ceilings movement.

During periods of increased electricity consumption, a network of valves and sensors detects this increase and triggers the release of water from the pools. The water flows through a series of channels and is directed into the levers, which act as the hydraulic control mechanism. As the water enters the levers, it exerts pressure, activating a system of pneumatic actuators, ultimately resulting in the upward movement of the ceiling.

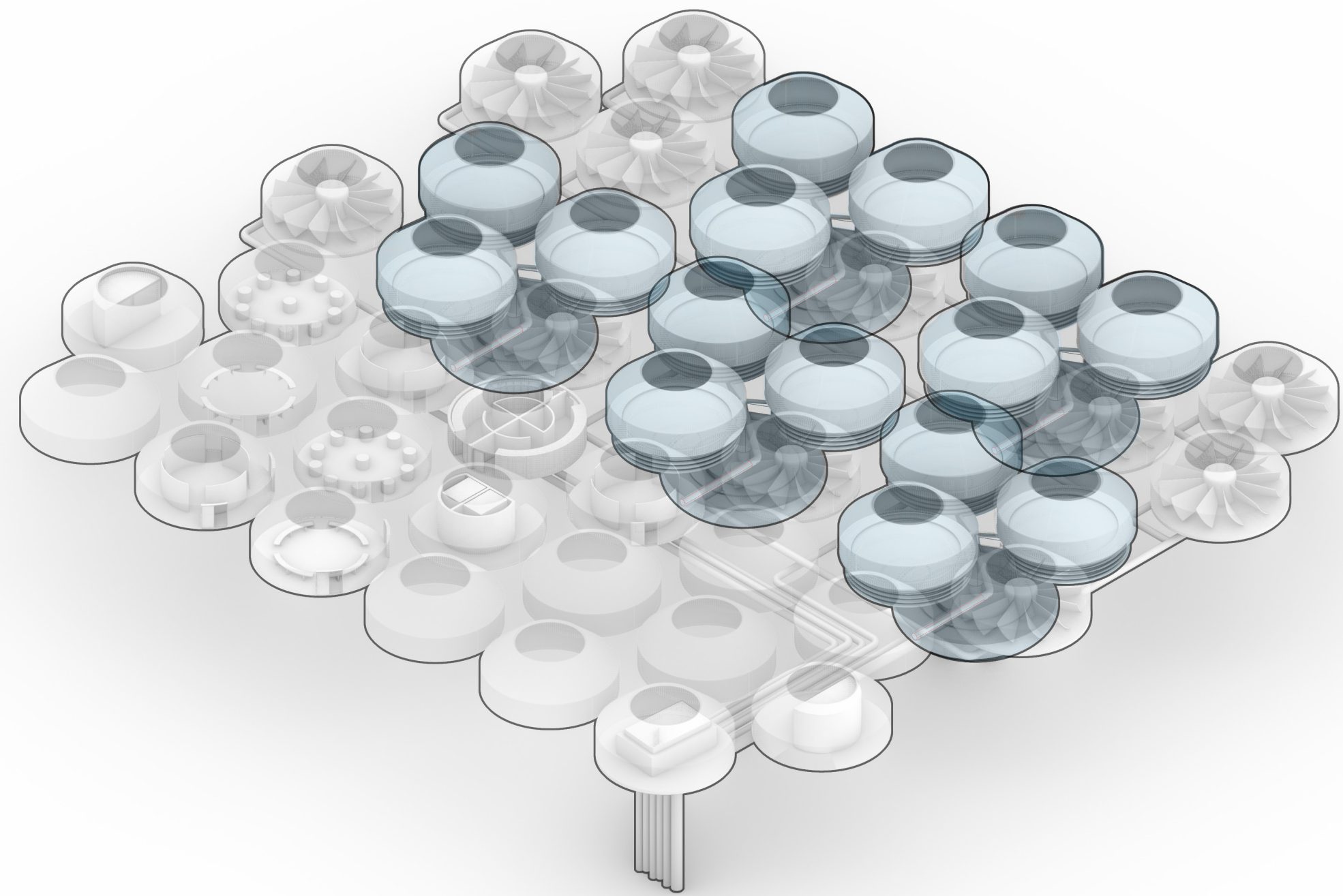
Conversely, when the national consumption of electricity decreases, the sensors detect the decline and regulate the water release accordingly. With a reduction in the amount of water entering the levers, the pressure subsides, allowing the ceiling to descend gracefully. This synchronized dance between water flow, hydraulic mechanisms, and pneumatic actuators ensures that the roof's movements accurately reflect the nation's energy consumption patterns.



