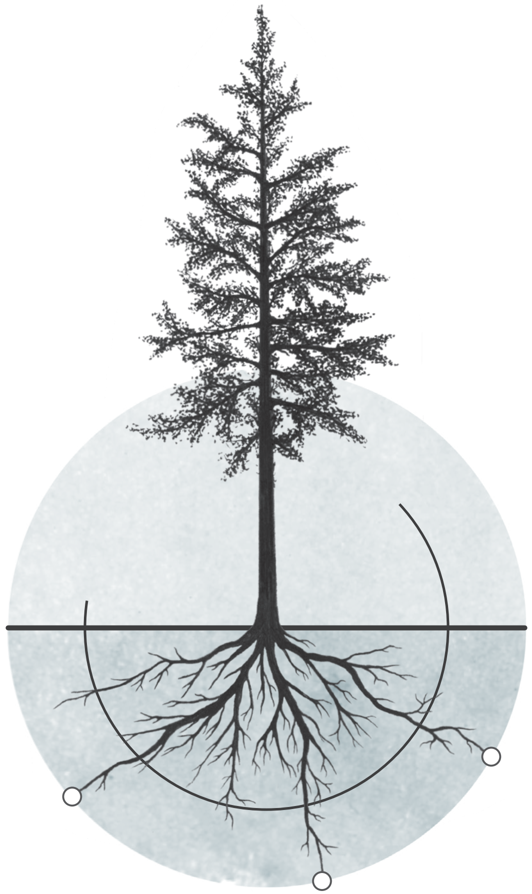

# WOODLAND HOUSE OF RECOMPOSITION

Architectural Master Thesis by Anna Sophie Bresson & Nikolaj Slumstrup Petersen

MASTER THESIS

University - Aalborg University, Denmark
Department - Architecture, Design, and Media Technology
Education - Master of Science (Msc) in Engineering (Architecture)

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Group 13

Anna Sophie Bresson

Nikolaj Slumstrup Petersen

Let’s talk about…
…the *beauty* of death
…the *possibilities* of
composting dead bodies

WARNING

Let’s talk about…
…future ways of designing for death
…innovative death architecture
…sustainable interments

”

*Given the moral capacity of architecture, it cannot be coincidental that in many of the world’s cultures the earliest and most significant works have been funerary. The fear of forgetting anything precious can trigger in us the wish to raise a structure like a paperweight to hold down our memories.*

- Alain de Botton -

# READING GUIDE

This report is the documentation and publication of the master thesis, *Woodland House of Recomposition*, at Architecture & Design in the spring 2018 created by group 13: Anna Sophie Bresson & Nikolaj Slumstrup Petersen.

The report communicates the design process of this master thesis project as well as describing and illustrating the final design proposal.

The report is structured into eight chapters in the following order: Prologue 01, Thematic studies 02, Site analyses 03, Program delimitation 04, Presentation of the design 05, Sketching phase 06, Synthesis phase 07, and lastly the Epilogue 08.

In Chapter 02 the reader is presented to all the research and thematic analyses of the thesis including several topics within sustainable design, designing for death, and decomposition.

In Chapter 03 the reader is introduced to the site, the Woodland Cemetery, followed by analyses of the site such as historical perspective, genius loci, the architecture and landscape, layerings, and mappings. This chapter together with Chapter 02 will culminate in Chapter 04 with a room program, target group definition, design criteria, and a vision for the project.

After the program the design proposal for the House of Recomposition is illustrated and presented in chapter 05, Presentation.

Following this chapter, the design process leading to this design will be unfolded in Chapter 06 and Chapter 07. In these chapters the reader will be shown sketches, models, trials, studies, calculations, workshops, etc.

Lastly, in Chapter 08 of the report, a conclusion and reflection is made on the whole process and project. In addition, the reader will find the bibliography and illustrations list.

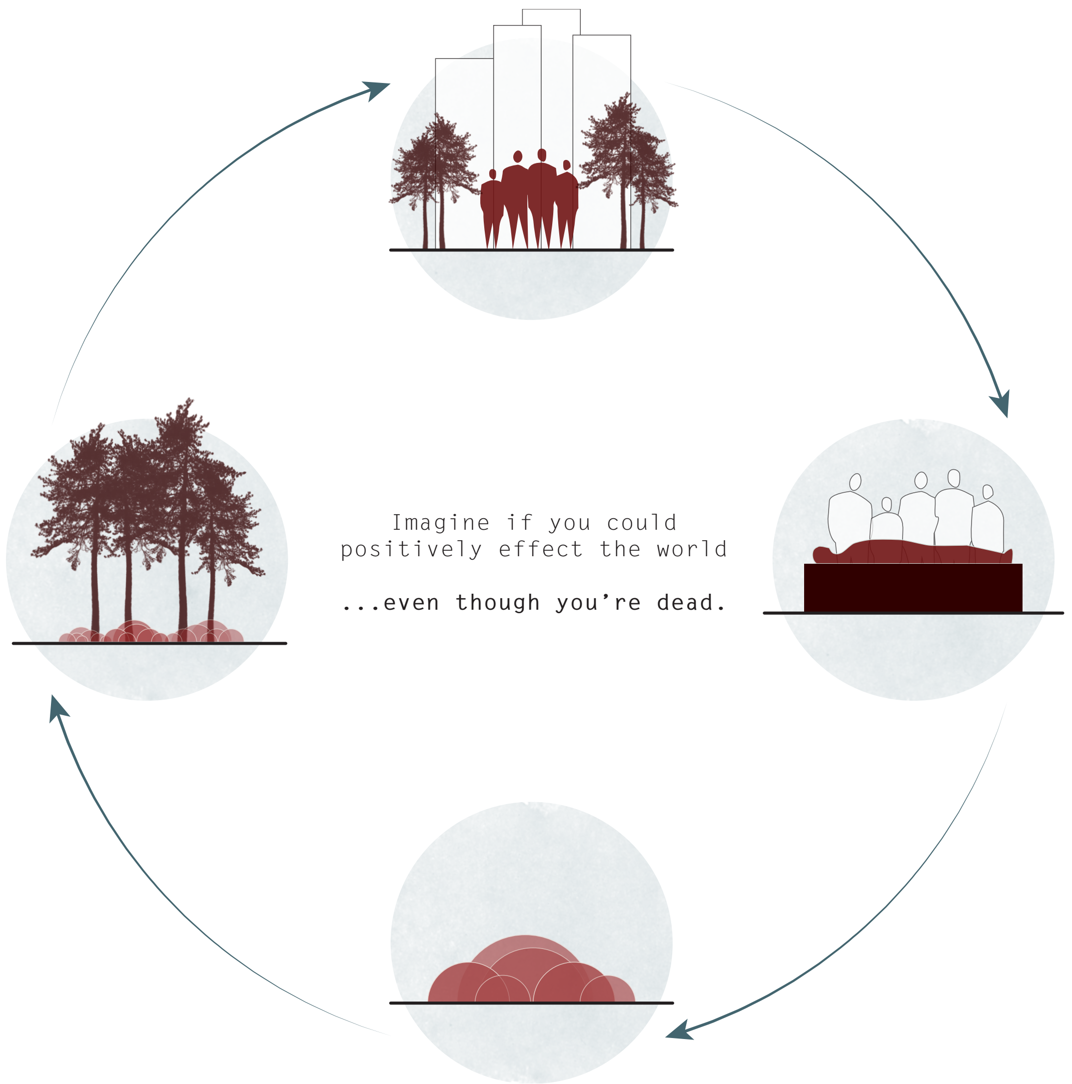
Additionally, six appendices can be found.

# ABSTRACT

In this master thesis, by Anna Sophie Bresson & Nikolaj Slumstrup Petersen, a sustainable building for a new way of interment have been created. With the title Woodland House of Recomposition, a house for decomposition of dead bodies as well as for ceremonies, mourning, and memorial have been designed. The house is located in the forest of Woodland Cemetery in the outskirt of Stockholm - the country with the largest group of secular people. In this historical setting, the Woodland House of Recomposition offers a new way of parting with our deceased in an architecture that gently balance its controversial and traditional elements.

Additionally with designing the first building of this kind - offering decomposition as an alternative to cremation and burial - the goal has been to prove that this way of interment in fact is sustainable in comparison with the common, environmentally harmful ways of disposal of our dead. This has been proven through a Life Cycle Assessment of the decomposition process conducted in this master thesis.

The Woodland House of Recomposition is holistic in its design concerning the three major focal point of the thesis: Sustainability, Designing for Death, and Decomposition. Thereby, the result of this thesis is a sustainable building that houses a sustainable interment as well as rooms for dealing with death - rooms such as the Chapels, the Mourning Hall, the Memorial garden, and the Life Room. In this thesis, both the architecture, the construction, the indoor climate, the decomposition process, the ceremony, and the rituals have been designed to merge into this new building: the Woodland House of Recomposition.


Imagine if you could
positively effect the world
...even though you're dead.

ILL. 1

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## 01 PROLOGUE



## 02 THEMATIC STUDIES



## 03 SITE ANALYSES



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## 06 SKETCHING PHASE



## 07 SYNTHESIS PHASE



## 08 EPILOGUE

# 01

## PROLOGUE

The following chapter describes and illustrates the problem and motivation - the starting point and catalysts for this thesis project. Additionally, an introduction will set the frame of the report for the reader. Lastly in the chapter the methodology of the design process is described.

*Current funerary practices are environmentally harmful and, for some, psychologically unsatisfying. The current practices are part historical convention and part funeral industry mandate. ...most people are buried in a conventional cemetery or cremated, emitting carbon dioxide and particulates into the atmosphere. These practices consume valuable urban land, pollute the air and soil, and contribute to climate change.*

\- Katrina Spade 2013 -

ILL. 1.1

# MOTIVATION

The world holds many variations of interment, though in Northern Europe we primarily operate with the cemetery burial and cremation. The principles behind these two methods can be drawn back several hundred years to the middle ages and before from where they also gain their appeal and traditional or religious attachment. But in a world critical of religious traditions and norms and an awareness of the environmental consequences of our actions, we now challenge the imposed context around these methods:

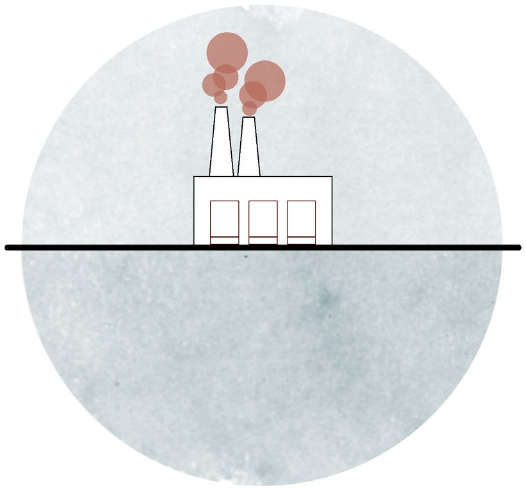
In the case of cemeteries the growing world population necessitates a need for higher capacity in graveyards where many of these are already saturated. The consequences of this are that people are being buried further and further away, making it difficult for the bereaved to visit the grave to mourn and maintain it, as the typical churchyard indicates one should. Additionally, it can be difficult to retain family graves or even to be buried at the same graveyard as your dead relatives. In other cases the price for even small graveyard spaces have increased drastically, excluding low-income people and forcing them to choose cremation in lack of other alternatives.

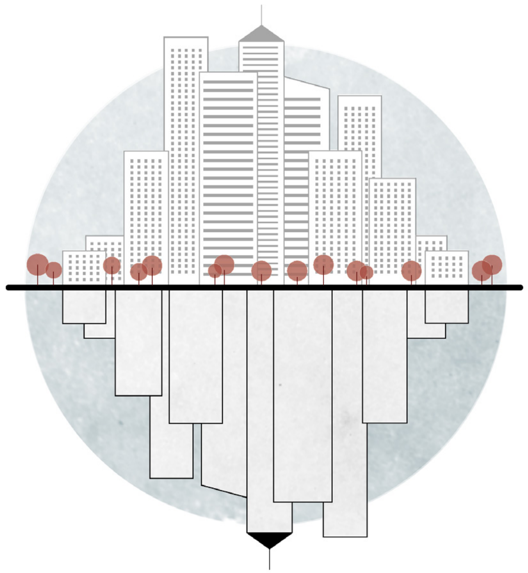
While cremation may solve the problem of graveyards running out of space, it fosters other problems such as release of $CO_2$, heavy metals, and toxic compounds. Regarding the metaphysical aspect, cremations are imposed with fewer traditions and therefore offer to address non specific religions as well as atheists - although it may also suggest leaving the interment without a spiritual outlet to mourn and process the loss.

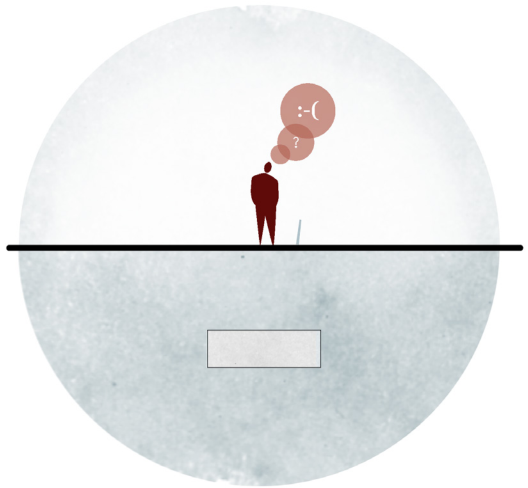
Most people in Northern Europe would likely acknowledge death – or at least the prospect of their own death – as a taboo or superficial subject. This comes from the detachment of death from our own lives and a unpersonal understanding, that death is mostly related to non-relatable catastrophes and war. Where death used to be a time of heartfelt remembrance - which it still is in many foreign cultures - it has in many ways failed to evolve along with technology and similar values in our modern western society.

This follows a general notion of how our break from religion, in especially Scandinavia, made us separate ourselves from an understanding of the needs of our mind. Becoming wiser on the fragility of the secular society might open our eyes to the importance of a well-balanced self and a clearer responsibility to ourselves directly as well as indirectly through our shared social and natural environment. This necessary change in lifestyle towards a more socially and environmentally responsible might automatically follow as a result of the current shift to more sustainable processes that shape society and keeps it running. In regard to this, our current idea and approach to death is severely overlooked and an important aspect to tackle.

This thesis will challenge the current perception on the personal death through the values and traditions related to historical methods. From here, we aim to rebuild them, based on new ideals and technology - in a secular yet still spiritual architecture. Thereby, shaping an approach to death and interment which integrates both the social, the built, and the natural environment holistically.








ILL. 1.1

CREMATION

*"The average cremation uses 106 liters of fuel to burn a single body, emitting about 245 kilos of carbon dioxide into the atmosphere. That's about 250,000 tons of $CO_2$ each year."*

- Katrina Spade -

CEMETERY BURIAL

*"If you turn a cemetery upside down it looks like the middle of the city - like a skyscraper. Nearly half of cemeteries in the UK could run out of space in the coming decades. Plans to reuse graves by burying original occupants deeper in their plots are being considered by many councils."*

- Dr. Julia Rugg -

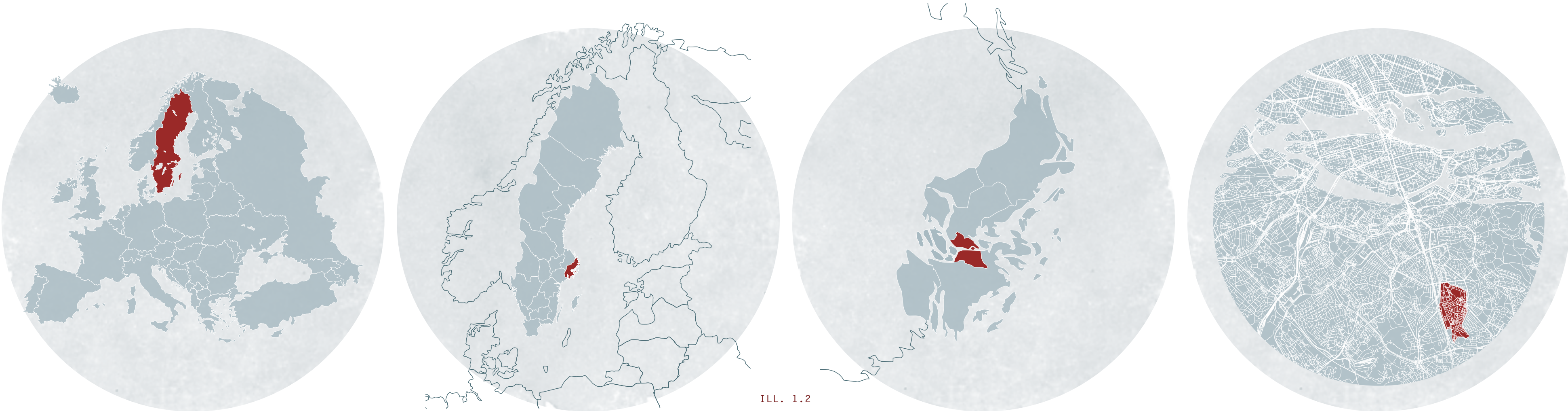
LACK OF (SECULAR) SPIRITUALITY

*"After losing my dad recently I need to be allowed to feel pain, but everyone is in such a hurry for me to move on. When have we become people who no longer take the time to feel? When did we get so busy?"*

- Frederikke Havgaard Jakobsen, 2018 -

## PROBLEM STATEMENT

By designing a sustainable building for a new way of parting with our deceased based upon decomposition of our dead bodies, can we then offer a holistic, sustainable, and spiritual way - both in architecture and function - of interment for the future?



ILL. 1.2

SWEDEN // SÖDERMANLAND & UPPLAND // STOCKHOLM CITY // WOODLAND CEMETERY

*Woodland House of Recomposition* will be the first of its kind – embracing ideals and technology with breaks on traditions and a forward-thinking narrative. Shaped by thoroughly defined values and principles, this house will be an environmentally and socially responsible building to service a growing, environmentally aware society who seeks a holistic method of parting with their loved-ones as well as a way of leaving their own body behind after death.

The idea behind this project originated from *Recompose*; a research group currently working with implementing the principle of interment by decomposition in the North American context with a focus on technical and legal aspects. Its founder Katrina Spade's master thesis was the original sources for the research of this master thesis and will also act as a base for our project theme in addition with more sociological studies in relation to understanding and design for death and mourning. However, the approach and design for this master thesis will focus on the Scandinavian context as well as having a primary focus on creating the architecture itself.

The location for this master thesis is a site within the Woodland Cemetery, Skogskyrkogården, in Stockholm. The site has been chosen due to its placement in a Nordic, secular-dominated country as well as its close proximity to a large city. In this way the site, and the Woodland Cemetery in general, provides a serene landscape and frame for a large group of people in a dense urban city to come and mourn or reflect. The Woodland Cemetery with its landscape and architecture constructed from 1920-1940 has made space for a new building - in this case a new crematorium, defined in a design competition held by the Stockholm Cemetery Committee in 2009. The site and the overall demands from the brief for a new crematorium will contribute to the frame for this master thesis. In this way, the design for the House of Recomposition will be an alternative solution to a new crematorium building. To respect and integrate the House of Recomposition into the already settled Woodland Cemetery, research and analyses of the landscape and architecture are made in addition with a site visit.

With the creation of this first *House of Recomposition* we will experiment with, challenge, and innovate the function decomposition as interment as well as the architecture by integrating research and technology in the design of the aesthetic narrative. Creating a pilot project comes with a great responsibility and opportunity for proving the hypothesis that this new vision for future interment is in fact a more environmental and social responsible building. This, compared to a benchmark crematorium, the tested through, amongst others, the knowledge and use of LCA. If we manage to prove this hypothesis true in this master thesis, our design will have the opportunity for laying the ground works for future houses of recomposition. Therefore, this master thesis will focus strongly on the integration of sustainable materials and technologies, atmospheres and sensations, the mourners and bereaved, body and mind, visitors and staff, as well as focus on spirituality and knowledge. If the hypothesis proves not to be true, the House of Recomposition will still act as an innovative and experimental stepping stone in rethinking the way we part with our deceased in a more sustainable manner.

Since *the Woodland House of Recomposition* neither has an existing typology or an existing building program to design from, much of this thesis will be centered around research to create what does not yet exist. This specifically: the needs of society and people concerning mourning and memorial, the requirements around the decomposition process, and the principles of sustainable architecture. To optimally collect and integrate knowledge gained in this thesis, the principles of *the Integrated Design Process* - Problem, Analysis, Sketching, Synthesis, Presentation - (Knudstrup, 2004) will be used to structure the thesis development. The thesis will be parted more directly into a *Research Phase* (Problem and Analysis) with the product being a building program and frame, and a *Design Phase* (Sketching, Synthesis, and Presentation) being the incremental development of the integrated building design.

**Research phase** // Based on the problem statement, the categories of the *Research Phase*, mentioned above, have been specified to Sustainable Design, Designing for Death, and Human Decomposition. These will primarily be used to categorize the thesis analyses, and secondly to continuously challenge the direction of the project in both its design process and final architectural proposal.

The subject of Sustainable Design will investigate the current acknowledged definitions, certifications, and standards of sustainability, to define our own tailed to this thesis project. At the same time, we will explore the tools used today to simulate the environmental impact of our own design. The knowledge gathered from this will help guide the whole design process to always strive for sustainable, integrated, and holistic solutions.

The subject of Designing for Death will guide us in exploring the human needs and attitudes towards death, while challenging the architectural symbolism that is apparent in both traditional and modern death-related architecture. These analyses, especially, will be used as a foundation for designing the building expression itself - ones first impression, and the general perception and narrative told through the architecture.

The subject of Human Decomposition will investigate the workings of the decomposition process and the technical requirements needed to uphold a healthy and efficient ecosystem within. By balancing and integrating these two aspects, we have the potential to create a holistic symbiosis between sociability and technology. Combined with the knowledge of Sustainable Design, we will then establish a strong foundation for the coming design phase and a greater possibility to answer the problem statement.