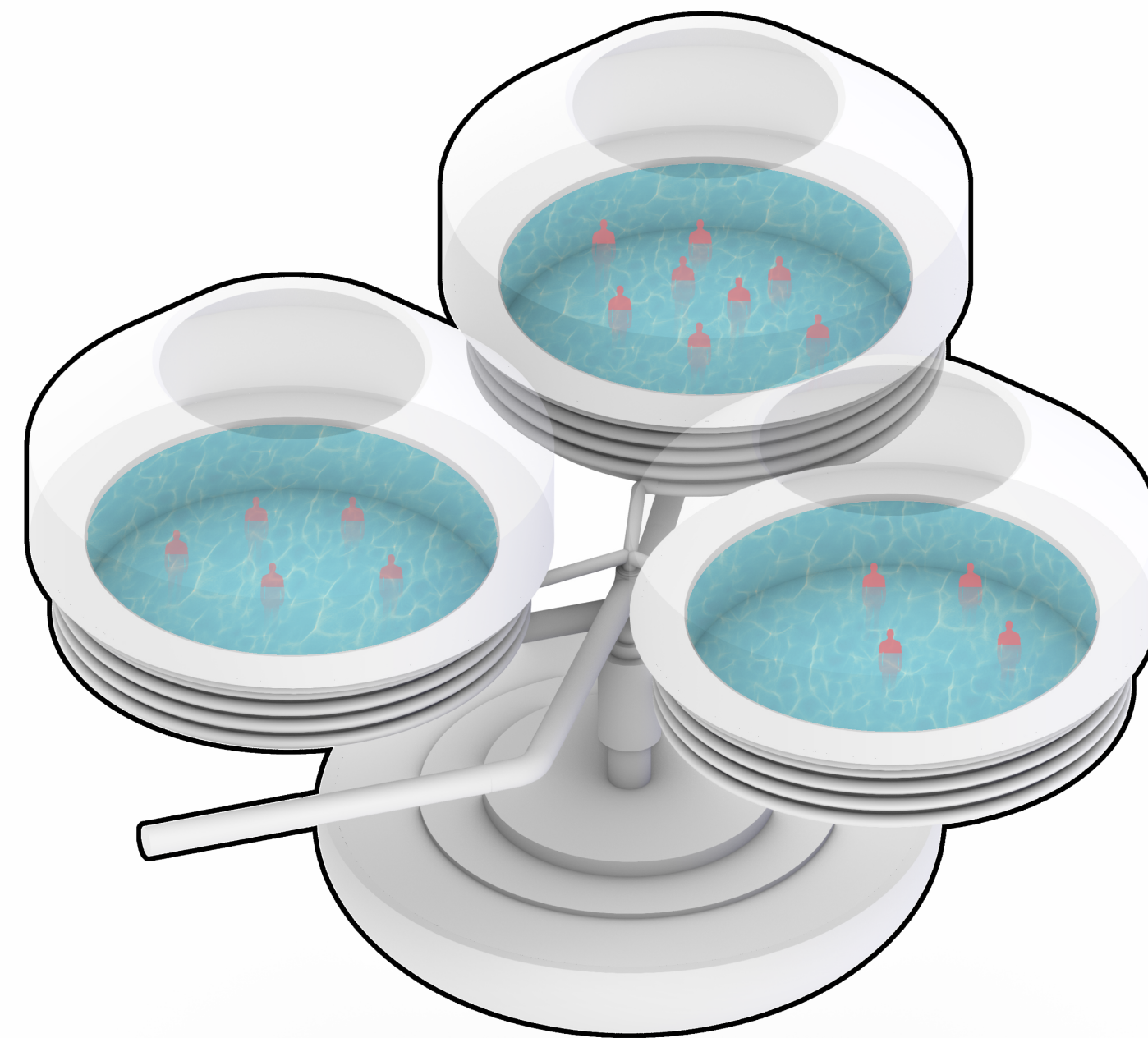
Hydraulic control mechanism



Hydraulic control mechanism

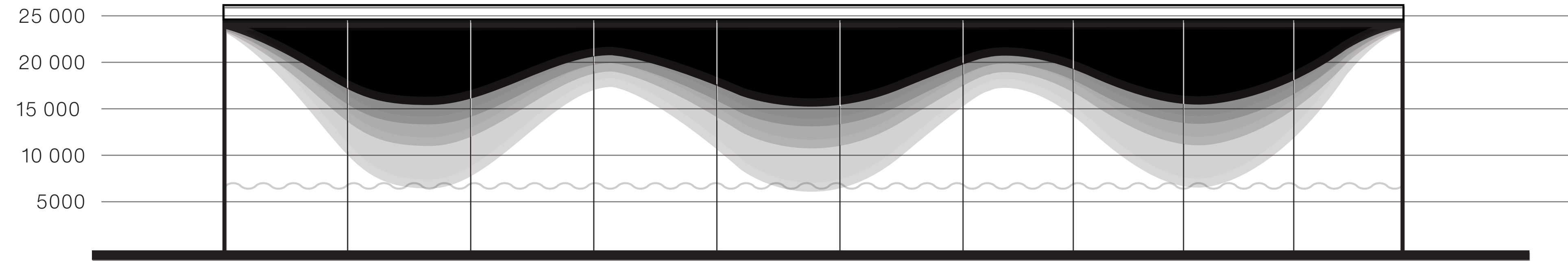


Pool location

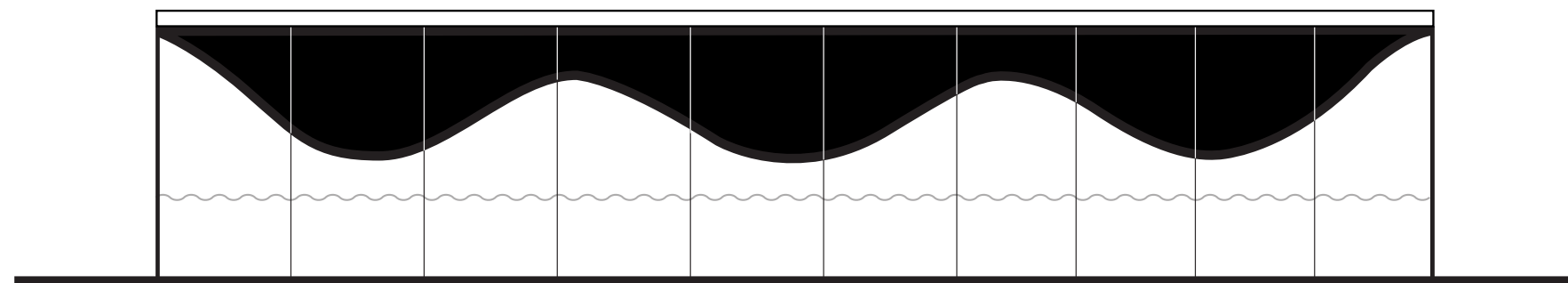
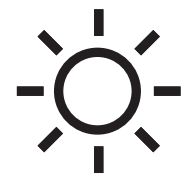


Pools

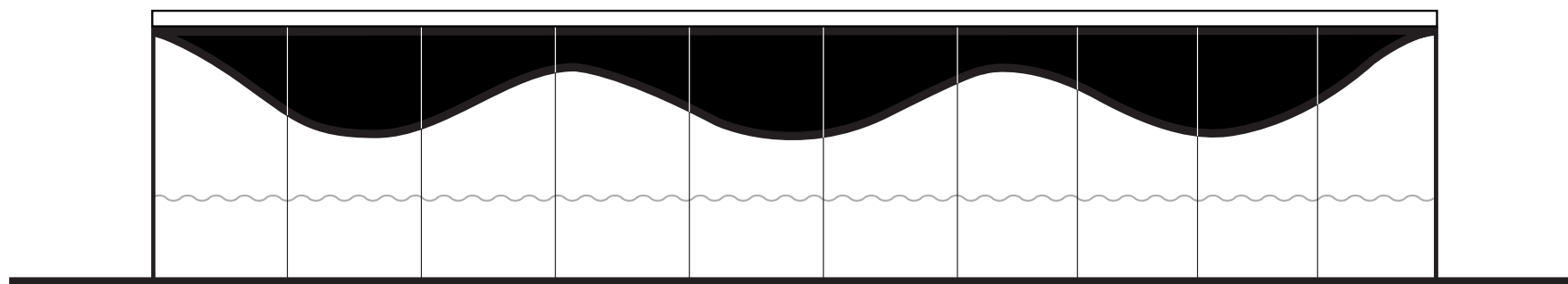
As it seamlessly integrates with the national consumption of electricity in Sweden, the ceiling not only captivates onlookers with its dynamic movements but also acts as a public measuring tool, aimed at educating and raising awareness about energy usage. At the core of its operation lies five times three interconnected pools, which play a pivotal role in controlling the mechanism by releasing water into a series of levers.