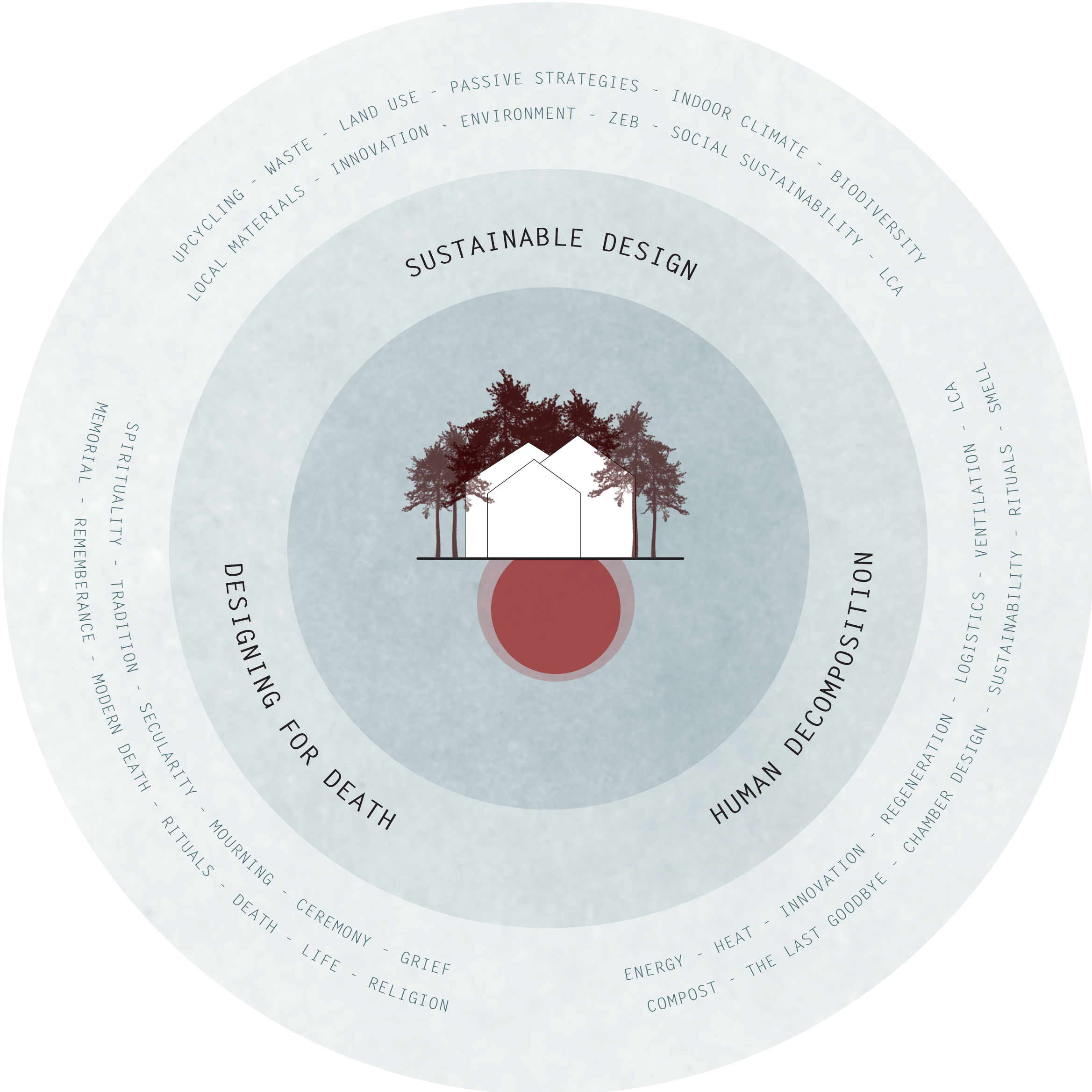
Additionally, weather data, historical references, and a site visit in the beginning of the semester will help us understand the environment in which we are working. This in regards of place as well as social, natural, and architectural importance.

**Design phase** // Many aspects of the project theme and frame are more closely connected to the actual design development. This requires them to be simultaneously explored, as the building takes shape. In the same principles as the focused analyses, made in the *Research Phase*, the *Design Phase* will be structured into thematic workshops. These workshop will act as a platform for the iterative processes and help explore the many essential elements of the building development. In this regard, the workshops will constantly intertwine and disentangle to form new ideas and solutions.

The workshops are structured with the same three key subjects in mind: Workshop 01-03 and 06 will primarily address the users and the social importance in the design through logistics, rituals, and sensual perception (Designing for Death). On the other hand, workshops 04-05 will investigate the building in detail with materials, energy, and indoor climate in regards to Sustainable Design. Lastly, the Human Decomposition is integrated into both workshop 02 and 05. In these, decisions on the design of the decomposition environment will subject the building design to change and vice versa.

The constant movement between these workshop means that the design development will be subjected to all aspects repeatedly - thereby providing a firm infrastructure for creating a holistic design: While the first set of workshops will shape the building based on ceremonies, room capacities, and daily routines, the other workshops will constantly challenge the decisions based on narrative elements, principles of sustainable design, and the technical requirements of both the building and the key function of the building - the decomposition of deceased.

The beforehand planning and structure of the thesis will help guide the design process while still allowing for freedom for the design process itself to evolve and guide us.


UPCYCLING - WASTE - LAND USE - PASSIVE STRATEGIES - INDOOR CLIMATE - BIODIVERSITY
LOCAL MATERIALS - INNOVATION - ENVIRONMENT - ZEB - SOCIAL SUSTAINABILITY - LCA
SUSTAINABLE DESIGN
DESIGNING FOR DEATH
HUMAN DECOMPOSITION
MEMORIAL - REMEMBERANCE - MODERN DEATH - RITUALS - DEATH - LIFE - RELIGION
SPIRITUALITY - TRADITION - SECULARITY - MOURNING - CEREMONY - GRIEF
ENERGY - HEAT - INNOVATION - REGENERATION - LOGISTICS - VENTILATION - LCA
COMPOST - THE LAST GOODBYE - CHAMBER DESIGN - SUSTAINABILITY - RITUALS - SMELL

ILL. 1.3

# 02

PROGRAM
THEMATIC STUDIES

The themes Sustainable design, Designing for death and Decomposition has been researched and analysed upon in this chapter to create a strong foundation for the design process of the Woodland House of Recomposition to come.


## SUSTAINABLE DESIGN

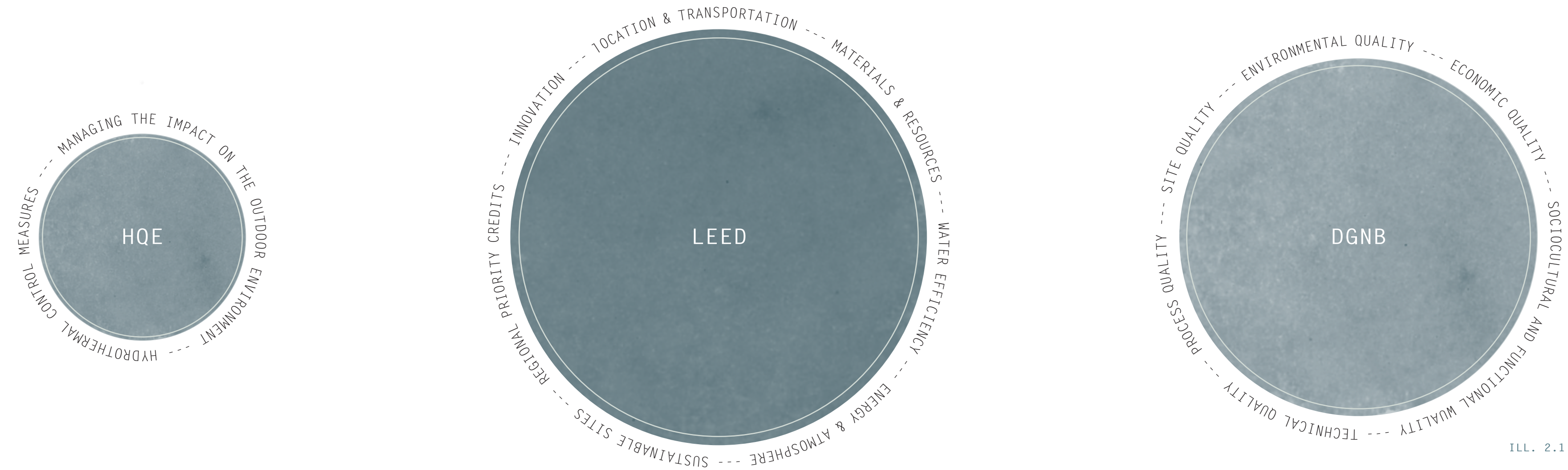
The following analysis of different definitions and approaches to energy and resource responsible design throughout recent history will be used to clarify the extent of the term sustainability in order for us to approach our building design and its functions with clear criteria.

Architecture has been one of the constant phenomenon of development throughout history and has always strived to represent either current trends and societal structures or an idealistic, but absent life. In this regard, architects and engineers have always tried to solve the problems of society and better the circumstances in which they operate. And as we now feel directly the consequences of our environmental neglect from our industrial growth, we must try to rebalance our relationship with nature.

The environmental movement started around the 1960s when people began to question the use of toxics and pesticides in farming. This quickly led to more concerns about air pollution by heavy industry and transportation as well as the growing accumulation of plastics in the oceans. The increasing attention to our relationship with the environment pushed scientists and politicians to address the many upcoming issues, and 'sustainability' were introduced to the public (Bernardi et. al., 2017).

Around the same time, the price of energy consumption pushed for higher energy efficiency as well as better heating and cooling technologies. This led to several studies and suggestions amongst the modernists and system theorists of the 1960s - one particularly being Buckminster Fuller's and Shoji Sadao's Dome over Manhattan: The idea aimed to completely regulate all of the domes ecosystems such as temperature and humidity to lower construction and living cost as well as energy consumption by removing the necessity for thick insulation and eliminating the need for heating (Kim and Carver, 2015). As mentioned, this was primarily from an economical point of view, whereas the following years introduces knowledge on resources and production materials and their overuse due to the continued economic growth. This notion was adopted and presented in the 1987 Brundtland Report and the Triple Bottom Line of Sustainability (also referred to as the Three Pillars of Sustainability) as seen in illustration 2.1 (Bernardi et. al., 2017).

The Triple Bottom Line of Sustainability was a general approach on the interrelationship between the social and economic aspect of society and their codependency with the environment. With an understanding of their equal importance and the impact of resource consumption versus the value created among the three aspects, sustainability turned into a political tool and a guideline for creating building designs

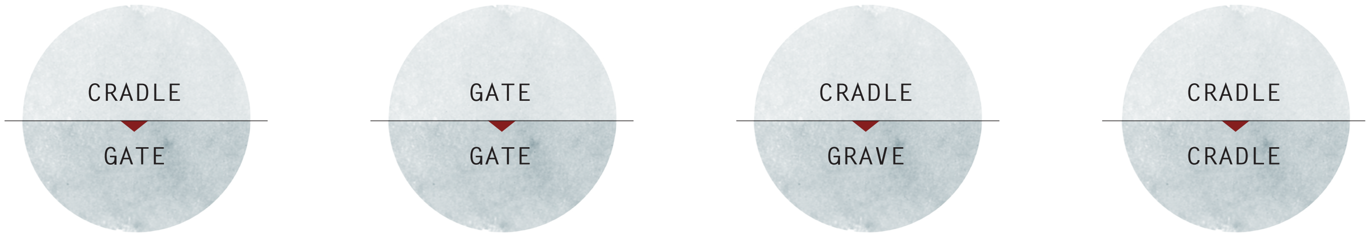



ILL. 2.1

that were holistically integrated with its cultural, political, and natural environment (Bernardi et. al., 2017). This was much in the same way as how the Roman architect, Vitruvius' unity of architecture suggested the trinity of construction, function, and beauty in order for good design to emerge (Worre; et. al. 2016). And just as this definition have been continuously redefined since to incorporate new knowledge and understanding, the definitions of sustainable architecture came to branch over multiple aspects of building design in the 90s and 00s:

As our relationship and dependence on technology grew parallelly in the end of the 20th century, systems for working sustainably and ideals to strive towards in the construction and design industries emerged. The first thoroughly defined certification for sustainable buildings was the 1990 BREEAM (Building Research Establishment Environmental Assessment Method) that categorized sustainable design in management, energy, health & well-being, transport, water, materials, waste, land use and ecology, and pollution (BSRIA, 2009). This certificate started a movement to quantify the sustainable quality of new buildings and in the following years the French HQE (1992), the North American LEED (1998), and the German DGNB (2007) followed (Everblue, n.d.). While most of the rating systems generally addressed the same categories of energy, material, water, social, health and waste, they each have their subdivisions and various definitions based on the political, cultural and environmental context in which they operate (Bernardi et. al., 2017). This difference in understanding 'sustainable design' encouraged a more common definition and indirectly resulted in the UN's adaptation of the aforementioned Triple Bottom Line at the 2005 World Summit on Social Development (Bernardi et. al., 2017) and later in the newly defined 17 UN Sustainable Development Goals from 2015 (United Nations, 2015). Although, the latter has a greater focus on politics and sociability and less on building design.

The fact that the many new and individually contextualized standards of sustainable design still mostly address the same aspects is a testament to a joined effort in securing a holistic and circular industry. Furthermore, as all of these standards are each a product of research and trials by experts of environmental systems, sustainability, and circular processes throughout the last 100 years, they must be concluded as being the closest thing to a truthful definition on sustainable design that we, with our current knowledge and technology, can produce and accept.




## LCA

This thesis will incorporate an LCA on the Woodland House of Recomposition and a crematorium benchmark. Therefore, it is necessary to clarify the extent of a building LCA and the system boundaries that we will operate with in this thesis.

The Life Cycle Assessment is a method of examining the total impact of a material, product, or process through all of its life cycle - combining resource use, human health, and ecological consequences (Bernardi et. al., 2017). The LCA has been more and more integrated in modern sustainable design as a means of quantifying environmental performance in relation to total carbon footprint, embodied energy, and the possibility of toxics. In most cases, the results are used to meet certain standards and certifications in sustainable design, but the increase in better and smarter LCA tools allow for usage directly in the design process to shape a more resource responsible design (Bernardi et. al., 2017).

Depending on the available data, the LCA can output information on Global Warming Potential (GWP), Ozone Depletion Potential (ODP), various toxics emission potentials (AP & EP), potential for depletion of resources (ADPe & ADPf), and primary and renewable secondary energy use (PEtot & Sec) (Trafik- og Byggestyrelsen 2016). In this thesis, however, we will only focus on the GWP and its energy consumption during its use, which we will compare with the crematorium benchmark.

The life cycle of a building is divided into five stages: The product stage, Construction Stage, Use Stage, End-of-Life Stage, and Reuse Stage - the latter being a separate calculation of benefits and loads beyond the system boundary as stated in EN 15978:2011 (Trafik- og Byggestyrelsen 2016). Of these five stages, an LCA typically operates in three ranges:

**Cradle-to-Gate** is an assessment of the beginning of a products life cycle, from resource extraction to finished product. As this range is independent of all later stages, it is most often used for the base of EPDs and the most frequently found.

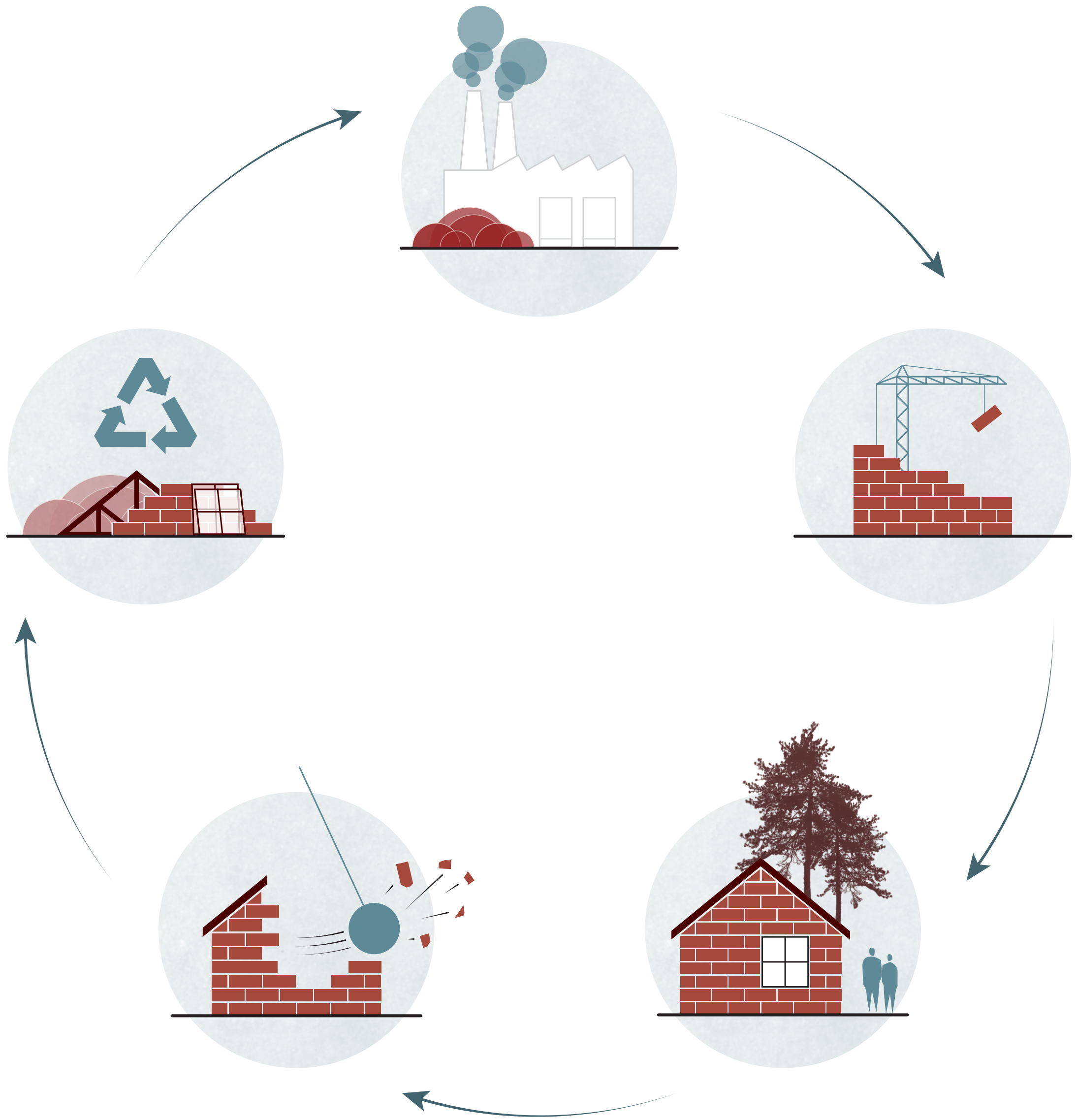
**Gate-to-Gate** is a partial assessment of only one stage of the entire production chain. This is often used as an in-depth assessments on various products and can address all sub-stages individually.

**Cradle-to-Grave** is the most used of the three for complete building LCAs as it address all stages from extraction of raw material to end-of-life resource processes.

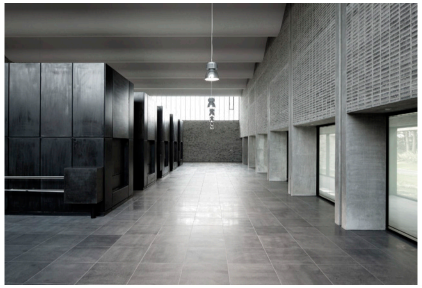
These later stages are important for understanding the environmental impact beyond the buildings construction itself as the use stage often represents 60 % of the total energy usage (Trafik- og Byggestyrelsen 2016). Furthermore, it is important to notice that the stages after the construction stage are scenario-based and that data therefore can only be based on assumptions. This also means, that data is often limited to only Cradle-to-Gate, making it difficult to output truthful and reliable results.

In addition to these three ranges, the term Cradle-to-Cradle has also been used to describe the instance where a product at the end of its life is able to fully return to its initial conditions - thereby making the product components completely reusable. This process is achieved by including the fifth stage; Reuse (Trafik- og Byggestyrelsen 2016, Braungart and McDonough, 2009).

In this thesis, we will attempt to include all stages over a 100 year life cycle.



ILL. 2.2

ILL. 2.3-2.6

## COMMUNAL CREMATORIUM // SECULAR CREMATION PRACTICE

In Ringsted, Denmark, a new communal crematorium, Fælleskrematoriet, was completed in 2013 with a greater capacity and the newest technology to be able to replace eight smaller crematoriums in the surrounding region. The crematorium is placed close to a park on a 50,000 sqm field that with time will be turned into an associated urn graveyard. (ArchDaily, 2015)

The crematorium is made for the community and therefore it does not distinguish between religious affiliation, or lack of same, of the deceased. The communal approach of the building is clear in the building's choice of not having a ceremonial, spiritual chapel as many crematoriums have (ArchDaily, 2015). Instead, it has a room from where the bereaved can overlook the cremation of the deceased. In this way placing the space for mourning and remembrance out in the landscape, individually connected to the many tombstones to be placed in the surrounding site. Therefore, the architectural expression indicate no kind of religious sublimity, but along with this neither does it reflect a certain kind of divine, spiritual or serene place and architecture one might associate with a house for the dead. The building focus more on its function as well as the importance of a well working workplace for its staff, which gives reason for the pragmatic and clean architecture of the building.

The crematorium has five ovens to be able to cremate an average of 22 dead bodies each day and additionally a cold room to storage maximum 80 dead bodies. This ambitiousness in capacity is also reflected in an ambitious vision of lowering their $CO_2$ emission from the cremations with 45 % as well as preventing toxic gases and heavy metals from being released. Furthermore, the excess heat from the ovens is distributed to the houses as district heating in collaboration with Ringsted Forsyning. (DR, 2013)

The focus on a great amount of natural daylight and architectural quality for the staff - and for the visitors - provides many views to the landscape surrounding the building. Additionally, it provides an inspiring openness and transparency into the building and the function of the building, not hiding the ovens and cremation process. Windows from the inside, as well as from the outside to the furnace room, gives both the bereaved and the local community an insight and closeness to the process, the dead, and death.

ILL. 2.7-2.10

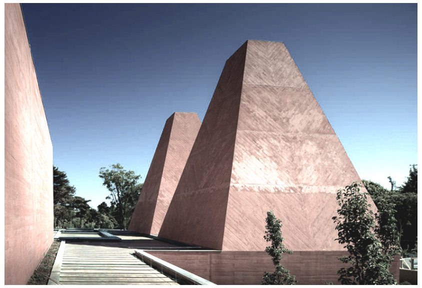
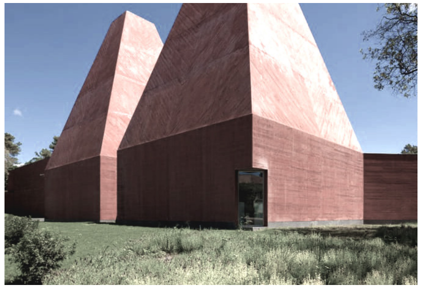
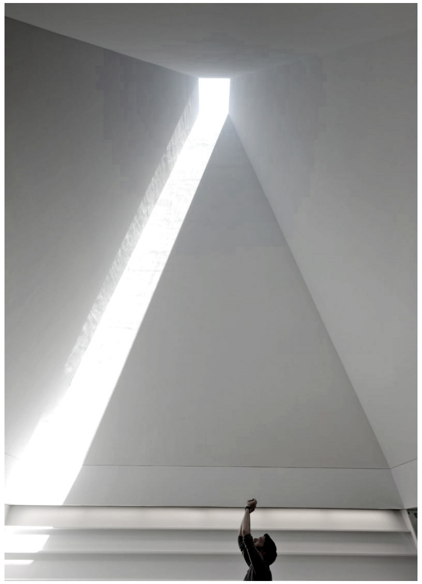
## TANATORIO SANT JOAN DESPÍ // MODERN FUNERAL HOME

In an already settled landscape, a new funeral home was to be built to add a masterpiece to the Fontsanta park and offer a building for one specific function: interment. The small, simple building is nestled into the existing hill in the landscape near Barcelona on an already existing cemetery (Batlle I Roig, 2011).