Public measuring tool



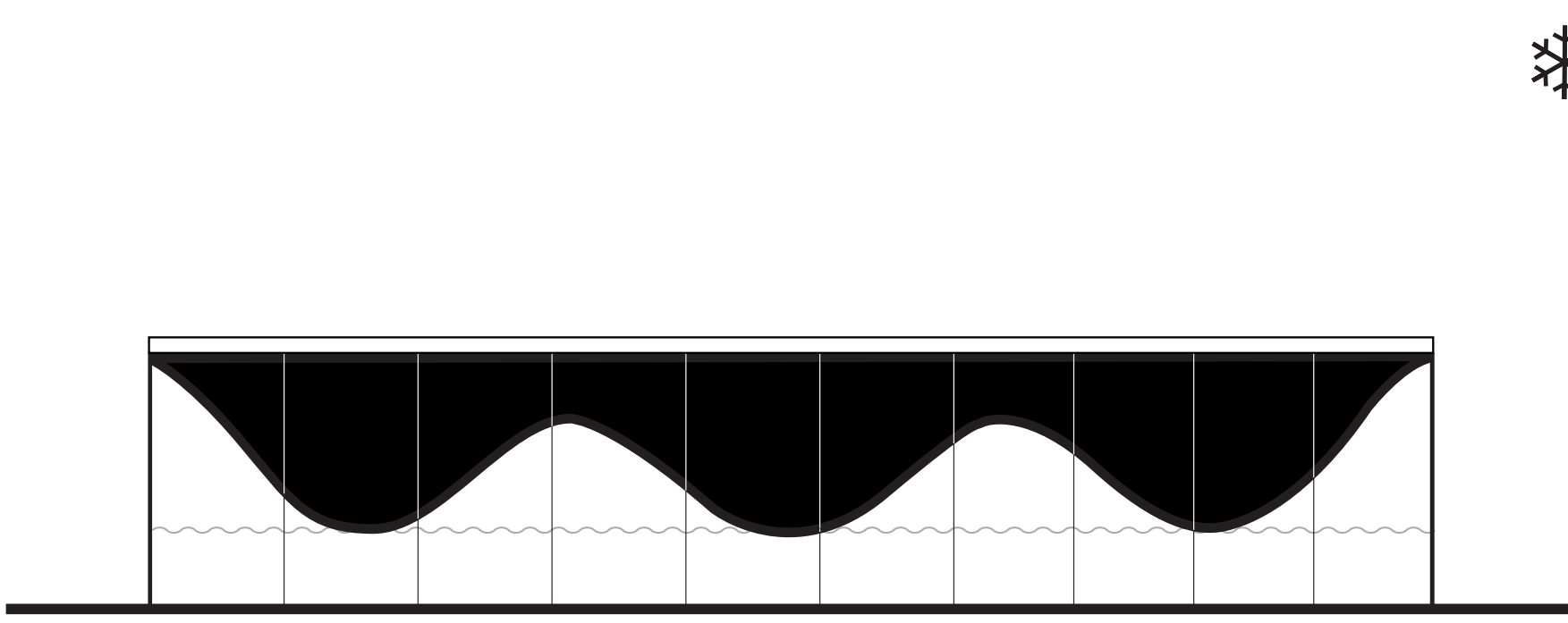
Night: 8MWh