An continuing long roof and a facade facing the parking lot and arrival creates an symbiosis with inside spaces and outside spaces. The coherent expression is created by the corten steel pillars of flat bars letting the light pass through creating different atmospheres during the day. These pillars creates in one end a sheltered interior space with a glass facade while in the other end, they stand free, creating an open border into a courtyard. In this way the spaces, inside and outside, are seen as one building and all are equally benefitting from the shifting daylight effect created through the pillars, though still with each their own atmosphere.

Its inverted pitched roof makes the building placed in front of the hill seem light and subtle. The roof creates an open, guiding, upwards feeling from both the front of the building and the opposite site facing the hill. In the middle under the pitch in between the entrance and the interment room, a more intimate sensation is created. The entrance space is open and light with the transparent facade and a solid roof above, while the room for the ceremony is the opposite: the mourners face of solid, concrete wall, letting them focus on the ceremony rather than a disturbing view. A large ceiling opening in the ceremony room provides divine light and a view of the sky. The ceiling and roof of concrete continues from the inside to the outside on the front facade, working as a shelter from the harsh sun as well as playing with the feeling of being outside inside - or inside outside.

While the choices of materials might be simple and consisting of only corten steel, wood, concrete, and stone, the tactility of the materials are quite remarkable. All of the concrete are moulded with pinewood boards giving it a more unpolished, raw and shifting expression. The steel pillars in a warm, brown-orange colour adds to the raw expression of the concrete while bringing warmth to the building. Inside the building, the corten steel together with the wood cladding on the interior walls creates a more warm, embracing atmosphere.

ILL. 2.11-2.14

## PAULA RÊGO MUSEUM // REFLECTION AND SPIRITUALITY

A challenge of the secular world, and its architecture especially, is to adopt and transform the well-functioning aspects of religious institutions into strong, secular aspects (Botton, 2013) - aspects as serenity, profoundness, symbolism, ability to gather and connect with people, guidance of people, allowing people to connect with their feelings, as well as its majestic and symbolic architecture. These might not be present in many secular institutions and buildings but a certain type of building functions might have been, and still are, on the right track in this matter: modern museums.

Modern museums in many cases has the ability to create a space for reflection and focus; in some cases almost embracing its visitor in a spiritual atmosphere. With modern museums, one often link a grand and characteristic architectural outer expression with an interior that focus on the specific and individual experience evoking our senses and thoughts in that exact space or room. It creates a specific frame for the visitors to interpret and project their own thoughts and feelings into – guided by elements like light, materials, shape, space, and views.

These things are all the case of the Paula Rego Museum designed by Eduardo Souto de Moura, with its characteristic architectural outer expression: the shape of the two towers reaching towards the sky and the clear earthy-red material. Inside the smaller, intimate rooms dedicated to art, the rooms themselves become art in their shape with few openings to provide light and framed views - an art that people themselves chose to come to see and have as a common element, sharing its architecture as their common shelter. Inside the towers, a single window in the very top allows a small amount of daylight to enter - a divine light from above as one might see it. This beam of sunlight changes throughout the day and season, thereby changing the light setting, perception and atmosphere of the room as well. In its simple, but specific physical space, it allows the receiver to reflect their own immaterial spatiality onto.

ILL. 2.15-2.17

## LIVSRUM HERNING // MOURNING AND GRIEF

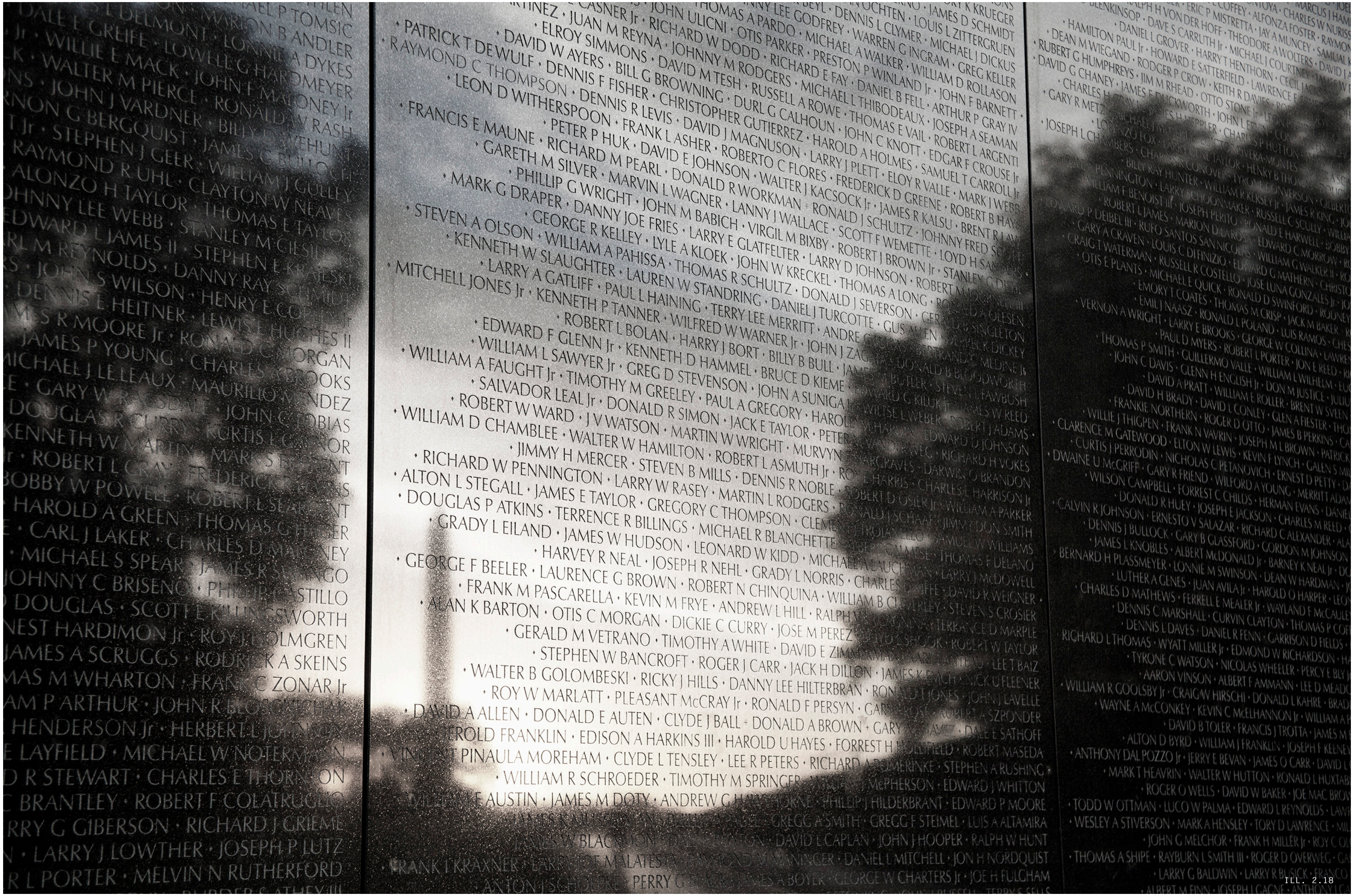
Life Room in Herning is part of the Project Life Room created by The Danish Cancer Society. The project includes seven Life Room Centers in various cities in Denmark in close connection to a hospital. This connection is to easily provide a more intimate, personal, and homely frame for both sick, families and the bereaved with the opportunity for more personal counseling from the hospital staff. The architectural focus and function concerns healing architecture with spaces for people to openly talk about life, death, cancer, sorrow and memories of sick or dead relatives as well as for the sick themselves to process their situation (Realdania, n.d.).

The Life Room in Herning focus on the human scale of both exterior and interior to create this private, homely architecture. The architecture and its plan solution is designed to be simple to not disturb, but rather create a calm space that the visitors do not have to try to figure out - an honest and readable architecture with few, strong elements (Claus Pryds, n.d.).

The long, linear plan creates a foreseeable flow within the building with views to the different rooms and several views to the shared, private garden. In this way the common areas do not disturb the private areas, but they are still connected.

The building consists of several small rooms and niches as well as larger common areas. One of these, the exercise room, is the only room with a larger, free volume and large windows, placed high as a contrast to many of the other rooms with a low ceiling that creates intimacy. The house in generel plays with contrasts: small and larger rooms, low and high ceiling heights, less view and much view, private and common, darkness and light.

The simple architecture is emphasised further through its choice of materials on the outside and inside as well as the different use of daylight. With wood dominating the interior, in some cases on both walls, floor, furniture, and ceiling, together with textiles, a warm, familiar, and safe interior is created.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FRANCIS E MAUNE · RICHARD M PEARL · DONALD R WORKMAN
GARETH M SILVER · MARVIN L WAGNER · LANNY J WALLACE
MARK G DRAPER · DANNY JOE FRIES · LARRY E GLATFELTER
STEVEN A OLSON · WILLIAM A PAHISSA · THOMAS R SCHULTZ
KENNETH W SLAUGHTER · LAUREN W STANDRING
MITCHELL JONES Jr · KENNETH P TANNER · WILFRED W WARNER Jr
EDWARD F GLENN Jr · KENNETH D HAMMEL · BRUCE D KIEME
WILLIAM L SAWYER Jr · GREG D STEVENSON · JOHN A SUNIGA
WILLIAM A FAUGHT Jr · TIMOTHY M GREELEY · PAUL A GREGORY
SALVADOR LEAL Jr · DONALD R SIMON · JACK E TAYLOR
ROBERT W WARD · J V WATSON · MARTIN W WRIGHT
WILLIAM D CHAMBLEE · WALTER W HAMILTON · ROBERT L ASMUTH Jr
RICHARD W PENNINGTON · LARRY W RASEY · MARTIN L RODGERS
ALTON L STEGALL · JAMES E TAYLOR · GREGORY C THOMPSON
DOUGLAS P ATKINS · TERRENCE R BILLINGS · MICHAEL R BLANCHETTE
GRADY L EILAND · JAMES W HUDSON · LEONARD W KIDD
GEORGE F BEELER · LAURENCE G BROWN · ROBERT N CHINQUINA
FRANK M PASCARELLA · KEVIN M FRYE · ANDREW L HILL
ALAN K BARTON · OTIS C MORGAN · DICKIE C CURRY · JOSE M PEREZ
GERALD M VETRANO · TIMOTHY A WHITE · DAVID E ZIMM
STEPHEN W BANCROFT · ROGER J CARR · JACK H DILLON
WALTER B GOLOMBESKI · RICKY J HILLS · DANNY LEE HILTERBRAN
ROY W MARLATT · PLEASANT McCRAY Jr · RONALD F PERSYN
DAVID A ALLEN · DONALD E AUTEN · CLYDE J BALL · DONALD A BROWN
HAROLD FRANKLIN · EDISON A HARKINS III · HAROLD U HAYES · FORREST H
PINAULA MOREHAM · CLYDE L TENSLEY · LEE R PETERS · RICHARD
WILLIAM R SCHROEDER · TIMOTHY M SPRINGER
ILL. 2.18

> *I think that architecture serves as a kind of vessel, a space for reflection, and I think that in cities we need these spaces more than ever.*
> - Steven Holl -

## MODERN DEATH

Death has always been a topic fascinated and feared by people through history, and death as a scientific study has become even more popular in newer time for especially sociologists. Many sociologists state that the key to understanding how the death culture has developed and changed through time is understanding the culture of our living society: our traditions related to death reflects our society. Analyzing how we live and structure our society now and in a historical perspective gives answers to why we say goodbye to our loved ones and choose to remember them as we do and did: why we choose to be cremated, interred in religious or non-religious ways, buried in the unknown grave, spread over the sea, or remembered by a stone on a grand, decorated graveyard. Vice versa analyzing ancient graveyards, burial traditions, and death rituals through history might give us answers to how people once lived and structured their society (Lunding et al, 2008).

Although death is made visible for us more and more through the media, death in our modern society is defined by sociologists Alain de Botton and Michael Hviid Jacobsen as a taboo that started in the middle of the 1900 (Botton, 2013; Jacobsen, 2001). In the current nordic context, this taboo might be less and less the case, but death and sorrow hasn't yet lost its superficiality. The death that we see on media is shown through terror, war, and catastrophizes, is overwhelming, impersonal, political and factual. This representation distances us from the personal, near, familiar and true death, making it more invisible and hard to process in our personal lives (Jacobsen 2001). Then when the personal death of some in our social circle appears, for a moment interfering with our everyday lives, the way many deal with it is in some cases by a simple "RIP :'( " posted on the deceased facebook wall - and less than a minute after, we scroll further on continuing our everyday life disturbed by adds, news, videos, etc.

*"After losing my dad recently I need to be allowed to feel pain, but everyone is in such a hurry for me to move on. When have we become people who no longer take the time to feel? When did we get so busy?"*
- Frederikke Havgaard Jakobsen, 2018

To understand and process death and a loss of a loved one, people - pre-modern as well as post-modern - have a need for structure, traditions, rituals and community as well as time and space (Botton, 2013). But after the post-modern society broke with traditions and distanced itself more and more from the religious world, our society today offers many opportunities concerning death and interment - but these alternatives are without new, structured and supportive traditions in a strong, physical community, thereby not able to guide the modern people in life and death in a secular manner (Botton, 2013).

*"Many Americans lack a guiding force like religion or cultural tradition to provide us with rituals or customs to help us deal with death."* (Katrina Spade, 2013)

How we choose to leave this earth today are in many ways old-fashioned: although we get better and more efficient through technology to e.g. cremate dead bodies and make the ashes of our dead ones into diamonds many still, and more to come, choose to be cremated. This way of interment adapted some – or were directly fitted into – the rituals of burial interment of the Christian Church in the early 1900. Nowadays, these rituals have for many been phased out by the rising number of selective religious people or non-religious people that choose cremation and an interment without its own, new traditions.

Today, people tend to replace religion with culture or lifestyle, giving their lives meaning through these. This does, however, not necessarily mean that these one-sided-communicative and somewhat individual aspects can guide us in our joint question of death (Munk, 2016):

*"...death has lost a part of its fabled mystery, that gave it a picture, and contributed to giving it meaning."* (Jacobsen, 2001).

The religions could and can provide us with a community and a structured space in where we together can give death meaning through words and pictures, making it part of our lives and relations. The question is how we can adapt these holy spaces into a modern, secular world where modern people are met with rituals they can relate to.

> *History shows that the way we die and our relation to death has changed throughout the last century - from a natural and comfortable way of viewing death to a death-denying attitude towards it.*
> - Michael Hviid Jacobsen -

## BURIAL ARCHITECTURE THROUGH HISTORY

To get an understanding of how a new way of interment could be designed and accepted as well as fulfill human needs associated with death and loss, burial architecture and traditions in a Nordic context is analyzed:

**Tumulus** // With the beginning of the agrarian society 4000 B.C. where agriculture would replace hunting, people started having a more permanent home. This led to graves being built as permanent and often grand monuments for honoring the dead of the kin (Kaul 1998). These monuments - inspired by the grandness of nature: the hills and mountains - became the dolmens, passage graves, and later the grand tumuli graves. Shared by all these was the mountain as a symbol which was used due to it closeness to the sky and thereby the afterlife and the sun, which at that time were worshiped. These graves and their traditions were created from the many stories and legends passed on from generation to generation and manifested in various pagan cults (Lidegaard, 1998).

Initially, the graves started as quite simple and were places very close to the home of the living in order for them to take care of the grave and by that secure good fortune, blessed by the dead. Through time the graves became more and more complex and monumental, which occured first as the plazas with long mounds forming a house for the death, similar to that of the living. As the inner chamber of wood was replaced with stone, the mounds turned into the dolmes with more and more bodies sharing the same dolmes as time passed. With these grand monuments, the amount and complexity of rituals increased. (Kaul 1998)

The people's belief in an afterlife was originally connecting the body and the soul - why the graves were carefully maintained with offerings and presents through several generations. Later in the middle of the Bronze Age, a new perception of the afterlife meant that the body and soul should be separated to ensure that the soul could find its way away from Earth to the afterlife. This was achieved by burning the dead bodies on large bonfires on land or at sea. The smoke from the bonfires would act as a guidance path (Lidegaard, 1998). The sea cremation was especially used, as the ship could secure a safe journey to the other world, which is also seen in that the graves made on land would often mimic the ships shape. Cremation, both on land and at sea, was present in most of the Iron Age and Viking Age.

As the burial graves were substituted with urns and urn graves, the tumulus became more of a memorial and a symbol of status such as those in Jelling, Denmark; Uppsala, Sweden and Borre, Norway (Kaul, 1998). They would, however, still often hold the urns and the larger tumuli meant for entire families turned into graveyards, with many smaller tumuli built in villages. These were in some way comparable to the Christian graveyards of today, where the dead was removed from the family home to a common place for everybody, as kins no longer lived separated but moved together creating villages and towns through time. (Lidegaard, 1998).

**Cemetery burial** // With the introduction of Christianity came new beliefs, traditions, and rituals along with the construction of churches replacing the tumulus over time (Kaul, 1998). But the need to grandly honor our loved ones and having death as part of the everyday life continued. The class-divided society that clearly manifested in the Romanticism, was visible in life as well as in death: the graves at the graveyards were demonstrating power and status through size, materials, and ornaments added with titles and profession carved in the stones. The churchyards became in some way a place to show off for both the dead and living with the living using it as a place to go for a stroll. As a contrast the lowest of the society were buried at a separate graveyard; Fattigkirkegården (Lunding et al, 2008).

As the divide in society became more vague through the beginning of 1900, once again the way of visibly honoring our dead changed: the shared graveyards – now for everybody – became less extravagant and more anonymous. Along with this anonymity and the fading of the fascination for death, so came the taboo of death (Lunding et al, 2008). The life of the living was rationalized and so were the graveyards and, to some extent, death.

*The enduring ambivalence of the configuration of crematoria is a result of the absence of any conventional ritual or ceremony that might determine a sequence of spaces.*
- Tom Wilkinson -

As the open landscapes with its graveyards became the way of burying, the religious architecture (churches, chapels and cathedrals) became dedicated as places for people to cope with death. The churches and chapels were majestic constructions that, like the tumuli, would honor our dead in a grand, profound, and aesthetically outstanding way. Additionally, by offering a majestic space for people to gather, they could through its beauty - material, form, ornament, and light - find meaning of life as well as of death (Botton, 2012).

Today's society is filled with opportunities, dissociation with traditions, and a focus on the individual seeking a certain lifestyle – affecting the way of decorating our graves in a much more personal - and for some implicit and mysterious - way, or choosing not to have a grave at all. In the latter by being buried in the Grave of the Unknown or having one's cremated ashes spread over the sea (Jacobsen, 2001).

**Cremation** // Before the spread of Christianity in Europe, cremation had remained the main way of interment through the Mycenaean Age and up into the Roman Empire (Cremation Association, n.d.). Christianity, however, did not accept cremation, and earth burial became the most common way of interment again. Later, as plagues were dominating the cause of deaths in the late 1800, the secular world interfered with the religious world and cremation got its comeback along with new technology. It is notable how cremation in the early Stone Age was of spiritual reasoning whereas it now was a practical solution to war and disease. The first modern cremations took place in the 1870s and became more accepted over the next 20-30 years. (Liv&Død, n.d.).

Though crematories were at first detaches from religion, the architecture would still reflect on religious architecture. The crematories therefore began adopting the stylistic trends of its time: in the mid 20th century, with the modernist style dominating our architecture, many crematories were as well built in a simple, modest and minimalistic style as a contrast to the decorated and extravagant churches and cathedrals (Winston, 2014). They would, however, still keep the light, sensations, serenity and materials as architectural means to create the desired atmosphere. Additionally, this minimalist architecture of the crematoriums reflected the societies view on death, becoming a more personal, rational and anonymous death, as mentioned earlier.

Our society has evolved enormously since the first cremations in modern society but why has the way of interment not changed merely in the same extent? As written earlier, the burning of dead bodies in the pre-modern society of Europe arose from a large societal problem: hygiene problems and illness leading to cholera epidemic leading to lack of space for the dead in cities, forcing the secular society to interfere – or collaborate - with the religious traditions of death. Though the idea of burning dead bodies took hold, it took the organizations, such as Foreningen for Ligbrænding, five years before the first cremation was allowed as a test and further 20-25 years before it became somewhat accepted in Denmark with priests allowed to be part of the interment and urns to be buried at churchyards (Liv&Død, n.d.). Since that the acceptance of cremation has kept rising with most people in countries like UK, Sweden, Denmark, Finland choosing cremation - unknown of the reason for this choice being an active choice or chosen due to lack of other attractive possibilities.

Today, we are facing yet again, a large societal problem concerning the environment of the Earth: global warming, resource scarcity, toxicity and pollution. Society must interfere once again with traditions and how our lives – and deaths – right now leaves a negative impact on Earth. Therefore, the timing for yet another stepping stone in history and a long fight towards a new way of interment is right: if society is ready for a change towards a greener lifestyle, the way of interment must be, too (Botton, 2012; Jacobsen, 2001).

## CURRENT AND FUTURE INTERMENTS

More people choose to be cremated with an increasing cremation rate at 70-80 % in Nordic countries, though most of these are taking place in the settings of Christianity (Sveriges Kyrkogårds- och Krematorieförbund, 2016). This latter statement reflects mostly an older generation with maybe another perspective on life and death, thereby not necessarily reflecting the society as it is now or as it is evolving into soon. Instead, a new survey of how the living people - especially young people - would like to leave this earth, could indicate a more actual picture of the wish for interment of modern people in nowaday society. But as one out of four Danes keep their wish of interment for themselves, not wanting to talk about it even with their family, this topic about death for the current society is hard to break down and understand (Liv&Død, n.d.).

One way to get a sense of how the current society wants a modern interment could be through statistics about people's relation to religious affiliation: more people, especially in Sweden, continues to leave the church as well as the rate of Christian baptism declining in Nordic countries (Danmarks Statistik, 2018; Swedish Institute, 2018). In Sweden 63 % of the population are members of the church, but only 29 % say that they are religious, making the country as one of the least religious in the world (Swedish Institute, 2018). This generation of people, who choose to have a secular 'name-giving' ceremony instead of a Christian baptism, a civil wedding instead of being wedded by a priest, as well as the generation of their children growing up: how will their choice of interment look like?

Looking at the living society of today, we see a rising focus on the individual lifestyle - a healthy, fit, sustainable, or conscious lifestyle dominating Scandinavian people. And as our lifestyle does it, our 'deathstyle' might also go more and more in this conscious way. This could be the reason why green burials are getting more popular in western culture as they reflect a deeper responsibility to nature and express one's choice of conscious lifestyle (Spade, 2013). The green burials are made in respect to nature, allowing the site for the dead to change with nature over time. This is also in some extent the case for the forest cemeteries, like Skogskyrkogården, where the small tombstones are placed on the terms of nature, or where, in some cases, the tombstones are even opted out and instead the family has been given a coordinate to a specific spot or tree (Spade, 2013).

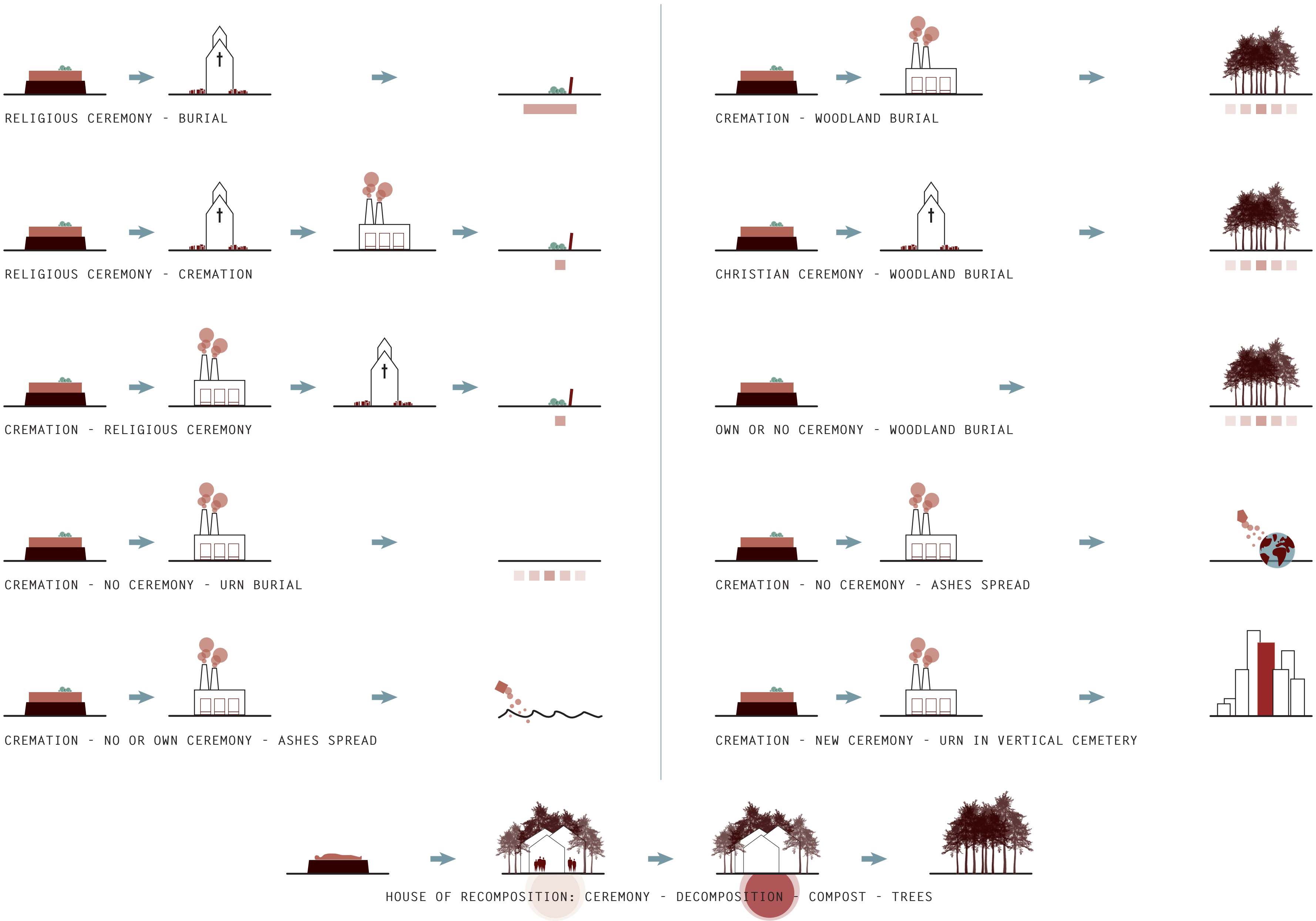
Sweden was in 2015 divided in 63,2 % of people affiliated to Christianity and 28,4 % seeing themselves as secular, irreligious, agnostic, or atheists with the remaining distributed over 1,4 % Orthodox, 1,2 % Catholic, 1,4 % Islam, and smaller religions and affiliations (Svenska Kyrkan, 2016; Myndigheten för stöd till trossamfund, 2015). The large amount of people without a specific religious affiliation, believing in various selected things, believing in nothing, or people who hasn't yet decided, is a expanding group of people in especially the Nordic context. This groups is without and in need of alternatives and new ways of interment detached from known religions, but still with strong traditions and rituals that can unite the large group of secular people to be guided and to find meaning of life as well as death.

*"Recognition is very important in a funerary situation regardless of it being religious or secular. For this the religious and well-known ceremony works very well as a template when creating a secular ceremony. Instead of saying "from dust you came and to dust you shall return" I say during my ceremonies "from words, thoughts and love you came and to words, thoughts and love you shall stay" while I throw soil - soil I have asked the bereaved to bring from a personal, memorable place. In this way adding a secular and personal meaning to the soil instead of only a religious meaning. Songs are still sung, but these are more and more modern, favourite songs of the deceased rather than hymns."*
*- Naja G. May 2018.*

The fact that cemeteries are in lack of space in both dense urban and rural areas as well as the 1,07 Bn people worldwide believing in islam where cremation is not an option, indicate a global need for coming up with adapted or new solutions for dealing with the dead and death (Spade, 2013).

Many has taken up this problem with the use of technology to make ashes into diamonds, horizontal graveyards into vertical graveyards in dense urban areas, or to give death and our remains back to nature with green funeral services (nfda.org, n.d.). But even though we now have the knowledge and skills to make ashes into various things or to be buried in a high rise, many of these new ways of interment are still based directly on the two options currently available: common burial or cremation, neglecting to innovate the actual way of dealing with the dead body.

The forest funerals, as mentioned, together with projects like Capsula Mundi (Capsula Mundi, n.d.) do take this subject of bringing the dead bodies back to nature and into a cycle as a new solution. But the forest funerals, as well as the vertical graveyards, do not solve the problem we are facing with lack of space in urban areas and resource scarcity. Neither has the Capsula Mundi alternatives provided us with a space or an institution to mourn, gather, and process a loss.


RELIGIOUS CEREMONY - BURIAL
RELIGIOUS CEREMONY - CREMATION
CREMATION - RELIGIOUS CEREMONY
CREMATION - NO CEREMONY - URN BURIAL
CREMATION - NO OR OWN CEREMONY - ASHES SPREAD
CREMATION - WOODLAND BURIAL
CHRISTIAN CEREMONY - WOODLAND BURIAL
OWN OR NO CEREMONY - WOODLAND BURIAL
CREMATION - NO CEREMONY - ASHES SPREAD
CREMATION - NEW CEREMONY - URN IN VERTICAL CEMETERY
HOUSE OF RECOMPOSITION: CEREMONY - DECOMPOSITION - COMPOST - TREES

ILL. 2.19

> *The experience of visiting a loved one is thus less about visiting the body (or remnants of the body),and more about visiting the place which has absorbed the body. Quite literally, the person lives on.*
>
> - Katrina Spade -

## MEMORIAL ARCHITECTURE

Death has, as mentioned, throughout history been continuously manifested in architecture as a way to permanently and physically hold on to those who have left us: building a grand monument as a memorial has always been the best way to make sure, that one - and the rest of the world - will never forget (Botton, 2013). Such is, for example the case with the dramatic yet still poetic 9/11 Memorial in New York City, showing the exact footprint of where the Twin Towers once stood, with the water falling down into the unknown absorbed by Earth, like the people were when buried together in the ruins - shared destiny, shared memorial.

By holding onto these memories, we simultaneously remember our loved ones and we learn from historical events - in this way to give reason and meaning to all the lives, that once were and to not make the death of our relatives insignificant and indifferent by neglecting or forgetting it (Sommer, 2008). By giving death meaning we can give life meaning too.

Death as represented in graveyards, chapels, and churches takes what is immaterial - the soul, the memory, the grief - and creates a physical, material space or element for it - in a way keep the body and soul together in one place. The same goes for memorial architecture, even though many of these are raised in places far away from the actual incident and the remains of the dead, making it clear how memorials are created for the living. It is the living who makes the material - a chapel or a statue - represent something immaterial - a memory or a soul.

In that sense, memorial architecture can be defined as a heterotopia, a term created by social theorist, Michel Foucault, which through the example of a mirror is described as the following:

*"In the mirror, I see myself there where I am not, in an unreal, virtual space that opens up behind the surface; I am over there, there where I am not, a sort of shadow that gives my own visibility to myself, that enables me to see myself there where I am absent: such is the utopia of the mirror. But it is also a heterotopia in so far as the mirror does exist in reality, where it exerts a sort of counteraction on the position that I occupy. The mirror functions as a heterotopia in this respect: it makes this place that I occupy at the moment when I look at myself in the glass at once absolutely real, connected with all the space that surrounds it, and absolutely unreal, since in order to be perceived it has to pass through this virtual point which is over there."* (Foucault, 1985). This indicates exactly how memorial and death architecture are a physical space dedicated to the immaterial.

By projecting what is hard to make sense of - death, loss, memories - into something we know - a place, a building, a sculpture - it gives people a physical and already defined outlet to focus on the mourning and processing of a loss. But this place or building doesn't necessarily has to be a specific and individual burial place of the dead, but rather, as Katrina Spade states, it can be the place that in a symbolic matter has absorbed your loved one (Spade, 2013): whether it being the 9/11 memorial; or a specific spot near the ocean where the ashes once were spread; or a woodland shared burial place without tombstones but with the presence of your loved one; or days like the Mexican Día de Muertos (Day Of The Dead) where people honor and remember the dead together, feeling the presence of their loved once as they walk through the streets (Reign Trading co., n.d); or a House of Recomposition containing both the ceremonies, memories, and remains of the decayed in a shared memorial embodied in the architecture.

In this sense, an understanding of memorial architecture can question the historical graveyards for its relevance in our modern world. Especially in a modern world dominated by mobility, opportunities, and new technology and a modern world demanding more space for the living while the dead keeps filling up our earth with individual, but repetitive memorials.

However, a great challenge might be how to design a shared physical place and space for people to project their own memories and sorrow into, when their lost ones have not died in the same way as is the case of memorial architecture.


EARN HOW THE GREAT STARVATION OF
E FARMING WORLD, WE HAVE MADE RATHER AN AMPLE REPOR

ILL. 2.20


ILL. 2.21

*Turning our loved ones into soil after death helps to strengthen our relationship to the natural cycles and helps us become stewards of the earth.*
- Katrina Spade -

## THE PROCESS OF DECOMPOSITION

The decomposition process itself is the central component of the House of Recomposition and still a very unknown territory. The architecture and ceremonies are directly dependent on the requirements of the process and the possibilities in interacting with the decomposition chamber. The following two sections will therefore address the process itself and its components as well as the additives needed to maintain a constant rate of decomposition and a healthy ecosystem within it.

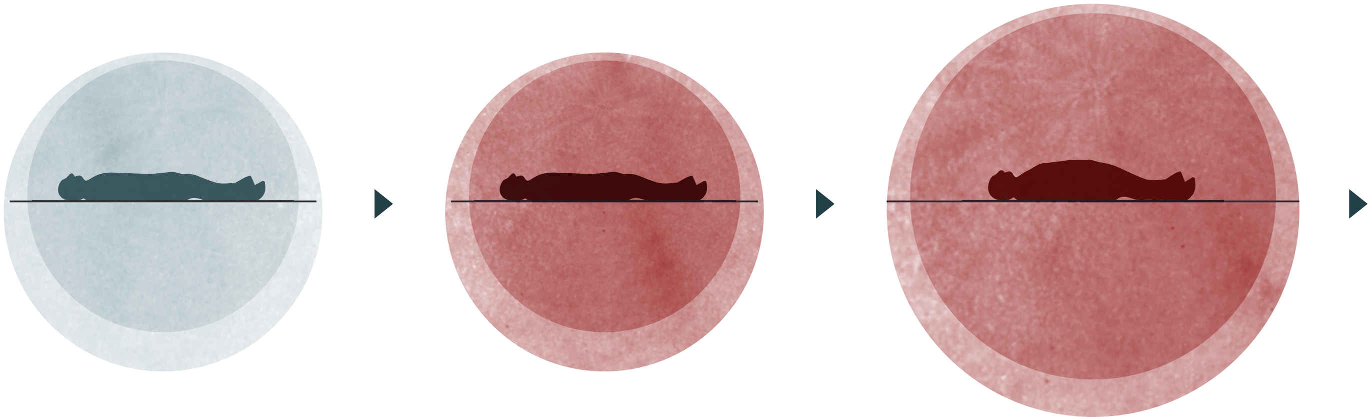
There are currently very limited information on human decomposition as most research is focused primarily on forensics and identification of bodies in relation to police work. The specifics about the time it takes for a body to decompose fully as well as how to speed up the process are not being covered. This exact research has only been active during the last few years by Katrina Spade and Recompose and nothing have been made publicly available at the time of writing.

There are, however, two categories of sources that are available and relevant: First are the forensic studies from North American Body Farms with their research on natural decay of human tissue and the effect it would have on the immediate environment (Scheve, 2008). Secondly, the practice of Livestock Mortality Composting on animal farms opens for knowledge on reducing livestock carcasses and butcher waste to nutrient-rich soil using bacteria and fungi (Payne, 2015).

**The decomposition process** // The major contributor to the decomposition itself is a combination of aerobic and anaerobic processes. Here, bacteria and fungi eats the organic tissue while producing metabolic heat enough to kill pathogenic bacteria and viruses and converting the tissue into a homogenous soil (Carpenter-Boggs & Price, 2008). The role of fungi is to break down the tougher materials that are too dry, acidic, or too low in nitrogen for bacteria to continue the complete decomposition (Olynciw & Trautmann, n.d). The bacterial decomposition is distributed between the various components of the human body - proteins, fats, and carbohydrates. The remaining water and minerals from the body will not decompose, but they will still be part of the end result (Hanna & Moyce, 2008).

**The decomposition stages** // Immediately after death the body will experience the shutting down of its many systems with its lack of blood flow and deactivation of muscles and organs. A few hours in, post-mortem paleness and formation of blood pools and purplish red discoloration of the skin becomes visible on the body. After around 12 hours, rigor mortis, which is the locking of muscles, goes into effect. Rigor mortis can last for up to three days, after which the tissue decay and leakage will cause the muscles to relax again. (Hanna & Moyce, 2008)

[1] The first stage of the actual decomposition is visible after 24 hours when the internal organs has begun to self-digest. This stage is called autolysis. As the body has no way of



delivering oxygen to the organs or removing waste, excess $CO_2$ will cause an acidic environment to form where cells will start to rupture. This releases the enzymes responsible for the self-digestion and the skin will start to form blisters and begin to loosen. The body starts to smell as methane and hydrogen sulfide as well as various fluids starts to excrete through openings and pores. (Hanna & Moyce, 2008; Scheve, 2008)

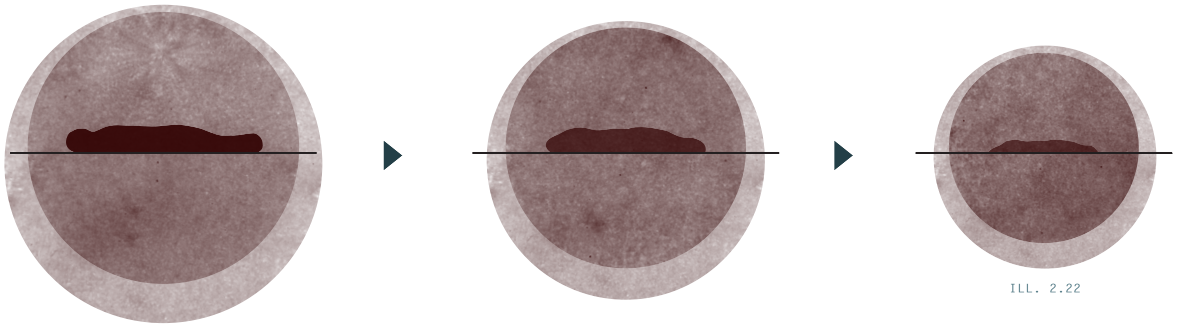
[2] Stage two, called bloat, happens after 3-5 days after death as the many gases and fluids produced in the first stage starts to build up in the body without means of escaping. The body can expand up to double in size and will grow fastest in areas with high enzyme such as the liver and high water content such as the brain. (Aftermath, 2017b; Hanna & Moyce, 2008)

[3] Stage three is the active decay with several steps over the following month: Around a week after death the body changes color to greenish as the blood decomposes and gas fills the veins. As the body starts to liquify, nails and teeth fall out. 2-3 weeks after death, black putrefaction appears where the cavities finally rupture and the gases escape. The body turns from green to black. The fluids now actively exit through the various orifices and organs, muscles, and skin slowly starts to liquify. (Aftermath, 2017b; Hanna & Moyce, 2008)

With most of its mass lost in the previous stage, the process goes into its last stage, called skeletonization or mummification depending on the outcome. In both cases the skeleton remains, but only in the case of mummification will the skin stay intact: here, the absence of moisture and oxygen will form adipoceres - a yellow wax-like substance which will cover the body and preserve the skin while the muscles and organs will still decompose from inside. This final stage can last anywhere between 50 days and a year depending on the conditions. (Aftermath, 2017b; Hanna & Moyce, 2008)

Typically, the conditions are not able to decompose the skeleton due to its content of collagen and inorganic constituents in the bone (Aftermath, 2017b). However, with sufficiently low pH-value and high enough moisture and temperature, the bone will break down enough to allow the microbes to attack the collagen (Hanna & Moyce, 2008; Spade, 2013).

**Odor and discomfort** // The main contributor to the odors of death is from the decomposition of protein. Of the various gases produced, skatole, indole, and hydrogen sulphide are responsible for the smell of feces and mould whereas sulphur and sulphide gases produce the smell of rotten eggs (Hanna & Moyce, 2008; Aftermath, 2017a). Additionally, methane



ILL. 2.22

and hydrogen is also formed as in the decomposition of proteins as well as various amino acids (Hanna & Moyce, 2008). These various gases produced in the decomposition process may severely interfere with the experience of the interment. A solution to isolate the smell while still allowing for the body to be placed in a chamber for decomposition without disturbing a ceremony is critical to the design and success of this project. Though the architecture around the process must express some openness and truth about the process and technology, the distinct smell of rotting flesh and feces must be isolated from the building interior before being filtered and reused as biogas to balance the energy consumption of the building.

**Duration of decomposition** // There are generally much disagreement concerning the duration of decomposition of animals and even more so of humans: According to some sources, conventional mortality composting of animals can take between 4 months to over a year depending on the materials and management (Carpenter-Boggs & Price, 2008) where others claims 2-6 months (Cornell Waste Management Institute, 2010). Katrina Spade also claims in her own master thesis from 2013 that livestock mortality composting takes 18 months (Spade, 2013) while she states in her TED-talk from March 2016 that it only takes nine months (Spade, 2016a).

The difference in months in the last two sources might be a case of Katrina Spade having gained new knowledge. Later in her TED-talk, she states that the decomposition of humans in her own Recomposition Centre will only take a few weeks (Spade, 2016a) while two articles about her project from May and October of the same year both states that the whole process - including decomposition of the skeleton - will take four to six weeks (The End, 2016; Ross, 2016). She does, however, explain in her Kickstarted-pitch from 2016 that they are still working on determining the exact amount of time it takes to decompose the skeleton under optimal conditions (Spade, 2016b).

There are no factual sources about the exact duration of the human decomposition process, but we may trust that Katrina Spade and her research group have been able to get far better information in their collaboration with the Forensic Anthropology Department at Western Carolina University (Spade, 2016a).

In this thesis, the decomposition chamber design and maintenance will therefore be based on a total decomposition within six weeks - including the bones.

*Needless to say, without dirt, humans wouldn't exist. Everything we depend on - from our food to our building foundations to the microbes in our guts - comes from this incredible stuff. And yet we are violently...*

## ECO SYSTEM

The decomposition chamber in the House of Recomposition will be constantly active for many years as an isolated ecosystem. However, we know from several studies that the outcome of the decomposition process has shown to be very dependent on the environments extrinsic conditions with clear differences between bodies buried above ground, underground, and submerged in water (Scheve, 2008; Hanna & Moyce, 2008). These studies mostly reflects on bacteria growth, aeration level, prevention of adipoceres, humidity, chemical richness, acidity, and density and porosity of the compost pile which are all indications that the decomposition environment must be carefully maintained.

How the ecosystem is maintained and what components is added and removed will be discussed in this section.

**Ventilation** // Oxygen is the main ingredient in the aerobic processes, but it is not produced naturally by the decomposition process. Therefore, many farmers choose to build their mortality compost piles in such a way that it can be naturally ventilated, or they will manually turn the pile occasionally (Carpenter-Boggs & Price, 2008). The presence of oxygen will feed the bacteria and fungi as well as oxidize various materials, prevent adipoceres, and break down compounds not normally compostable (Hanna & Moyce, 2008).

The microorganisms can generally survive with an oxygen content of around 5 % (Cornell Waste Management Institute, 2010). However, the porosity and varying densities of the compost material will cluster the oxygen in pores leaving parts un-exposed. Therefore, several sources suggest an optimal oxygen content of 10 % or above (Cornell Waste Management Institute, 2010; Alberta Agriculture and Forestry, 2001). Outside air typically consist of around 21 % oxygen and will act as the source due to its abundance and inexpensiveness (Cornell Waste Management Institute, 2010).

Of the many different gases produced by the decomposition process, $CO_2$, $CH_4$, and $N_2O$ are the most common (Savage, 2013). However, the specifics on amounts of gases emitted from organic decomposition processes are limited to data on co-composting with manure. Though this data is not optimal, we deem it to be close enough for us to dimension the ventilation of the decomposition chambers.

The article "*Greenhouse Gas Emissions during Cattle Feedlot Manure Composting*" from the Journal of Environmental Quality Abstract from 2000 presents this data: the total emissions add up to 168 kg carbon dioxide, 8.1 kg methane, and 0.19 kg nitrous oxide per ton of composting material along with other gases of significantly less amounts (Savage, 2013). For one person and the added carbon material, this equals to around 66 kg worth of gases emitted. Converting these three amounts to volume using densities from The Engineering Toolbox, the total amount of gases produced is 24.24 m3 per hour (The Engineering Toolbox, n.d.). As mentioned earlier, the outside air holds 21 % oxygen. With the production of 24.24 m3 of gases per hour, 22.04 m3 of outside air needs to be pumped into the chamber per hour to uphold the mentioned 10 % oxygen content. With the 21 % oxygen gone from the air, the remaining 79 % will be pumped out again along with the various gases from the decomposition process adding to 41.65 m3 of gas per hour. For the exact calculations, see appendix 02.