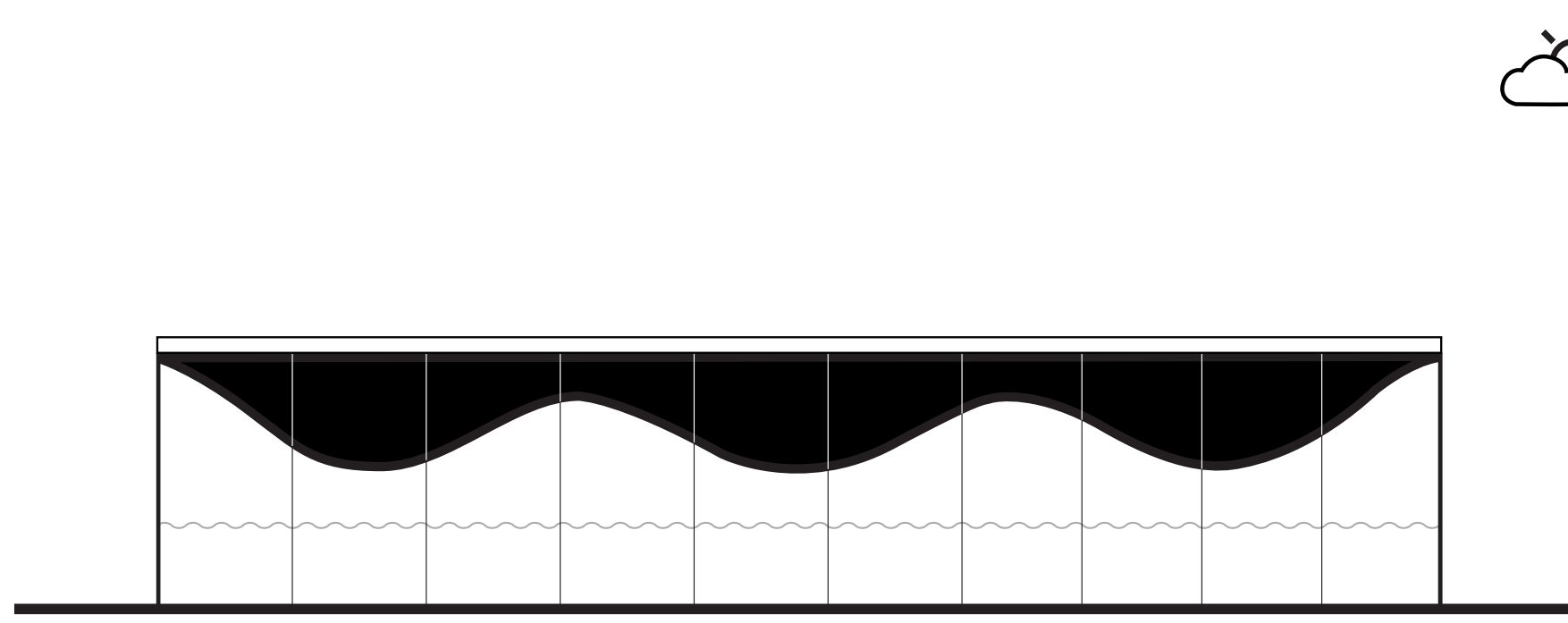
Morning: 10MWh



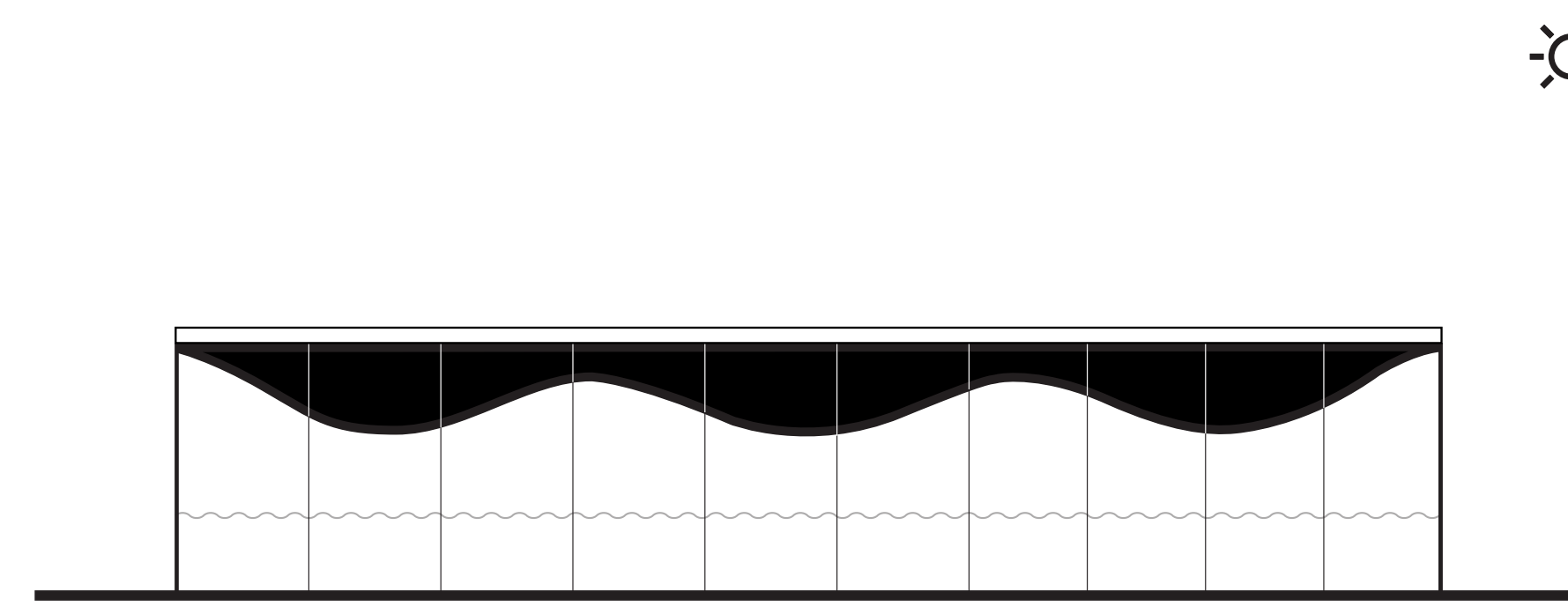
Midday: 16MWh