The air is expected to be continuously pumped into the chamber by an industrial compressor, while the remaining gasses will be extracted by a dedicated ventilation system.

**Moisture** // The moisture and water level can both accelerate and decelerate certain aspects on the decomposition pro-

”

*...mistreating the dirt beneath our feet through our agricultural, logging and development methods. Soil degradation is the direct cause of famine and drought, and the indirect cause of war and human misery,.*

- Katrina Spade -

cess: Many of the gases produced from the decomposition of the proteins will interact with water in anaerobic processes, reducing both the gases themselves and the water expelled from the body (Hanna and Moyce, 2008). However, balancing the moisture level properly will also allow for enough aerobic processes to form sugars and carbon dioxide which will feed the microorganisms and speed up the decomposition process as well as prevent the formation of adipoceres (Hanna & Moyce, 2008). Furthermore, exposure of the skeleton to moisture will prevent the bones from drying out and instead help the fungi to break them down enough for the bacteria to eat them (Carpenter-Boggs & Price, 2008).

It is specified that a volumetric moisture content between 40 and 65 % is optimal as moisture under 40 % will slow microbial activity and aeration will limit above 65 percent (Alberta Agriculture & Forestry, 2001). The moisture/water will be added regularly through nozzles in the ceiling of the decomposition chamber.

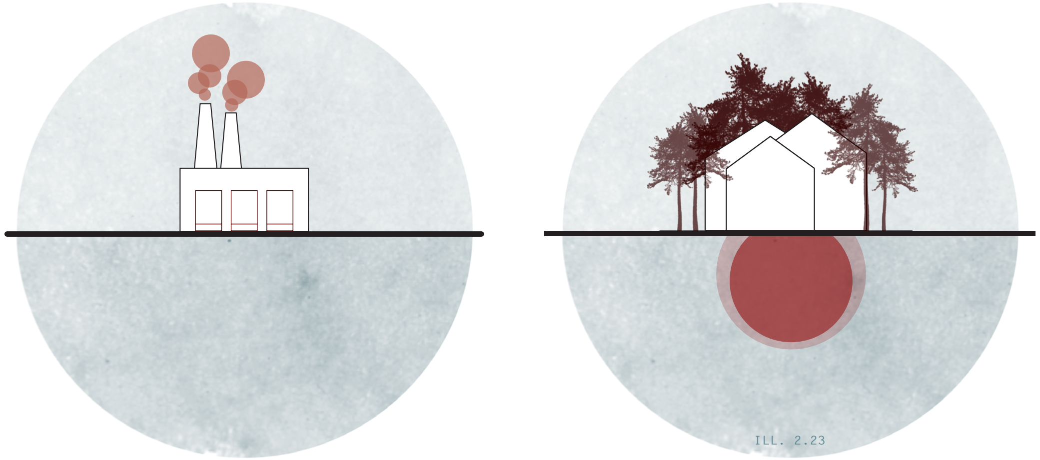
**Temperature** // As mentioned in the '*decomposition process*'-section, heat is produced by the microorganisms as they break down tissue and materials. As the temperature rise to 40°C, heat-resistant microorganisms take over the processes and as the temperature continues to rise to around 55°C, the early bacteria start to die along with any human or plant pathogenic microbes, reducing the risk of disease spreading (Cornell Waste Management Institute, 2010). In general, the higher the heat the faster the decomposition rate (Hanna & Moyce, 2008) but left to itself, the heat can rise to 75°C, severely hindering the decomposition process (Olynciw & Trautmann, n.d).

The temperature of the chamber is best kept between 40°C and 60°C (Cornell Waste Management Institute, 2010). The chamber will be able to give off most of this heat to the building and the memorial garden, while the air compressor, adding oxygen to the chamber, will simultaneously keep the temperature below 60°C.

**Carbon material** // In general, the materials in the body is not enough to initiate a complete decomposition. This is due to something called the C:N ratio - or the ratio between carbon and nitrogen: too much nitrogen will develop more ammonia and methane while too low nitrogen levels risks killing the microorganisms. The ideal ratio for composting organic material is roughly between 30:1 and 40:1 (Carpenter-Boggs & Price, 2008). As animal carcasses are generally quite dense and high in nitrogen and moisture with a C:N ratio of around 5:1, an absorbent material high in carbon must be added to the decomposition process surrounding the body completely (Carpenter-Boggs & Price, 2008). Typically, sawdust and wood chips are used with C:N ratios of 100-250:1 (Carpenter-Boggs and Price, 2008). These are used due to being inexpensive and in high abundance as they are considered a waste product from sawmills and the likes.

To successfully compost an animal or human body, 11.47 m3 of carbon material is needed per ton of bodyweight (Cornell Waste Management Institute, 2010).

**Result** // After 6 weeks, the resulting compost will no longer be human. It will not have memories and it will not be its own isolated living environment. It has taken its last steps in its human cycle. Instead, it is now an incredibly nutrient-rich mass that has taken its first step in becoming one with nature again. It is ready to join the living soil that makes up our natural foundation - both figuratively and literally.




## LCA OF CREMATION PROCESS

The LCA of the decomposition process must prove from a general point if it in facts is a more sustainable choice than current ways of interment. In this regard, not only is a benchmark needed for comparison but also a very clear understanding of which system boundaries to include - life cycle stages as well as necessary systems and additives.

**Benchmark data** // The crematorium oven benchmark will be based on an LCA by Dutch chain analyst and LCA expert from Rijksuniversiteit Groningen in the Netherlands, Elisabeth Keijzer. In her paper called The environmental impact of activities after life: life cycle assessment of funerals she thoroughly compares cremations to burials with all aspects included (material production, transport, disposal, visitor transport, etc.). Though this paper does also include an LCA of burials, only the data from the cremation will be used. Apart from the CO2-emissions from the burning of fuel and the energy won from heat recovery, all ressource data for the benchmark crematorium LCA will be from Keijzer's paper.

**System boundaries** // The two LCAs will be focused primarily on operational energy (B2) but will still include production emissions (A1-A3) of the oven and decomposition chamber. When available, the LCAs will also include disposal (C4). For comparison, the two LCAs will each be calculated based on a building lifetime of 100 years.

Lastly, the energy gain from heat recovery will also be included in the LCA and factored by the grid emission factors of district heating in Stockholm.

**Benchmark results** // The crematorium process is dependent on a large amount of heat, fueled most typically by natural gas, as well as an environment capable of isolating the heat and systems to extract the flue gases. These systems are all quite costly in electricity, and few of the materials can last very long with the intensity of the 1000°C contained in the oven - specifically the equivalent of 13.7 years with 5 cremations a day (Keijzer, 2016). However, as seen in the cremation LCA, neither the production emissions nor the operational energy are the main contributors to the GWP with the flue gas representing 97 % of the total greenhouse gas emissions. On the other hand, the large amount of heat can be recovered to assist district heating, adding a negative carbon impact of -20.88 kgCO2eq per cremation and resulting in a cremation carbon footprint of 147.4 kgCO2eq per cremation.

For the full LCA with all data and sources, see appendix 02.

Total carbon footprint

147.36 $kgCO_2eq$
pr. interment

107,648,425 $tCO_2eq$
pr. 100 years

Energy consumption

56 kWh
pr. interment

2.53 $kgCO_2eq$
pr. interment

Oven construction GWP

2.36 $kgCO_2eq$
pr. interment

235,451 $kgCO_2eq$
pr. oven unit

Flue gas emissions
($CO_2$ & $NO_2$)

163.37 $kgCO_2eq$
pr. interment

Heat recovery

320 kWh
pr. interment

20.88 $kgCO_2eq$
pr. interment

Oven lifetime

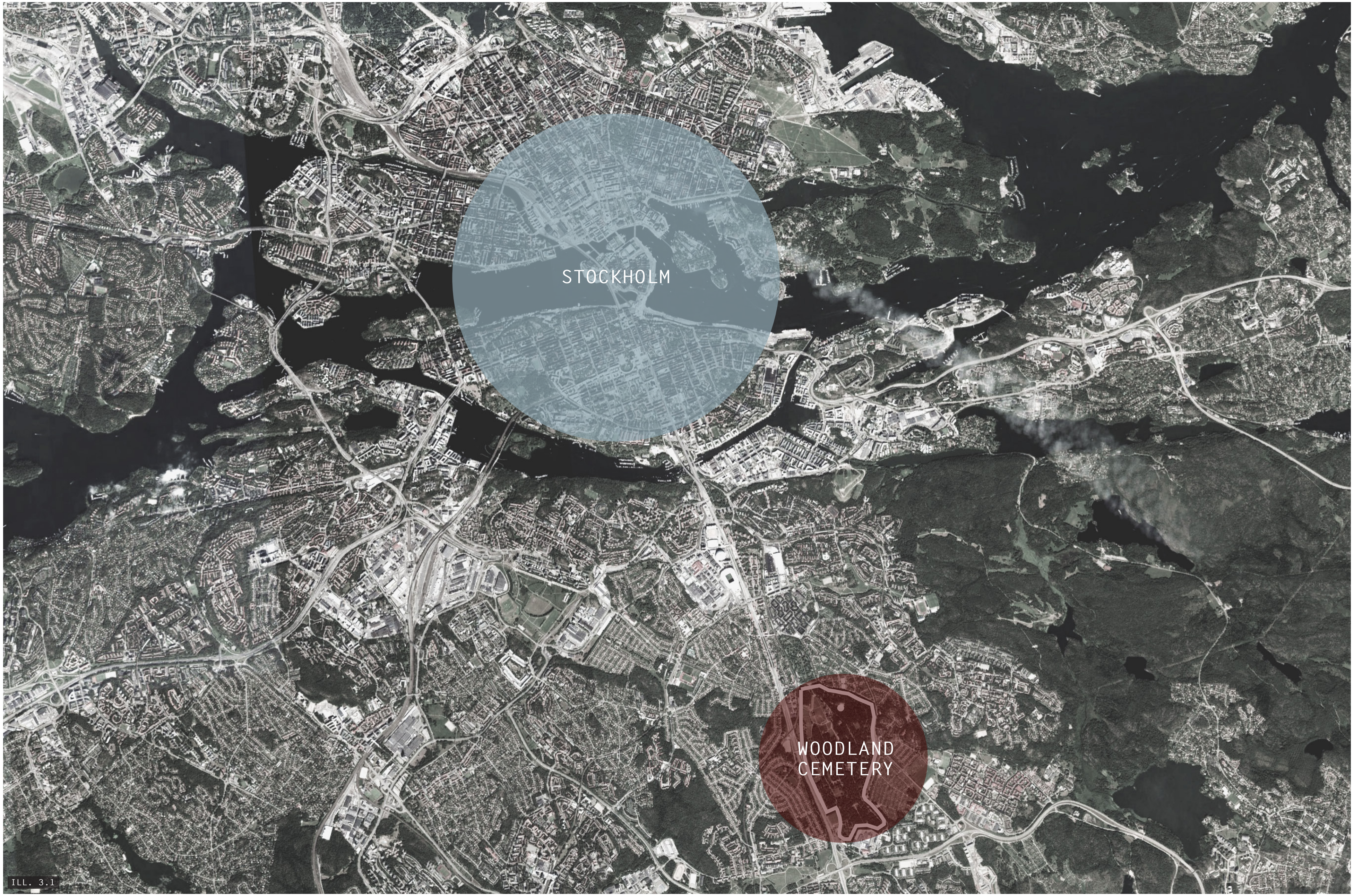
13.7 years

25,000 interments

# 03

PROGRAM
SITE ANALYSES

The site of Woodland House of Recomposition, Woodland Cemetery, is in this chapter investigated and analyzed to understand and utilize the exiting environment. The analyses includes climatic analyses, genius loci essay, layering, and mapping.


STOCKHOLM
WOODLAND
CEMETERY
ILL. 3.1

> ”
> *The Woodland Cemetery is included on the UNESCO World Heritage list and ranks as an artistic masterpiece and a unique example of the integration of architecture and landscape into a single composition.*
> - Stockholms Stad -

## THE WOODLAND CEMETERY

In the early 20th century Stockholm needed, as many other capitals did and does, more land to bury its deceased citizens. In the suburbs of Gamla Enskede, South of Stockholm, a large land with a field and a forest near an existing old cemetery was chosen. The secluded area in a very close proximity to Stockholm city was and has since been a perfect place for the inhabitants of Stockholm to easily and quickly arrive to and through the landscape and architecture on the site being provided with a serene frame to mourn or simply go for a walk (Stockholms Kyrkogårdsnämnd, 2009).

This close connection to a large, dense city with rising population is one of the reasons for the choice of site for this master thesis. This together with it being a site that has its strong focus on death and serenity as well as architecture and landscape.

The masterplan for the Woodland Cemetery was won by Gunnar Asplund and Sigurd Lewerentz in 1914. The cemetery opened in the 1920s, but the design of Asplund and Lewerentz was not completed before 1940. Their design for the Woodland Cemetery included four buildings built in different styles throughout the years from the 1920s to the 1940 (Stockholms Kyrkogårdsnämnd, 2009).

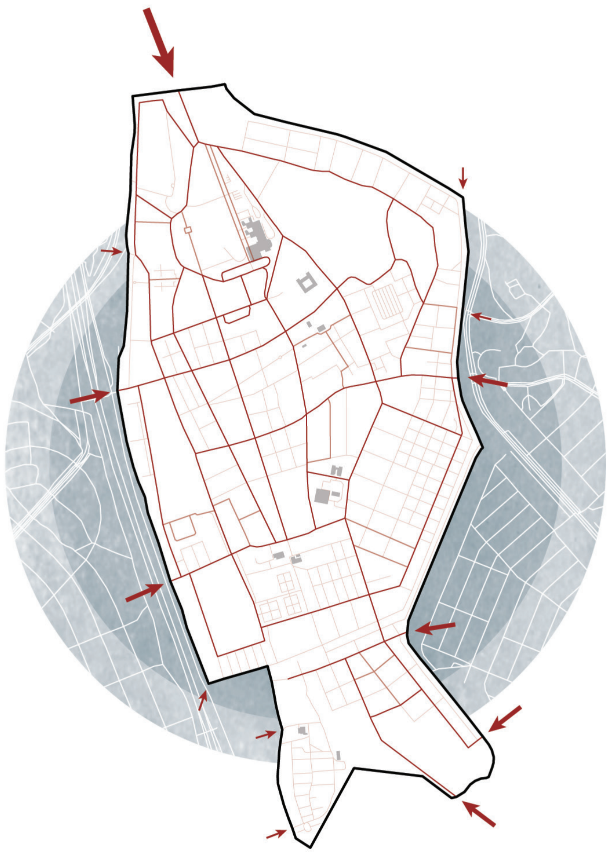
Since its opening, the Woodland Cemetery has added over 100.000 gravestones in between the spruce trees of the 100 ha. cemetery (Stockholms Kyrkogårdsnämnd, 2009). This gives a clear picture of how the dead is filling up our land as well as the fact that with rising population, even larger cemeteries like the Skogskyrkegården cannot keep up with this development forever.

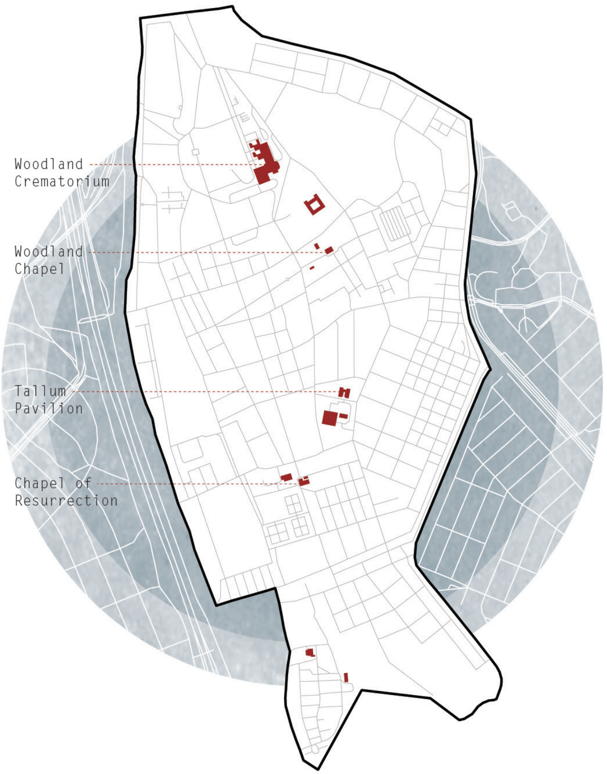
With the cemetery's profound focus on nature, where gravestones and buildings are placed on nature's terms, it fits well for this master thesis with a focus on bringing back nature to the people and the people back to nature - in their lives as well as in their deaths. Furthermore, the cemetery's focus on nature fits well with a focus on natural materials and sustainable design in general in this thesis.

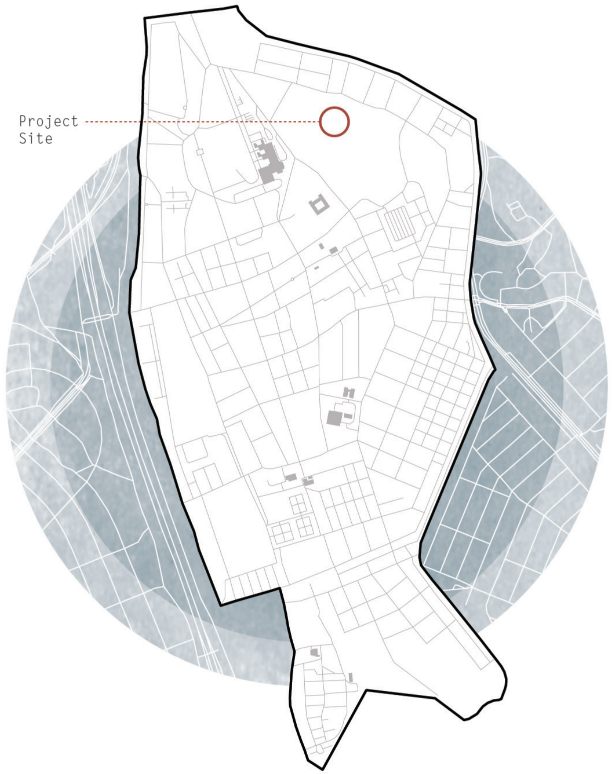
*"...a new symbolic and spiritual landscape with a living relationship between man and nature. The individual grave was toned down in favour of a wholeness which could be supportive to mourners. The ritual of the funeral ceremony, from grief to acceptance and consolation, was expressed through the contrast between dark and light in the landscape. [...]. The open landscape encountered at the main entrance offered the message that grief could be endured with the support of a grandiloquent platonic landscape."*
(Stockholms Kyrkogårdsnämnd, 2009)

The buildings in the Skogskyrkogården being constructed over time in different styles and with different functions, as mentioned, might also indicate, that this cemetery is the right frame for yet a new building with its own style and own function adding a building to its historical timeline of architectural buildings. Although, the boards wish for preserving the cemetery's place from 1994 on UNESCO's World Heritage List of natural and cultural heritage sites and respectfully honor the historical architecture (Stockholms Kyrkogårdsnämnd, 2009) is going to be an interesting challenge with this master thesis' vision for a radical idea in function and maybe also architecture.

## LAYERING






### ENTRANCES, ROADS, PATHS

Due to the size of the site roads are dominating the site. However, the roads are still made of gravel and the traffic does not feel dominated by the few cars but rather of pedestrians and runners. There is access to the cemetery from all direction on either the main roads or the smaller foot paths that interlinks the various areas and buildings.

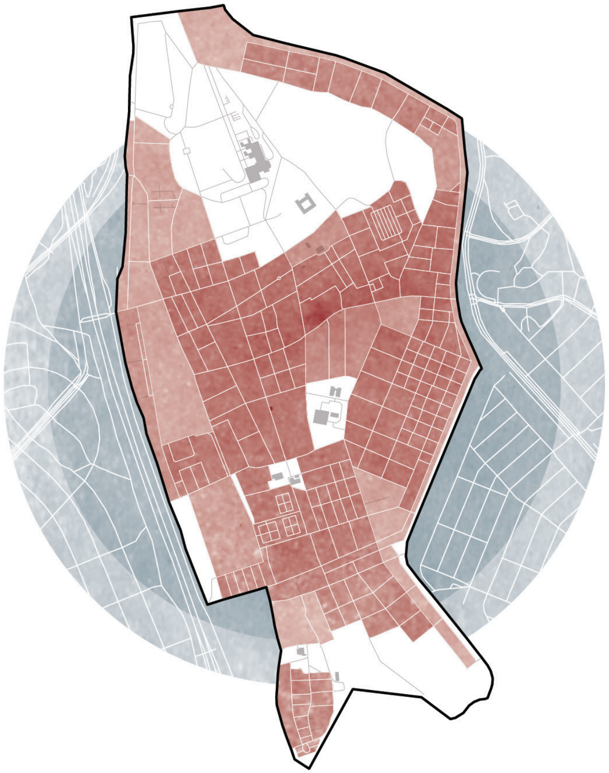
### BUILDINGS

Apart from the four public buildings, various staff functions are scattered throughout the site. The larger of these are placed respectively by the Tallum Pavilion, between the Woodland Crematorium and the Woodland Chapel, and by the Chapel of Resurrection. Several smaller sheds can be found around the periphery of the cemetery.

### SITE

Our project site is located in-between the dense forest behind the Woodland Crematorium with access from the north-easternmost road. The site is approximately 3500 m2 in size from forest edge to forest edge.

## LAYERING



ILL. 3.2-3.7

### GRAVE DENSITY

It is interesting to see how most areas of the cemetery is already allocated for graves, although these are still not all filled yet. Only the fields around the crematorium and the dense undergrowth around the cemetery are still free of graves. As of now, the cemetery house approximately 100.000 graves.

### VEGETATION

The map above displays only the density of the trees on the site but the placement of the smaller vegetation (bushes, undergrowth, etc.) is generally identical. The similarity to the map of grave density only further proves how the graves are placed in the intimate environment of the forest.

### TERRAIN

The Woodland Cemetery is positioned in the relatively flat area of Gamla Enskede. It's rolling landscape is 1,8 km long and rises from 47m to 50m above sea level in the north. Apart from this slope, the general highspots are situated primarily near the Woodland Crematorium and Almhöjden in the north to around 68m above sea level.

ILL. 3.8

> ”
>
> *Architecture is not just an object that you place in the environment. [...]. Your experience of the architecture starts far away from the building. Architecture is not only the house in itself; it also includes a big area araound it. All of this is architecture.*
>
> - Wang Shu -

## THE LANDSCAOE AND ARCHITECTURE

The masterplan of the Woodland Cemetery is created by Gunnar Asplund and Lewerents. They each took on a role in the process to come; Asplund took on most of the architecture and Lewerentz became head of the landscape design. Work on the Woodland Cemetery, initially consisting of paths and landscape, started in 1917, three years after the conclusion of the competition. (Stockholms Stad, n.d.)