Winter: 150 TWh

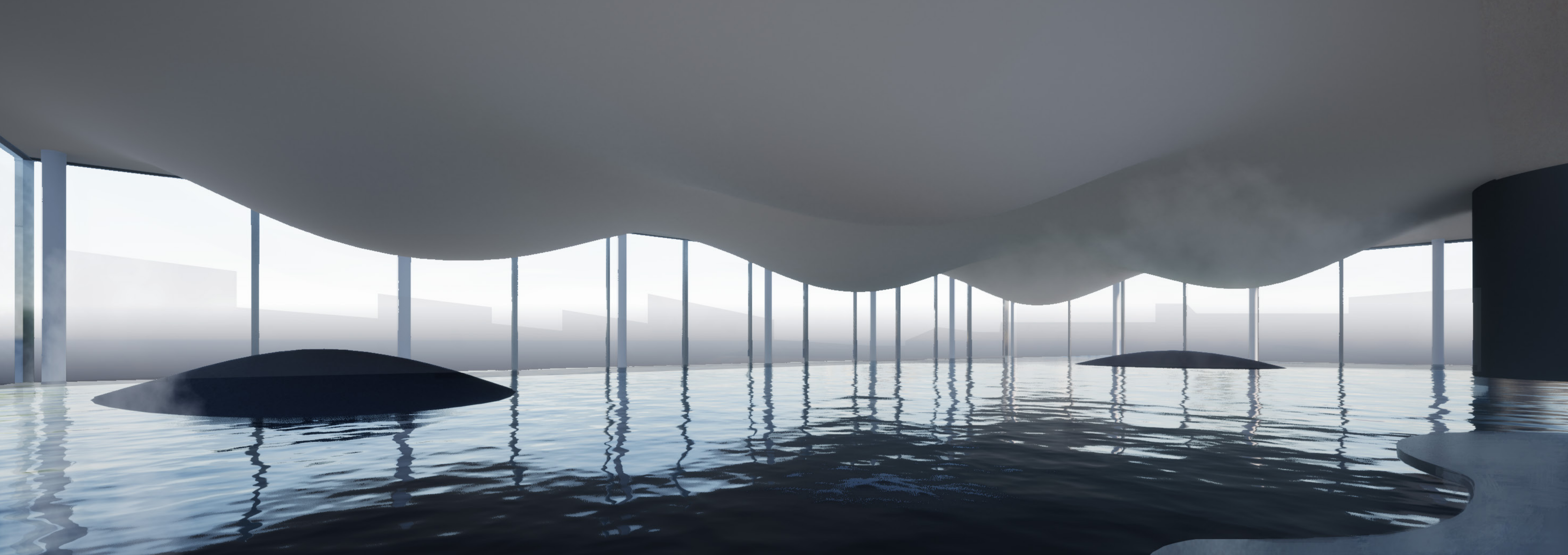


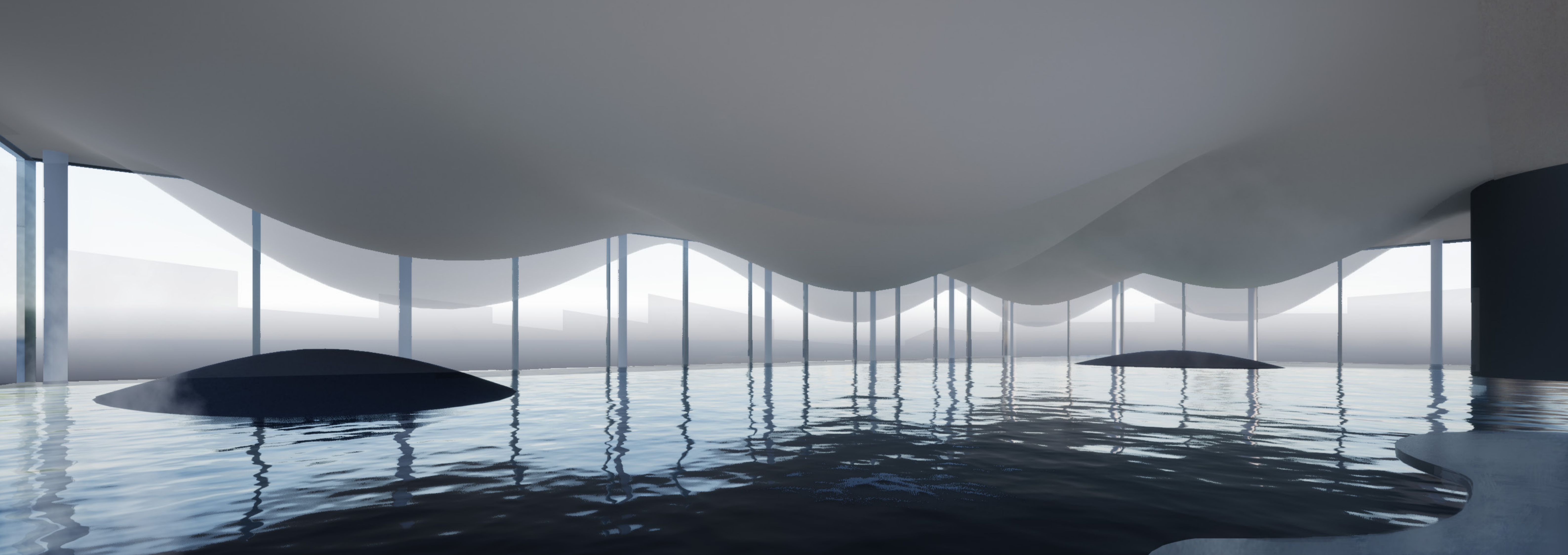
Fall: 100 TWh

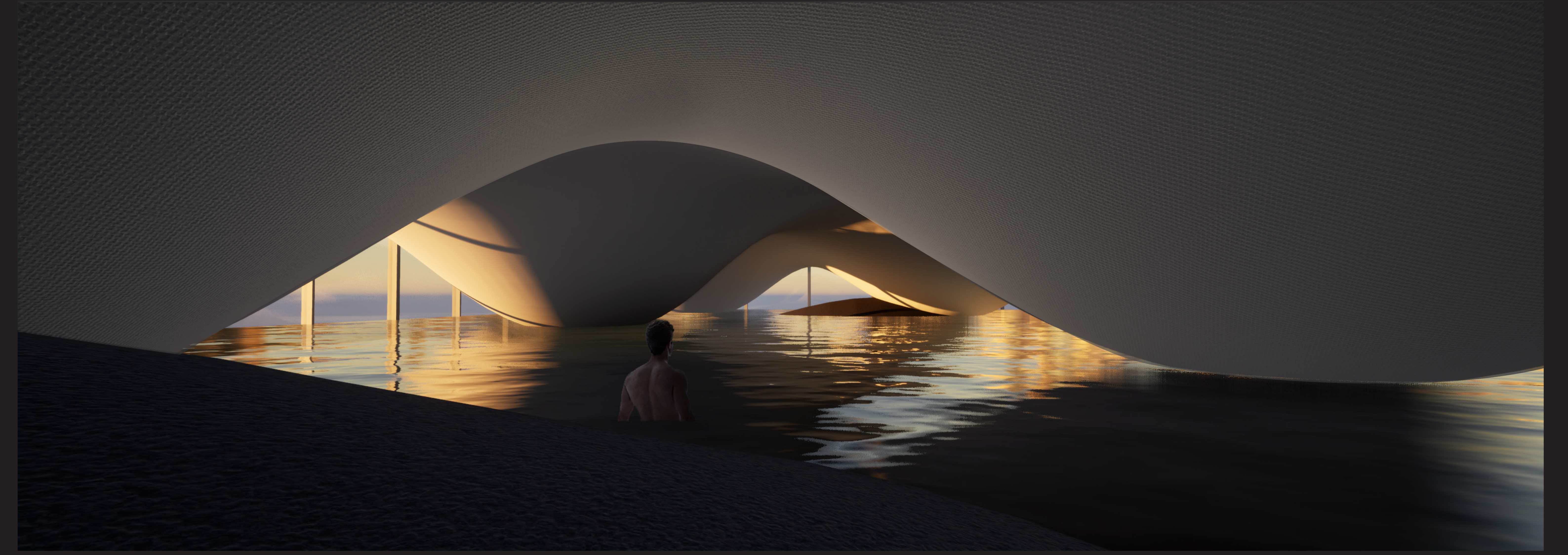


Summer: 80 TWh