**Landscape** // The landscape of their competition design Tallum is regarded the actual reason for why they won: from the 53 entries, Asplund's and Lewerentz's design was the only one to truly exhibit the sense of the nordic forest and the importance of making nature the dominant feature (Stockholms Stad, n.d.). As written on the cemetery's website: *"There are no graves in sight — a sign that nature is the central focus, not the graves. These are mainly located in the depths of the woodland. In contrast to other cemeteries of the time, the graves are quite small. No grave was to be larger than any other, to show that in death all people are equal."* (Stockholms Stad, n.d.). This last part of the quote states the ideology that death are one of the few shared event of the life of all humans and therefore should be made equally represented. Furthermore, it also explains how the graves do not overwhelm the landscape but simply remains equal or even secondary to the natural environment in which they rests.

The strength of letting nature guide the bereaved, however, was not only evident around the graves, but also in ones arrival and departure from the different chapels and landmarks of the cemetery. As is the case for the design of the Almhöjden: as the stairs follows the natural curvature of the hill, each step becomes slightly lower to lessen the effort and to ensure that the visitor arrives calm and not tired out to properly experience the sense of stillness in this place of meditation. In regards to letting nature guide the bereaved in the architecture, both the Woodland Chapel and the Chapel of Resurrection aimed to shape a mood for mourners before the ceremonies through dense and tall trees. After the service, a seperate opening out into a small, but open clearing in the trees would help to reconcile the loss by filling them with light and life (Stockholms Stad, n.d.).

**Woodland Chapel** // The first building to be constructed on the site was the Woodland Chapel in 1920 around the same time as the outer wall started to take shape. Initially designed as a stone church, Asplund was pushed to rethink the building as being made from timber due to limited funds, resulting in the current chapel. The chapel is shaped, as many of Asplunds buildings, as a synthesis between the square and the circle - the square shaping the walls of the outer boundaries and the circle directing the placement of columns and the ceiling. This principle proved to Asplund especially effective at reflecting his narrative and has been used in several of his later buildings including the later mentioned Tallum Pavilion and the Stockholm Public Library. In all of these three examples he managed to shape the building around the experience of the interior with distinctive attributes of space and light as well as a clear hierarchy between the outer common functions and the inner sanctums. (Stockholms Stad, n.d.)

**Tallum Pavilion** // Constructed in 1923 originally as a staff and service building. A renovation in 1998 in relation to the cemetery's inclusion in the UNESCO World Heritage Sites in 1994 gave it the name The Tallum Pavilion and opened it up to visitors as a visitor center. The unusual design with its curious windows and the steep, tent-like, metal-clad roofs was controversial at first but it became since accepted as quite appropriate to hold the staff canteen and changing rooms. (Stockholms Stad, n.d.)

*"It is better to obey the demands of the place than those of the age."*
- Gunnar Asplund -

**Chapel of Resurrection** // Not long after the Woodland Chapel was taken into service it became clear that the size of it was insufficient to meet the demand of the growing population of Stockholm. Lewerentz was therefore commissioned to design a slightly larger chapel in the southern part of the cemetery which became the Chapel of Resurrection, finished in 1925 (Stockholms Stad, n.d.). Lewerentz was known to be headstrong but also quite stubborn. This was reflected quite clearly in the unusual asymmetry in contrast to the already existing architecture on the site. Lewerentz wanted to accentuate the Seven Wells Path from the Almhöjden by constructing the chapel with an entrance from north to an exit to the south. The idea was rejected as it opposed the tradition of orienting churches and chapels towards east. Lewerentz chosed to follow the demands but kept his entrance asymmetric towards north and the exit towards west as mentioned earlier (Stockholms Stad, n.d.).

The chapel is dominated by the classicist style which was typical of Lewerentz at the time until he too, in his later career, turned to modernism. The classical interpretations is especially seen in the large portico and main entrance, the white mosaic floor, the window and ceiling details, and the proportions of the room itself. The very tall and narrow space is further emphasized by the organ, which is hidden under the ceiling in the back, filling the room with reverberant music from above (Stockholms Stad, n.d.).

**Woodland Crematorium** // The dissociation and growing number of cremations compared to burials in the 1930s, persuaded the Stockholm Cemetery Committee to integrate a crematorium on the site. Initially, the committee worked towards Asplund and Lewerentz designing the crematorium together, but Lewerentz became disillusioned and the commission went to Asplund alone (Stockholms Stad, n.d.). The crematorium were completed in 1940 with three chapels - the Chapel of Faith, the Chapel of Hope, and the Chapel of the Holy Cross.

Asplund was at the time especially affected by functionalism with its core in the mixture of flexibility and thoughtfulness, clearly seen in the architecture: all three chapels are rectangular in shape, of similar proportions, and have a very pragmatic atmosphere of light and colours. The lack of ornaments and art - which is only ever present on the back wall - along with the organ placed aside the altar on floor level further emphasizes a sense of simplicity, modesty, and calmness. This is also apparent in the detail of all the corners being rounded (Stockholms Stad, n.d.).

When looking at the crematorium from the open field in front with the three distinctive chimneys in the background, this relationship with the hills are further emphasized in the different heights of the chapels: Starting from the main entrance to the cemetery the hill leads the visitor through the columbariums and past the chapels to arrive at the portico and main entrance of the crematorium. The portico itself with its slender, high columns and roof are quite grand in its architecture. This experience if further strengthened by the meticulous sculpture of Resurrection in the middle of the space under the central skylight opening. In contrast, the main entrance to the crematorium is kept in the order to distinguish this exterior grandeur from the modesty of the interior - a contrast that is generally apparent throughout the architecture: where the publicly accessible areas and spaces are tall and open, the places where people interact with each other, the architecture, themselves, and the dead are small and intimate. Additionally, all windows are small or faded, all doors are placed in the corners, the exterior spaces are filled with small gardens, enclosed by low walls with small gates, and generally filled with beautiful details. Asplund's architecture embodies the strength of how one's perspective commands, which in principle express quality - but it is undoubtable that quality is always apparent in the architecture of the Woodland Cemetery.

ILL. 3.9-3.20

*From the buzzing street in the middle of Södermalm where the Sunday brunch people have taken over the streets you enter the metro under the houses down in between the rocks of Stockholm. The train leaves the dark underground tunnels, entering out into the outskirts from where you look back at the city surrounded by the ocean with cracked ice blocks on top. The train takes you through the suburbs covered in snow. Only 10 min after standing in the center of the city you are walking down the metro stairs, turning right at the flower shops along an avenue of black, quirky trees with a tall forest on your right site. You follow the stone wall surrounding the forest until you reach an opening looking to your right up at the Woodland Cemetery. With the low stone walls protecting the forest on each side of you, you follow the road until the walls turn opposite ways and the road shifts from asphalt to grass covered with new snow. From here the landscape unfolds itself with trees only in the periphery of the open site near you. Here it feels as if two different worlds collide; a collision in where two worlds that from the faces of the people from the different worlds seems to naturally co-exist.*

*As you walk up along the sloping landscape on a sacred path between structured walls forming graveyards leading up to the Woodland Crematory, you pass by an old couple quietly walking towards a grave with flowers in their hands. On the other side of the wall, in the hilly landscape, you see the other world with children and parents sledding down the hill, shouting of happiness and life. As you walk further up, the yellow walls of the graveyard turn into a building; the open frames in the walls into windows and doors; the gardens into courtyards; and you have now reached the Crematorium. A tall structure with wooden ceiling shelters you and the entrance of the building from the falling snow, creating an inside-outside space. An opening in the middle of the ceiling with a sculpture under it frames the sky above. In this square plaza people walk diagonally from the parking lot towards the small group of people in the corner. There a family safely gathers before entering the chapel to say a final goodbye. The family seems to only notice each other in their own world and you too slowly close out the happy screams from the children and the distant traffic noise.*

*In the middle of these two worlds – sorrow and joy, death and life - on the Path of the Seven Wells running along the middle axis of the Woodland Cemetery, the worlds blend: mourners, runners, visitors, tourists, architect students, and dog walkers walk and share the same path.*

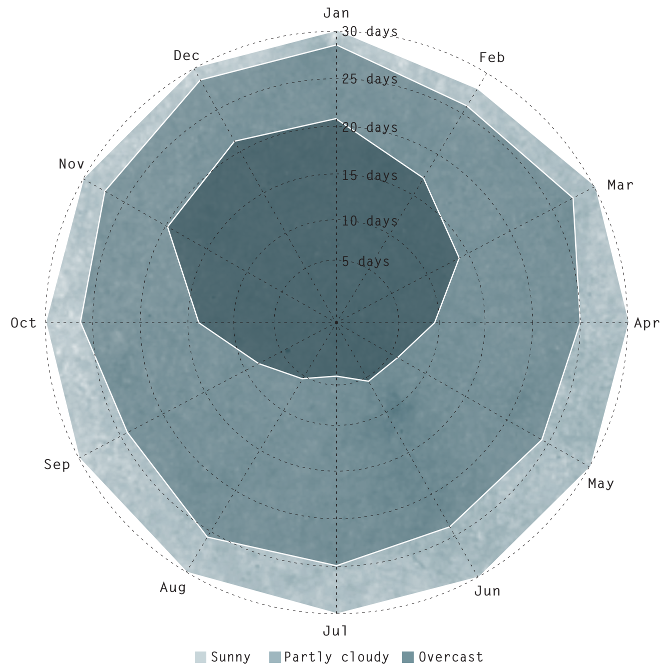
*You walk away from the main path to a path in the outskirt of the cemetery. You are now surrounded by trees. It seems as if there are endless of spruce trees with endless gravestones in between them. And just as the endless forest embraced you, a small clearing with the Chapel of Resurrection reveals itself through the trees. From every clearing where a building rest, you cannot spot the next, due to the dense forest, letting the cemetery impress you again and again. Shifting from nature to hidden pockets of remarkable architecture back to nature again - using nature to clear your head from disturbances and impressions, making you ready to take in new:*

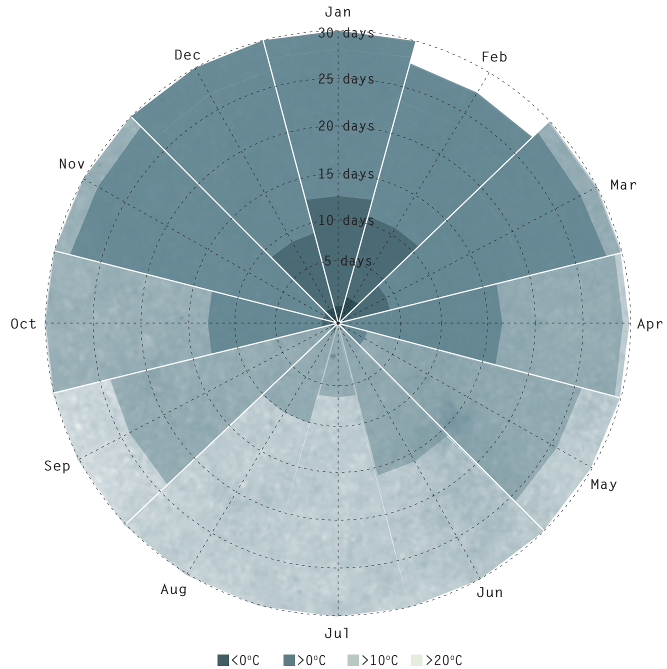
*The nature leads you further through the forest of tall spruce trees and thousands of gravestones to the next pocket. A low, slim and deep port frames a hidden view of a building settled closely in between the trees allowing you to only see a door and white columns. The portal resets your sense of space as you walk through, focusing your mind on this exact moment with the embracing and sheltering forest. As you walk further on the path, the building ahead of you reveals itself and you are now standing at the Woodland Chapel. It feels as if the chapel has found its nest right here at this exact spot, in a perfect balance with nature around and above it. And as you stand here next to the chapel, with its pyramid shaped roof, you - the chapel and you - look up together at the tree tops high above with the clouds drifting by in between the patterns of the branches. This pocket is a contrast to the open landscape of the Almhöjden where you started and now enter out onto again.*

*In the footsteps of others, you walk in the deep snow up on the top of the Almhöjden, giving you a view to the Remembrance Garden in front of you on another hill, and a view back at the Woodland Crematorium. A stairway in the landscape leads you down in between the two hills and further down to the entrance in between the stone walls on each side. Yet again it creates a long, slow transition between the Woodland Cemetery and the outside world. Despite the snow increasing and a world covered in grey clouds, more and more people arrive as you leave. You hop on the metro, and before you know it you are back in the buzzing city life of Stockholm.*

ILL. 3.21

## CLIMATIC ANALYSES



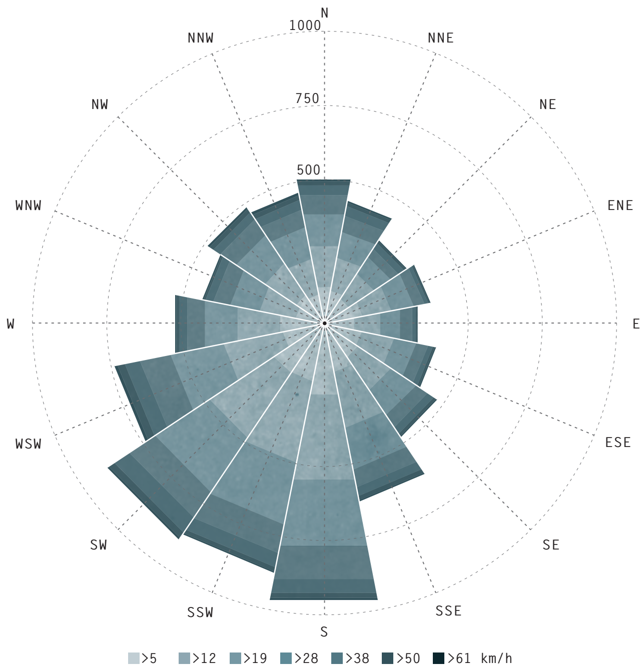



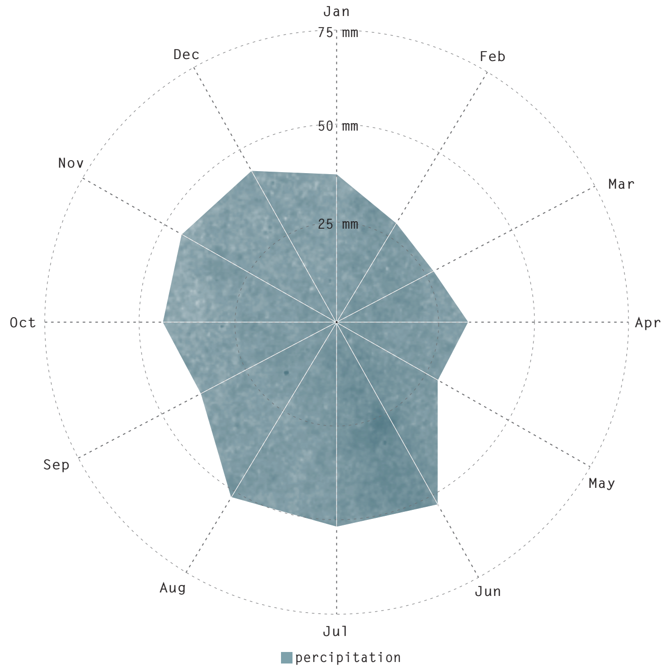

### SUN

The site is located just south of the Arctic Circle, creating a great variation of hours with sun throughout the seasons. On the longest day the sun is up for about 18 hours in contrast to the shortest day of only five hours. The daylight hours in Stockholm are in 55% of the cases partly or fully clouded (Climatemps, n.d.), making the direct sunlight precious. For the design, the low winter sun, as well as the case of often overcast sky, must be a focal point when integrating the local climate in the design process - in a aesthetic as well as low-tech matter.

### TEMPERATURE

The warmest months in Stockholm are June, July and August with an average maximum temperature being respectively 19, 22, and 210C and likewise an average minimum temperature of 11, 14, and 13 0C. Opposite, the coldest months within Stockholm are January and February with average maximum temperatures of 00C and average minimum temperatures at -40C. The high temperatures can vary up around 30°C as well as varying cold temperature can reach down to -12°C. (Meteoblue, n.d.)




ILL. 3.22-3.25

## WIND

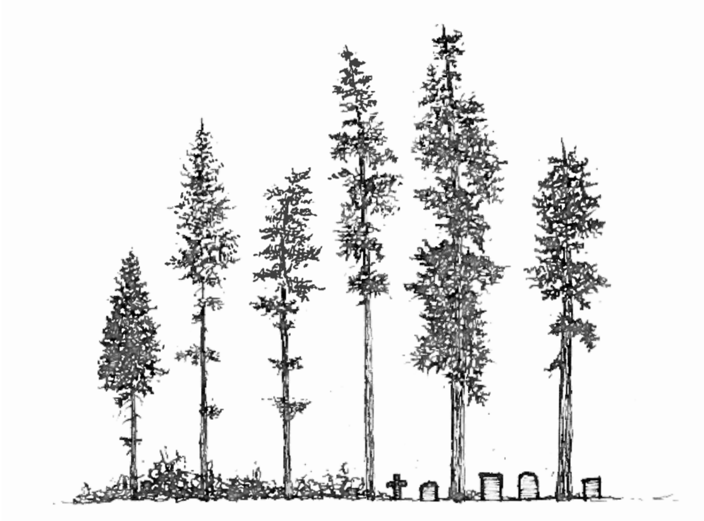
With a varying landscape with both open field, dense forest, long linear paths, high bare trees, and low bushes, the wind situation must be carefully thought of in the many different cases. Our specific site being placed in an opening in the dense forest might be a challenge concerning sufficient natural ventilation.

In general the dominating wind in Stockholm is from Southwest and South. The strongest winds occurs between November and February. (Meteoblue, n.d.)

## PRECIPITATION

The months with most precipitation in Stockholm is the months of July, August, September, and November (DMI, n.d.). The snow season may occur from October all the way into early May with February being the month with most snow (Meteoblue, n.d.).

The snow in a practical, technical as well as aesthetic matter must be thought of during the design process - the snow being an aesthetic quality as well as a practical challenge for people to arrive to the site and transport themself inside the site.



ILL. 3.26

## VEGETATION, MATERIALS, DETAILS

Along with the previous site observations, photos and notes were taken of the different aspects concerning vegetation, landscape, materials, architectural details, and visitors. The following mappings are a study on the expressive identity of the Woodland Cemetery, its natural environment, and its buildings.

The vegetation is dominated by the tall spruce forests, providing intimate surroundings for the graveyards with various densities around the cemetery. The thick crown forms a roof over the many visitors who shares the atmosphere between the slim trunks and the low stone graves - even in the winter. The edge of the forests is dominated by birch trees and bushes that blur the line between the dense woods and the open, bare landscape. The bushes themselves are both naturally and wildly growing in between the trees as well as neatly trimmed and structured to walls in the graves, monuments, and buildings. Though the winter and snow left the mapping of vegetation quite limited, the many trees and bushes of evergreens and conifers managed to still provide a feeling and understanding of the dominating vegetation on the site.

The architecture on the site is dominated by subtle, natural colors mainly in sand, earthy, and yellow tones, though still with a clear difference in materials and proportions in the buildings: the Woodland Crematorium represents itself in panels of light yellow sandstone and desaturated green painted metal roof to not steal the beauty of the barren landscape in front, whereas the Woodland Chapel sits solemnly in white walls to match the light between the tree trunks and its black roof to match the tree crowns. When not using sandstone tiles, the wall material is of either white concrete, painted wood cladding, or rough stone. In general, the most apparent materials are of delicate colors but highly tactile as seen in the sandstone and rough stones as well as in the portico wooden ceiling. Lastly, many of the details stands out in either metal or in wood as in most of Stockholm's window frames.

The tactile and natural materials are also used in the landscape design in the low stone walls and gravel roads and paths. Apart from the grass covered field in front of the crematorium, the groundcover is generally kept wild with fallen branches and bushes where it is not occupied by graves. These areas are also the home to the local wildlife of foxes and hares whose footprints can be seen throughout the cemetery.

ILL. 3.27-3.56

> ”
>
> *Since Skogskyrkogården is a multi-ethnic cemetery serving faiths other than Protestant Christianity, the cross is not intended to represent a symbol of faith, but rather a symbol of the circle of life and death.*
>
> - Stockholms Stad -

## VISITOR DEMOGRAPHIC

At our site visit, observations were made of the visitors from that day and how they used the site as groups or individuals.

**Families / groups** // In the open landscape in the northern part of the site, young families with children were using the site as a playground. The children and parents sledded down the Almhöjden and a group of young parents with prams met near the Almhöjden. Around this field, couples and smaller groups were going for a walk on the paths - both the paths around the open field, the remembrance garden and the Seven Wells Path. These groups of people were using the site as a park and a way to meet nature in the middle of the city. These people might be local from the nearby housing areas or from the city via the metro.

**Exercisers** // Many people at the site, mostly young, were jogging and running - often alone, but occasionally in couples or with their dog. These people ran inside the forest in the outskirt of the site on the larger roads and paths. These many intersecting paths and the 5 km circumference of the cemetery makes the perfect setting for people to go for a short or long run in a calm, serene setting.

**Bereaved** // A ceremony took place at the Woodland Crematorium with guests mainly arriving by car. The cars were parked just next to the crematorium with the opportunity to drop people off very close to the building. At the entrance, in the corner of the plaza outside the building, a group of family members were gathered and talking to each other before entering the building. The funeral guests were not interacting much with the site which might be due to the snowy weather or the fact that their only reason for visiting the crematorium was the specific ritual of saying goodbye.

**Mourners** // On the smaller paths and in between the graves, many people were coming to the site to visit a deceased loved one. Most of these were older couples or families, and many had brought fresh flowers from the flower shop next to the metro station to place at a specific tombstone or at a common spot outside the House of Resurrection or the Woodland Chapel. The mourners were mainly arriving by foot, and only few arriving by car that parks on the few parking spots in the middle of the cemetery and then going for a walk.

**Tourists**: Near the buildings, on the big paths as well as on the smaller hidden paths, tourists and other curious people were exploring, studying and photographing the landscape and architecture of the Woodland Cemetery. These, of course, also include ourselves.

In most of the cases, the various group of people were using different spots and paths within the Woodland Cemetery and did in that way not disturbing each other. And even though the visitors could see and hear each other, they didn't seem to be disturbed by the different activities taking place. In that way, children, pedestrians, runners, mourners, bereaved, and tourists can all use the Woodland Cemetery in their own way at the same time.

ILL. 3.57

# 04

## PROGRAM DELIMITATION

Conclusions, definitions and delimitations are made upon all the research and all the analyses. This to create the frame and design criterias for the thesis ensuring the design process to follow the right direction. This chapter includes target group, ZEB strategy, room program, capacity delimitation, etc.