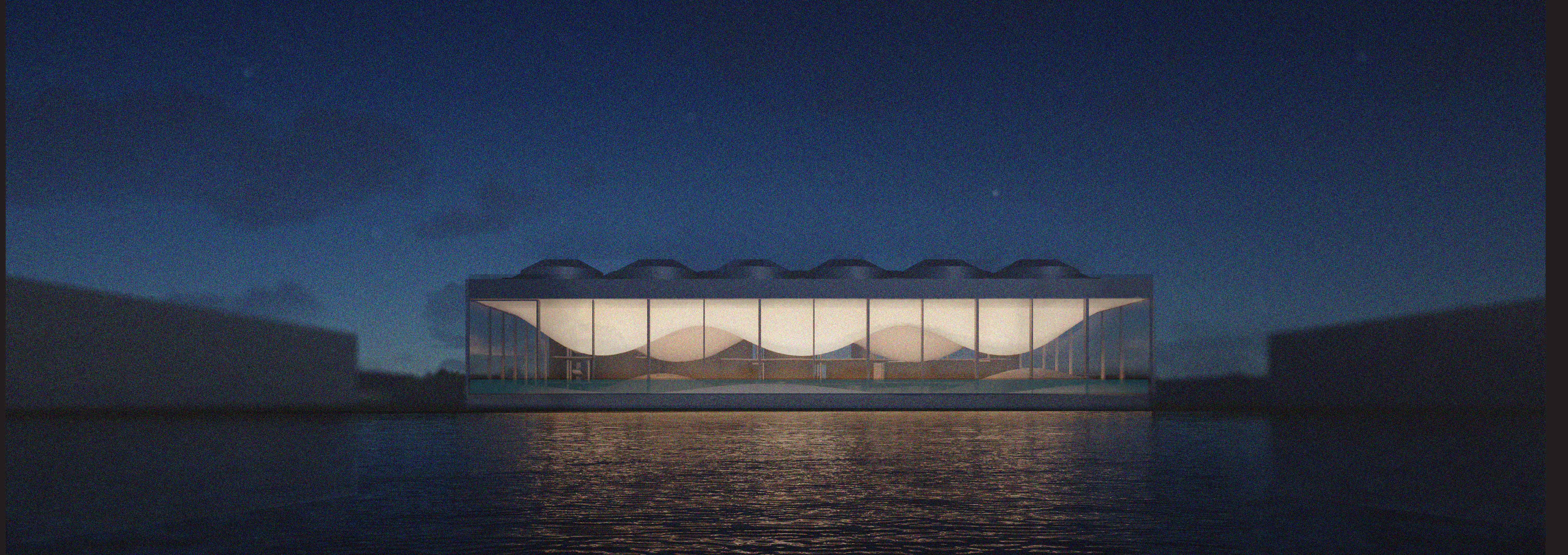












IV

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