## TARGET GROUP DEFINITION

### TYPES OF VISITORS

The Woodland House of Recomposition will, through its architecture and function, focus on the following four types of people: The bereaved, the mourner, the spiritual, and the curious. Through these target groups, this thesis project seeks to accommodate the different types of visitors that will be using and interacting with the architecture. Therefore, by defining these four types of people, the visitors' needs can be met and taken care for through aesthetics, atmosphere, functions, etc.

**The bereaved** // This type of visitors comes to the house in relation to a very recent death of a loved one. The bereaved might be there before the interment ceremony to be guided in the planning of practical matters. The bereaved is in a vulnerable, and for many, a new and sudden situation and are in need of a calm, serene, and safe atmosphere. Furthermore, the bereaved will be interacting with the house in connection with the actual ceremony of parting with the dead - the main function of the building. Therefore, the flow of the ceremony within the architecture must address the needs and situation of a bereaved. The bereaved can range from an old lady who has just lost her life partner, a family who have lost their grandmother, or a group of young people who have lost a classmate.

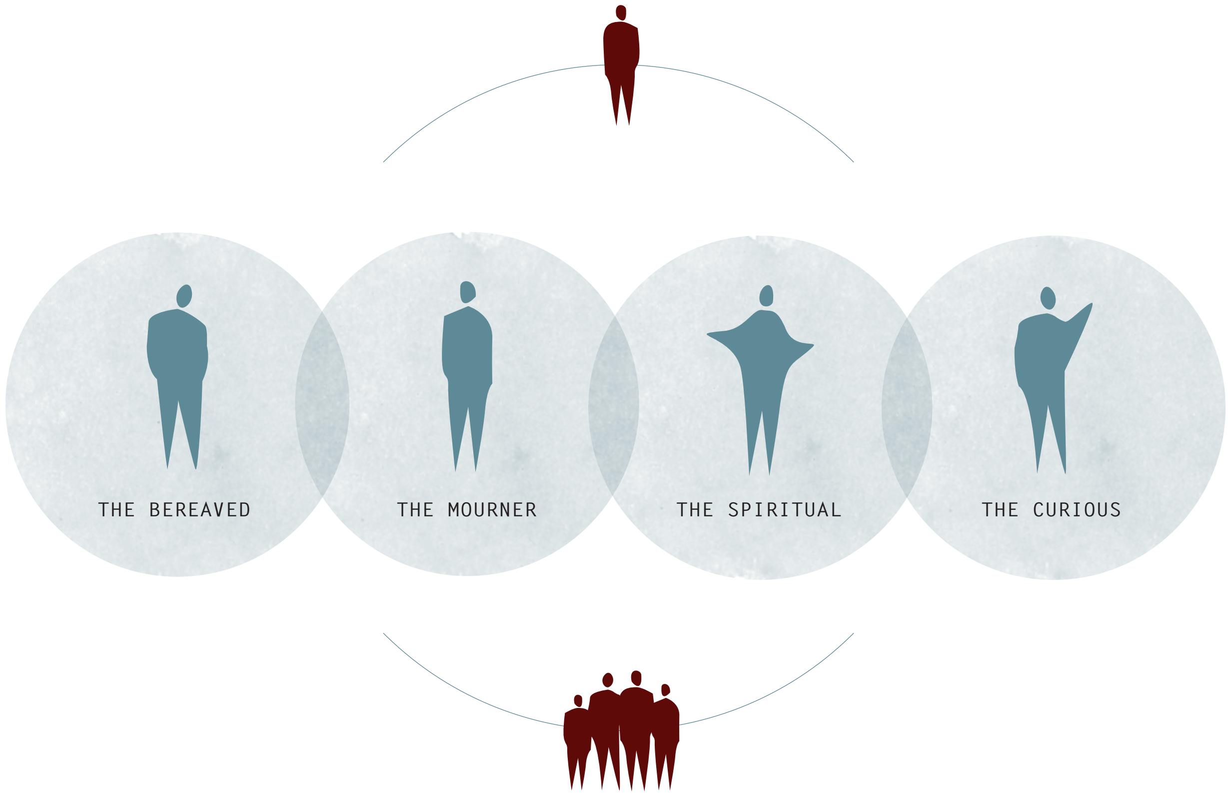
**The mourner** // The mourner is the visitor who will come to the site and house occasionally to mourn and remember a loved one regardless whether it is a recent and past loss. This by leaving a flower as a gift of remembrance or by coming to the house to 'talk' to the deceased. Furthermore, the mourner include the people who come to the house to get counseling by professionals to be part of mourning groups in an effort to process the loss of a dead one. The mourner can be people who have lost a loved one, a family member, a friend, etc. due to an accident, severe illnesss, age, or other circumstances, therefore looking for answers and ways to process a loss in a long term perspective.

**The spiritual** // The spiritual might be the atheist or the cultural Christian, who find it hard to identify themselves as true believers of Christianity but neither do they find themselves as non-believers. The spiritual seeks a frame for serenity, community, spirituality, and reflection to find meaning of life and death. Similarly to the mourners, this type of visitors can be represented by all types of people.

**The curious** // This type of visitor is curious about new ways and opportunities of interment. The curious might be a person with a sustainable mind-set or lifestyle interested in how subjects within our lives, and deaths, can be changed in a more green way. The curious might also be a type, curious about the process of decomposition and death on a more scientific matter.

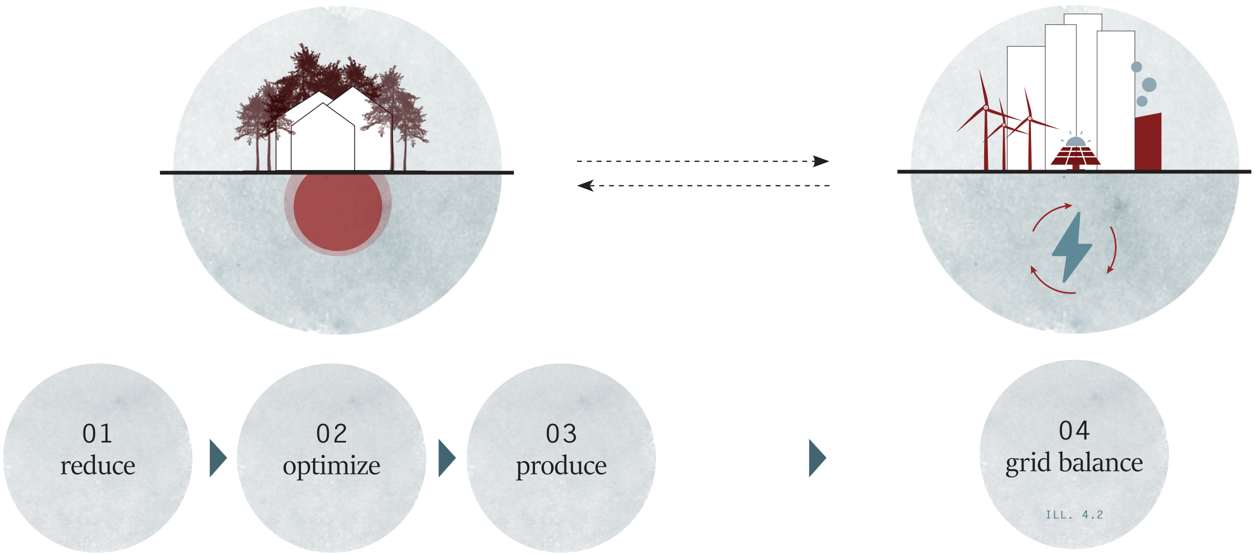
The curious can be individuals or groups seeking answers, innovation and knowledge.

Besides the defined four types of visitors, spaces, in a general perspective, should be made to create a safe atmosphere both for groups of visitors and for the individual person. The individual person is especially important due to an even more vulnerable state of mind, and the spaces must accommodate the different needs of both sizes. It is important to notice that these two sizes of groups can be represented regardless of the four visitor types - it being friends, classmates, families, or colleagues identified as bereaved, mourners, spirituals, or curious people.




ILL. 4.1

## ZERO ENERGY BUILDING




ILL. 4.2

### DEFINITION & STRATEGY

With a goal for the Woodland House of Recomposition to be sustainable in both its architecture and function, a Zero Energy Building is aimed to be achieved. In an effort to design from the very beginning towards a ZEB, a strategy for the design process and a definition of a Zero Energy Woodland House of Recomposition has been formed, illustrated above.

What makes a building a Zero Energy Building has different definitions - Net Zero Site Energy, Net Zero Source Energy, Net Zero Energy Costs, Net Zero Energy Emissions (Marszal et al., 2010) - and very different ways of interpretations: a non-sustainable or non-energy efficient building can by definition be a ZEB by simply producing enough energy on site to compensate for the unnecessary large amount of energy consumed in the operation time. But this approach is not viable on the long run nor an optimal solution for the sustainable architecture the world needs. For this thesis and project to approach net zero from the very start, a strategy with four steps has been formed: Reduce, Optimize, Produce, and Grid Balance (Kongebro et al., 2012).

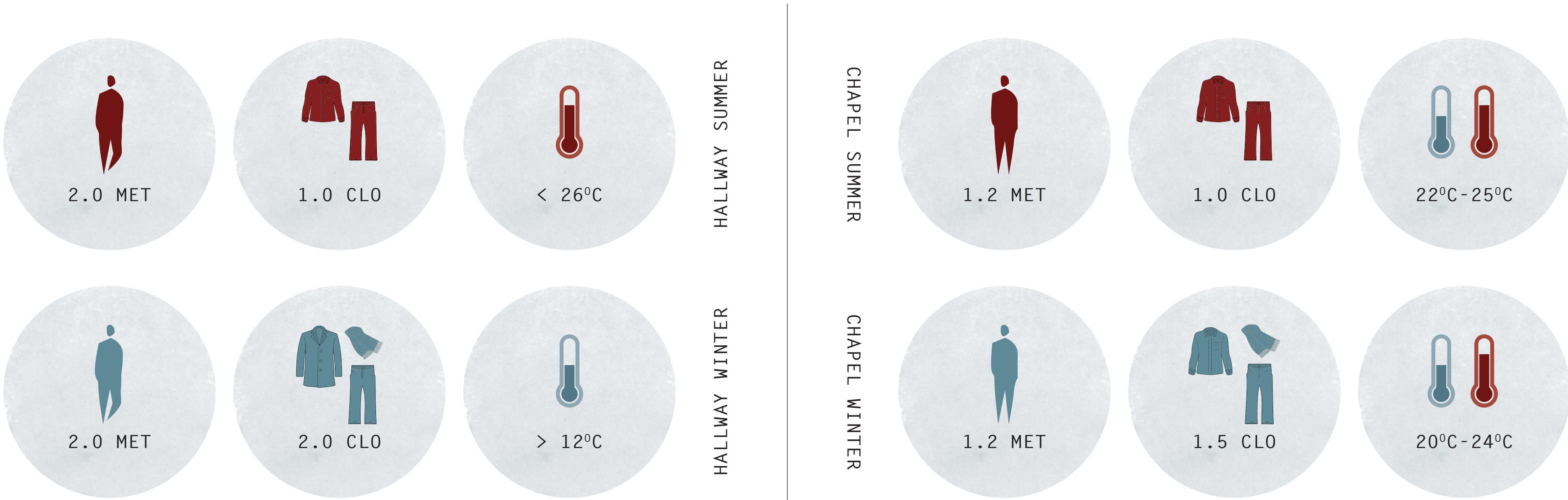
**Reduce** // Passive strategies must be integrated from start to reduce the need of heating, reduce the need for mechanical ventilation, and eliminate the need for cooling – all to reduce the total energy consumption. For this, a ventilation strategy must be implemented and a balance between passive heating, light, view, and heat loss must be integrated in the window design.

**Optimize** // Integration of technical aspects such as mechanical ventilation must be optimized to create a building working efficiently to lower the energy consumption.

**Produce** // A final effort to create an net zero energy balance is to produce renewable energy on site. This can be done by eg. integrating photovoltaic solar cells on the building.

**Grid Balance** // This fourth step has been formed to support and maintain an efficient, sustainable, and well-established public grid to which everyone can contribute with renewable energy as well draw from when on site is not an option - a professional and efficient grid balance.

# INDOOR CLIMATE




ILL. 4.3

## DEMANDS AND PERCEPTION

For the indoor climate, delimitations are made separately for the different thermal zones since some of these are desired to be perceived in quite different ways, creating contrasts through the building. Based on requirements from the EN 15251, amount of clothes (clo), activity level (met), and visions for atmosphere and perception, requirements for the indoor climate has been defined as illustrated above.

The chapels and the hallways connecting the building together will be further defined in this text for both a summer and winter comfort scenario:

For the chapels, an embracing, closed atmosphere is to be created, focusing on the interment and the people attending. Therefore, the visual comfort is prioritized highly to ensure no disturbing view, using the sun as a spiritual element, and using the view to nature as a healing element. The thermal comfort must not be too varied with a desired range of 22-24°C in summer time and 20-24°C during winter. These are set due to the extra amount of clothes people are expected to wear at formal events such as funerals even in summer months. To deliminate these, the graph for the 'optimal operative temperature' has been used (see apeendix 04). The atmospherical comfort can be critical due to the large amount of people gathering in one room. To control this the $CO_2$-level must not exceed 850 ppm.

For the hallways the temperature is desired, in some extent, to follow the outside temperature, allowing the temperature to vary much more than in the rest of the building. This, to create a strong connecting with the outside environment and to create a contrasting flow within the building. To strengthen the perception of being outside in nature and bringing nature inside, venting is to be enhanced in the hallways from May to September. Thereby, fresh air is being ensured, the temperature will be cooled down on hot days, and the sounds of nature are allowed to enter the building.

## CAPACITY DELIMITATION

Inhabitants of
Stockholm 2017:
910,000

Inhabitants prognose,
Stockholm 2030:
1,757,000

Share of Swedish people
choosing cremation 2016:
81.3 %

Interment capacity of the new
Woodland Crematorium 2018:
7,500 pr. year

Share of Swedish people
choosing decomposition 2050:
min. 40.4 %

Interment capacity of the
House of Recomposition 2050:
min. 4,000 pr. year

### DEATH STATISTICS

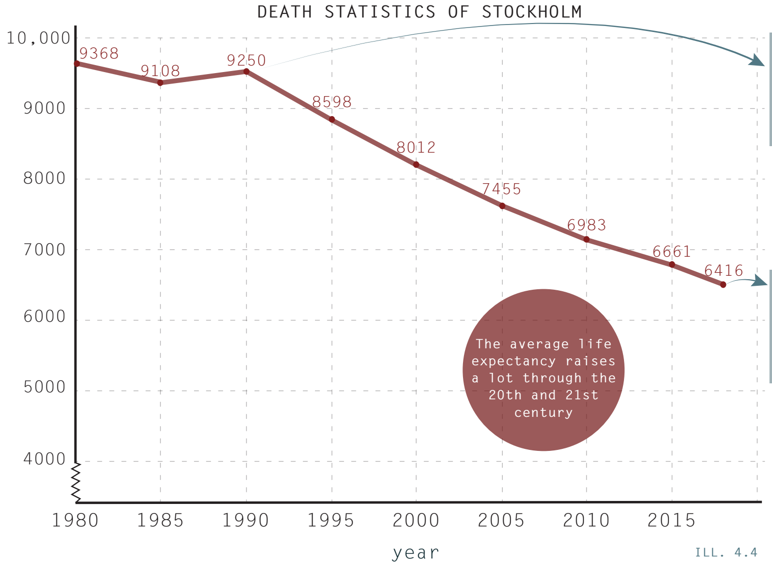
Although it started with much scepticism, cremations had a steep climb in popularity - a history we expect to reoccur for the House of Recomposition. Therefore, in this section, crematorium statistics has been analyzed to determine the decomposition interment capacity for Stockholm, specifically. Additionally, statistics on death rates, birth rates, life expectancies, and cremation rates, in Stockholm specifically, will help making prognoses to determine the future capacity of the House of Recomposition.

The death rate in European countries is in decline. But when studying the birth rate and the life expectancy rate, these gives the answers to why: the people dying in these years are born in the 1930s where fewer people in eg. Sweden were born and those who were born then lives longer nowaday - in a way the death rate is being postponed (ill. 4.4) (Statistics Sweden, 2017). However, research as well as our own analyses indicate that the death rate once again will increase showing a normal picture of the longer-living inhabitants (ill. 4.6).

An analysis of the cremation rate from early 1900 up until today is used to see how long it could take for the society to accept and take use of decomposition of dead bodies (SKKF, 2016). Noticeable here, is the expected faster change due to less religiously affiliated people, less rigid systems, and the internet spreading the news. In this way, the House of Recomposition will be designed for meeting the needed capacity up until 2050 as a reference year: a prognose of minimum 40% of the 8,500-9,000 dead people within Stockholm being decomposed (ill. 4.7). From 2050 a new House of Recomposition can then be opened to accommodate the growing demand as well as it being located away from the first house, to create its own local and close community.

As a conclusion, the capacity of the House of Recomposition must be minimum 4000 dead bodies pr. year - 40-50% of the total 8800 dead people of Stockholm - equivalent to approximately 10 dead bodies pr. day in total as a very minimum. However, with sustainability in mind, the project should strive towards meeting the capacity requirements of the new Woodland Crematorium.

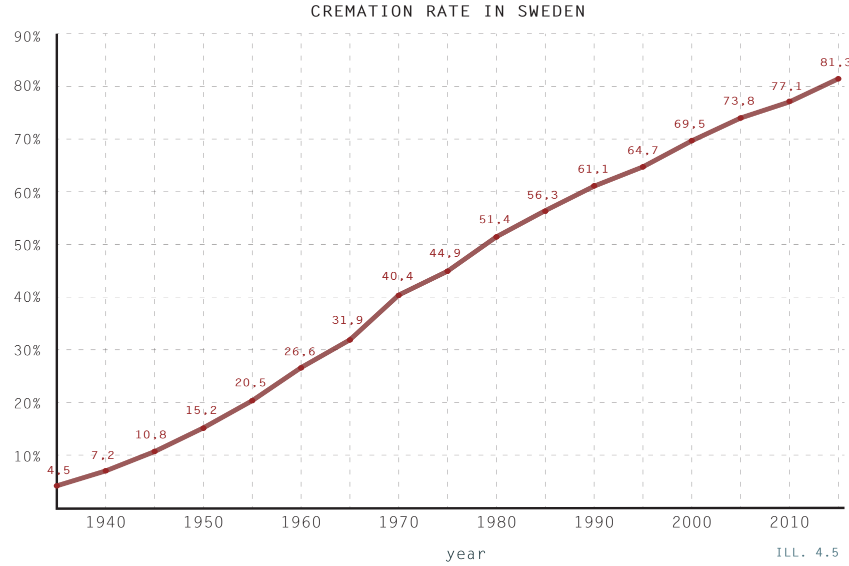
To accommodate this within the opening hours while still providing time enough for the ceremonies to take place, different solutions must be investigated. As well as having a flexibility in mind of future changes in the capacity. For these solutions the capacity should be attempted to be as large as possible by having more than one ceremony chapel and/or more than one decomposition chamber. In this way meeting the changing numbers of dead - the chance of more people choosing to be decomposed and the rising numbers of inhabitants.



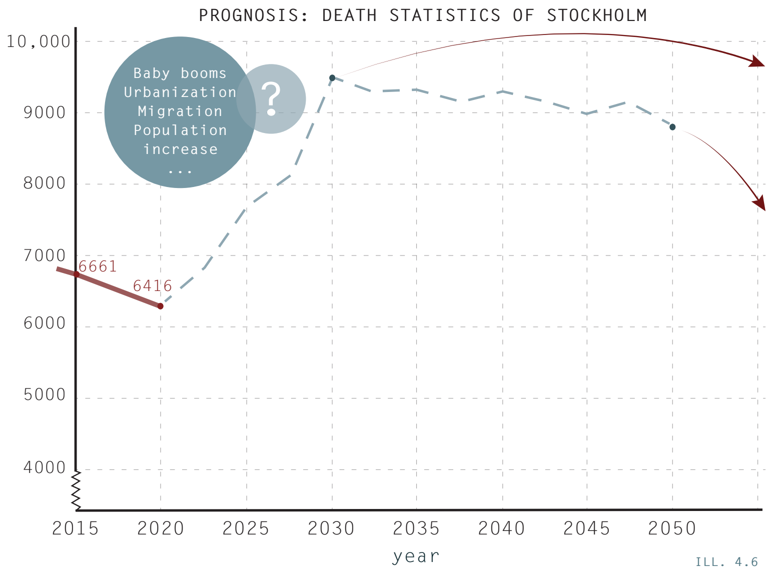

ILL. 4.4

Average life expec. <u>1990</u>: **77 years**
The people who died in 1990
must have been born around: **1913**
Number of born in 1913: **130,200**

Average life expec. <u>2017</u>: **83 years**
The people who died in 2017
must have been born around: **1934**
Number of born in 1934: **85,092**



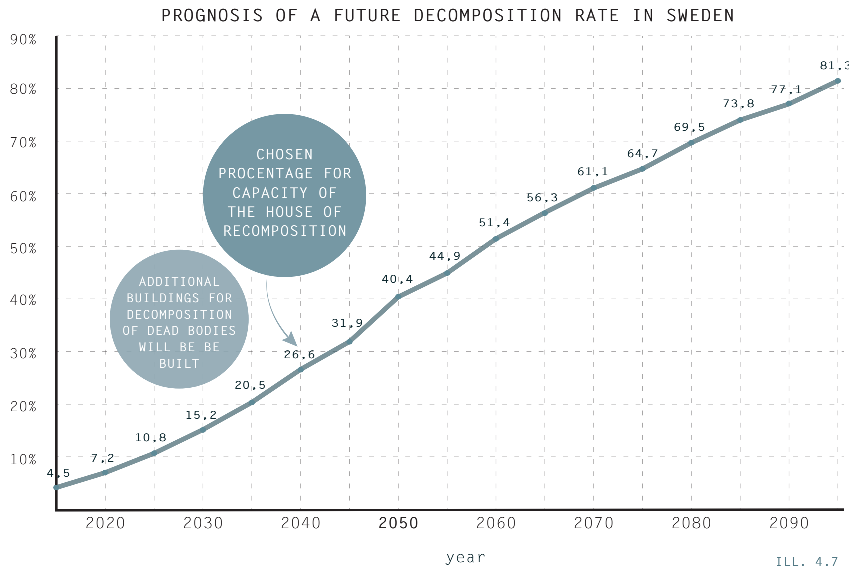

ILL. 4.5




ILL. 4.6

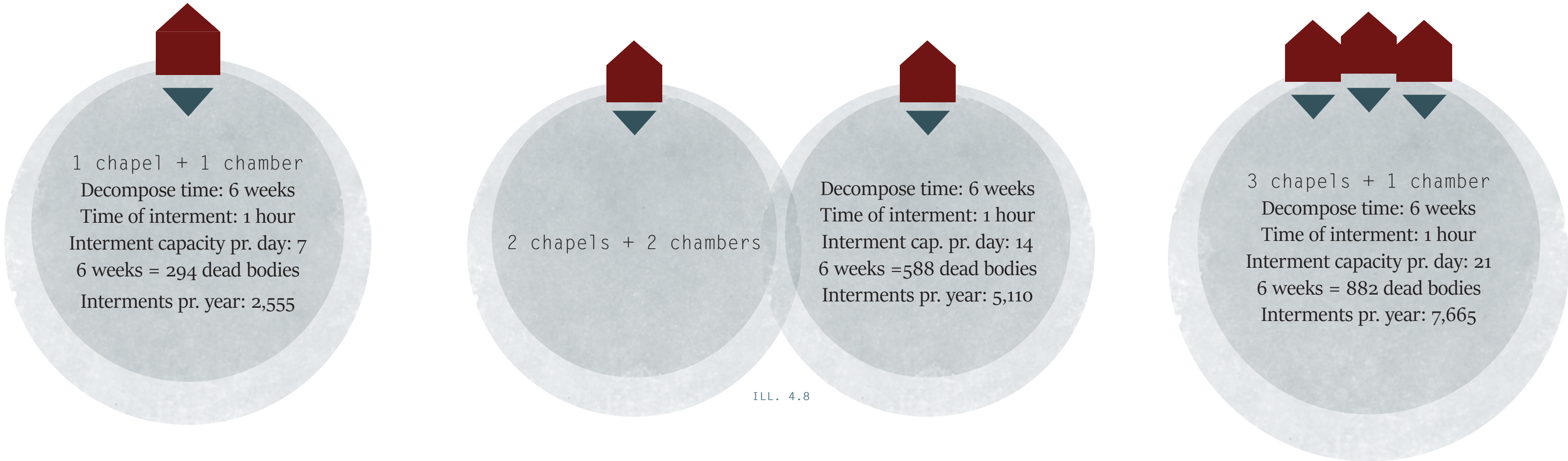
Average life expec. <u>2030</u>: **84 years**
The people who dies in 2030
must have been born around: **1946**
Number of born in 1946: **132,597**

Average life expec. <u>2050</u>: **87 years**
The people who dies in 2050
must have been born around: **1963**
Number of born in 1963: **112,903**




ILL. 4.7

## ROOM PROGRAM




ILL. 4.8

### FUNCTIONS

The room program is based on the analyses of 'designing for death' and 'decomposition' as well as from the competition brief [appendix 01] for the new Woodland Crematorium II along with knowledge from our MSc01 design of the Hatlehol Church (Bresson et al., 2017).

The ceremonies will take place in chapels designed for both smaller and larger gatherings. The sensation in these will be designed to provide a spiritual and intimate atmosphere - even if only few relatives takes part of the interment ceremony. Additionally, more than one chapel will allow the House of Recomposition to have a much larger capacity of interments pr. day. The House of Recomposition might also become more lively as the mourners will find comfort in seeing or knowing that other people in the house going through the same sorrow - a sense of community in life and in death as well. The chapels will all be connected to a decomposition chamber wherein the bodies will be laid to undergo the decomposition process. The decomposition chamber is then further connected to a technical room, responsible for maintaining the decomposition process as well as a compost processing room for handling the material extracted from the bottom of the chamber.

In the building space for mourning, remembrance, and reflection must be integrated. Here, people will have the opportunity to mourn their loved ones privately, remembering them with a flower or a private talk. This mourning space must provide an intimate, embracing feeling for the bereaved to have a divine, safe, and impressionable frame for mourning.

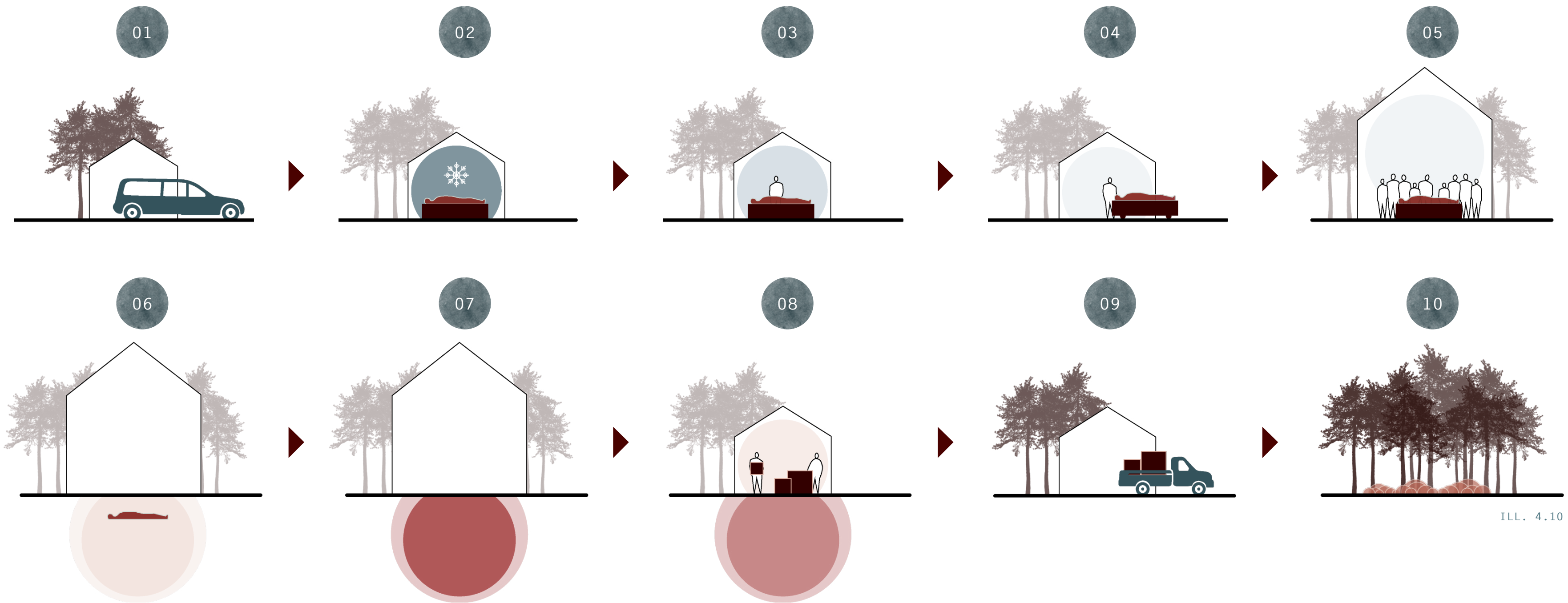
For the mourners processing a difficult loss, functions for counseling and social events must be integrated in the building in the meeting rooms and the Life Room. These functions must have a homely, safe, and intimate atmosphere, co-existing with functions for the ceremony along with curious people visiting the building.

A part of the building houses the staff functions and the practical functions for running a House of Recomposition. Besides offices and dining areas for the staff, rooms for cold storage of dead bodies, technical room, and preparation room for the dead bodies are important to integrate. A small storage room for rental coffins will also be necessary to accommodate situations where people want to have a church ceremony elsewhere with a coffin, before transporting the deceased to the House of Recomposition. Or in cases where people choose to have the dead body placed in a compostable coffin in the chapels  instead of them being wrapped in a degradable cloth.

| FUNCTIONS | QUANTITY | CAPACITY | AREA ($m^2$) | TOTAL AREA ($m^2$) | PERCECPTION | NOTES |
|---|---|---|---|---|---|---|
| Entry hall | 1 | - | 50 | 50 | Inviting, denial & reward, light | View to nature and the building interior |
| Life room | 1 | 30 | 90 | 90 | Spacious, warm, embracing | Available for various social events |
| Counseling rooms | 2 | 4 | 12 | 24 | Calm, soft light | Undisturbed access |
| Waiting area | 1 | - | 35 | 35 | Homely, intimate, soft light | Seating and wardrobe |
| Rest rooms | 3 | 1 | 3 | 9 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Offices | 2 | 4 | 25 | 50 | Calm, diffuse light | View to nature, distinguishable from public |
| Staff room | 1 | 10 | 40 | 40 | Homely, calm, soft light | View to nature, distinguishable from public |
| Changing rooms | 2 | 1 | 9 | 18 | Intimate, soft light | For staff, w/ shower and toilet |
| Restrooms | 2 | 1 | 3 | 6 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Small chapel | 1 | 40 | 135 | 135 | Divine, grand, embracing, spiritual | Reverb.: 1,0-1,6s // Def.: 70% |
| Depot | 1 | - | 6 | 6 | - | For music equip., chairs, ceremonial objects |
| Gathering niche | 1 | 40 | 45 | 45 | Spacious, soft light | For gathering before and after ceremony |
| Restrooms | 3 | 1 | 3 | 9 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Medium chapel | 1 | 80 | 210 | 210 | Divine, grand, embracing, spiritual | Reverb.: 1,0-1,6s // Def.: 70% |
| Depot | 1 | - | 10 | 10 | - | For music equip., chairs, ceremonial objects |
| Gathering niche | 1 | 80 | 60 | 60 | Spacious, soft light | For gathering before and after ceremony |
| Restrooms | 5 | 1 | 3 | 15 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Large chapel | 1 | 150 | 320 | 320 | Divine, grand, embracing, spiritual | Reverb.: 1,0-1,6s // Def.: 70% |
| Depot | 1 | - | 15 | 15 | - | For music equip., chairs, ceremonial objects |
| Gathering niche | 1 | 100 | 100 | 100 | Spacious, soft light | For gathering before and after ceremony |
| Restrooms | 9 | 1 | 3 | 27 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Garage | 1 | - | - | - | - | Direct access to corpse reception |
| Body preparation | 1 | 2 | 55 | 55 | Ceremonial, light, clean | For prep. before storage and ceremony |
| Morgue | 1 | - | 100 | 100 | - | Storage drawer stacked in threes |
| Compost storage | 1 | - | 60 | 60 | - | Preparation and packaging of compost |
| Tech. room | 1 | - | 75 | 75 | - | Well isolated (noise) |
| Daily maintenance | 1 | - | 15 | 15 | - | Cleaning, washing, and refuse |
| Restrooms | 1 | 1 | 3 | 3 | Intimate, dimmed | Accessible from entrance hall and chapels |
| | | | | | | |
| Transfer hall | 1 | - | 330 | 330 | Ceremonial, soft light, warm | Accessible for transfer of bodies and compost |
| Mourning hall | 1 | - | 440 | 440 | Dark, private, sacred | Perceptually seperated form the rest |
| | | | | 2352 | | |

ILL. 4.9

## FLOW




ILL. 4.10

### FLOW OF THE HOUSE OF RECOMPOSITION

A great challenge in the Woodland House of Recomposition is the logistics and connections between the back of house (B.O.H) and the front of house (F.O.H). Yet, there is still a need for visually separating these two for the better of the visitors and the working staff:

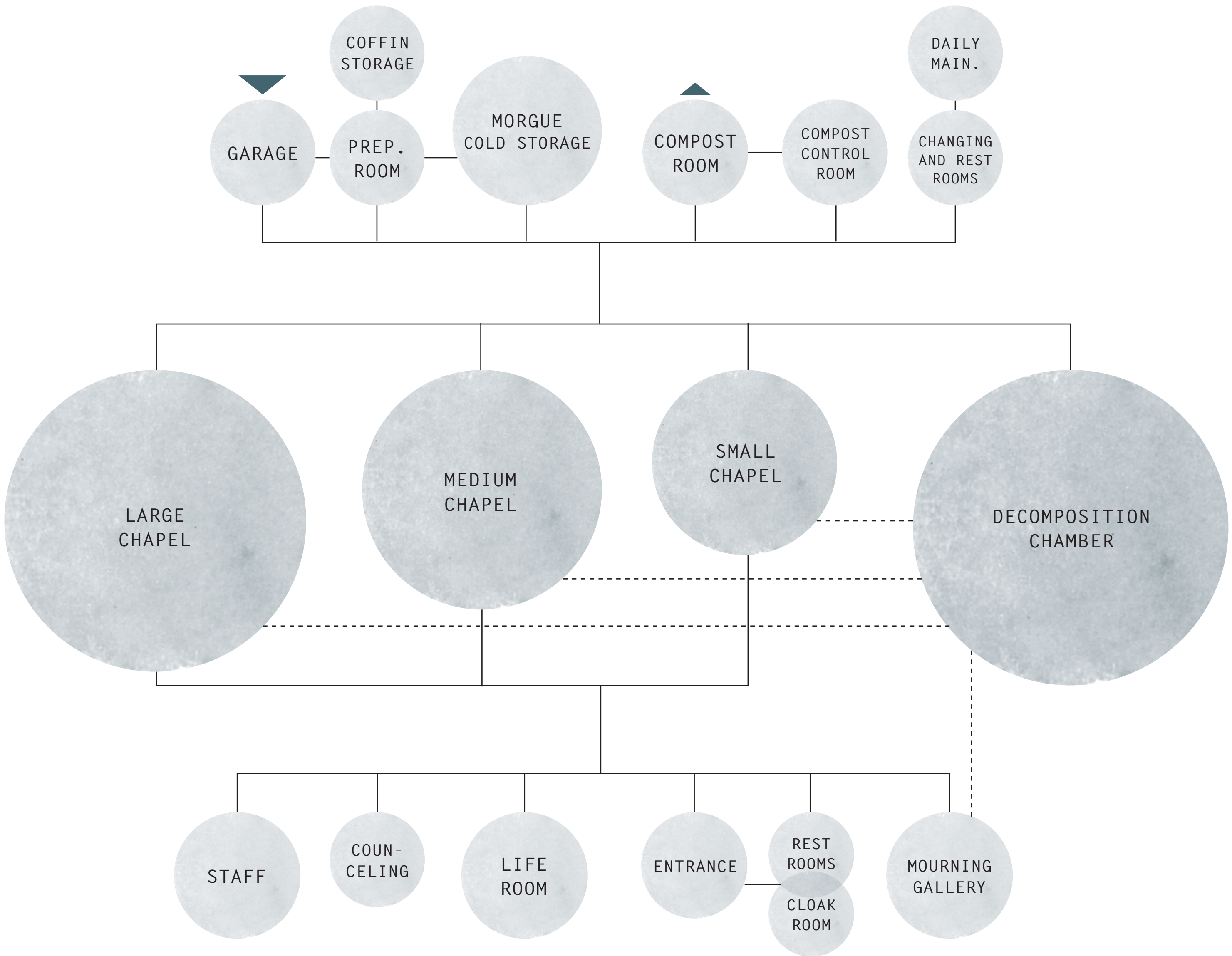
While the B.O.H must have a logical and practical flow for the people of the building to work efficiently every day, the F.O.H must provide a great experience, guiding the visitors through the building and spiritually through the mourning process.

These two flows shares the function of the decomposition process as well as the chapels where the bereaved enters in front for the ceremony and the staff enters from the back to take care of the ceremony before and after. Additionally, while the F.O.H must be accessible for the staff to easily be available for mourners in need of guidance and advice, the visitors may not be connected to the flow of the B.O.H.

Both the B.O.H and F.O.H will have their own entrance that must visibly be very different and placed far from each other. This, since the B.O.H entrance will be the place for the hearse to arrive with the deceased as well as an every-day and undisturbed entrance for the staff. In contrast, the F.O.H entrance should be clear and grand, guiding and welcoming people easily into the building.

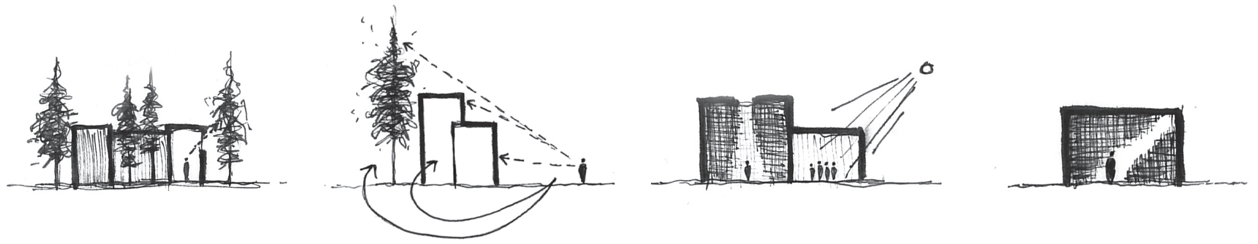
The illustration above shows the flow of the deceased from arrival to decomposition and further how the compost contributes to forests and parks.

The illustration on the right illustrates the overall flow diagram of the building functions.


COFFIN STORAGE
DAILY MAIN.
GARAGE
PREP. ROOM
MORGUE COLD STORAGE
COMPOST ROOM
COMPOST CONTROL ROOM
CHANGING AND REST ROOMS
LARGE CHAPEL
MEDIUM CHAPEL
SMALL CHAPEL
DECOMPOSITION CHAMBER
STAFF
COUN-CELING
LIFE ROOM
ENTRANCE
REST ROOMS
CLOAK ROOM
MOURNING GALLERY

ILL. 4.11

# DESIGN CRITERIA



## ARCHITECTURAL EXPRESSION

// Use light and shadows to distinguish the atmosphere and perception of the different functions. Additionally, to emphasize scale, depth, and details.

// Use light and shadows and acoustic climate to create a sense of calmness in rooms for mourning and processing loss.

// Design for clear distinction and transition between public functions and ceremony functions to meet the need for shared, lively spaces and private, intimate spaces.

// Create a building that embraces and guides mourners and bereaved as well as inviting spiritual and curious minds.

// Create a readable design that declares the decomposition chamber as the main function of the building.

// Use the gesture of 'denial and reward' in th architecture to engage the visitor in exploring the building.

// Activate the visitor's body and mind through sensations and atmospheres evoking both the sense of seeing, feeling, touching and hearing.

// Create poetic and sublime spaces for mourning and reflection through light, materials, shape, and views.

// Integrate the building into the surrounding nature and investigate the border between interior and exterior.

// Use nature and light as a means of aiding the mourning process.

// Visually express the sustainable ideals that is embodied in the building.

// Use light, shadow, and contrast in the lighting to express grandeur and spirituality.

## SOCIAL, HEALTH, AND WELL-BEING

// Develop an interment that is honest and recognisable.

// Create an environment and atmosphere within the building of safety and comfort.

// Design for neutrality in relation to religion and secularity.

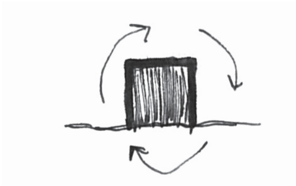
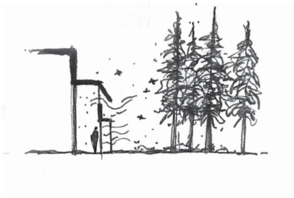
// Create a balance between privacy and community for visitors and especially mourners.

// Facilitate a healthy atmospheric and thermal climate with proper ventilation.

// Filter gases from the decomposition process to eliminate smell and reduce pollution.

// Provide a healthy working environment for the staff.

# DESIGN CRITERIA

ILL. 4.12-4.19

## SITE, INFRASTRUCTURE, AND ECOLOGY

// Create a regenerative design that contributes to the genius loci of the site.

// Create synergy with the natural environment, flora, and fauna.

// Design a readable and spiritual arrival to the site to aid in the comfort of the bereaved.

// Maintain the idea of the secluded and undisturbed building in the forest that is typical of the Woodland Cemetery architecture.

// Design a building that in a respectful manner is integrated in the forest and context of the Woodland Cemetery while still creating an innovative design.

## MATERIALS

// Use local materials to integrate the local identity and reduce transportation emissions.

// Create a robust architecture through the choice of low-maintenance materials, contributing to a long building lifetime.

// Integrate the properties of the chosen materials (tactile, acoustic, visual, etc.) in the architecture to aid in the shaping of atmosphere of the various rooms.

// Utilize material properties for the improvement of acoustics in especially the chapels.

// Use sustainable materials with focus on local materials, recycling and upcycling.

## ENERGY, HEAT, INDOOR CLIMATE

// Design toward a Net Zero Energy Building.

// Utilize the heat produced by the decomposition process to aid in heating the building.

// Utilize the methane produced by the decomposition process to aid in electricity of the building.

// Design for an indoor climate that in the hallways reflects the outside temperature to enhance the strong connection with the sorrounding landscape.

// Design the indoor climate of the chapels to be stable througout the year and stay within the defined comfort temperatures.

// Fulfill the requirements of max. 100 hours above 27 celcius degrees and max. 25 hours above 28 celcius degrees in a year.


ILL. 4.20

## VISION

With the realization of this project, we aim to design an architecture and its use, based on decomposition of deceased as a sustainable, open, and honest way of interment.

We aim to design this method of interment to break the silence around death and emphasize the beauty of life and - in death - its reentry into the circularity of nature. Along with this, we aim to design a safe environment for mourning and leave-taking that reflects the needs and ideals of modern society regardless of religious affiliation.

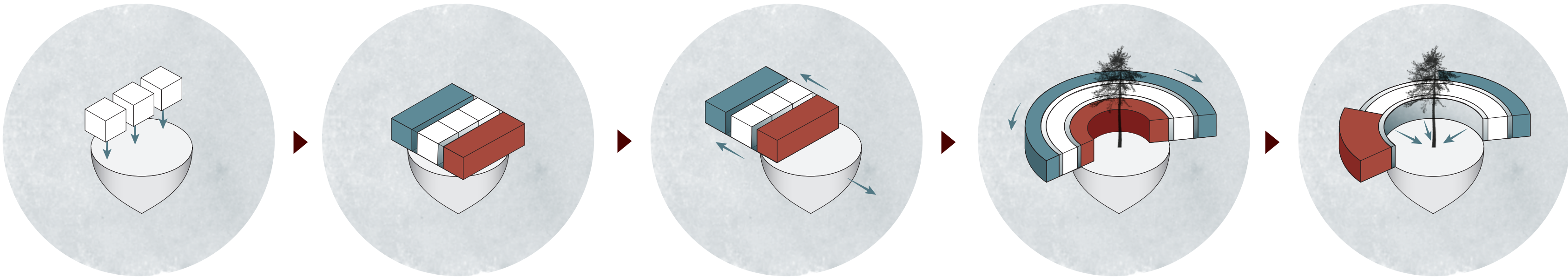
We aim to design a symbiosis between this new method of interment and an architecture that integrates a calming environment, spiritual atmosphere, holistic funeral ceremonies, safe social gatherings, and transparent research facilities. This building will reflect the sustainable mindset of its function through a holistic, honest and robust architecture which will persist through all of its lifetime.

We aim to develop an architecture and technology that we can prove to be more environmentally sustainable than current methods of interment in its balance between energy consumption, space efficiency, emissions, material reuse, waste, and pollution.

# 05

## DESIGN PRESENTATION

In the following chapter the final design proposal for *the Woodland House of Recomposition* is presented through words, visualizations, and diagrams. Furthermore, this chapter seeks to conclude if the decomposition process in fact is a more sustainable choice of interment.



*Imagine if you could positively effect the world*
*...even though you're dead.*

You can

The Woodland House of Recomposition, located in the Woodland Cemetery near Stockholm, is the first of its kind offering decomposition of our deceased as a sustainable, innovative, and holistic alternative of interment.

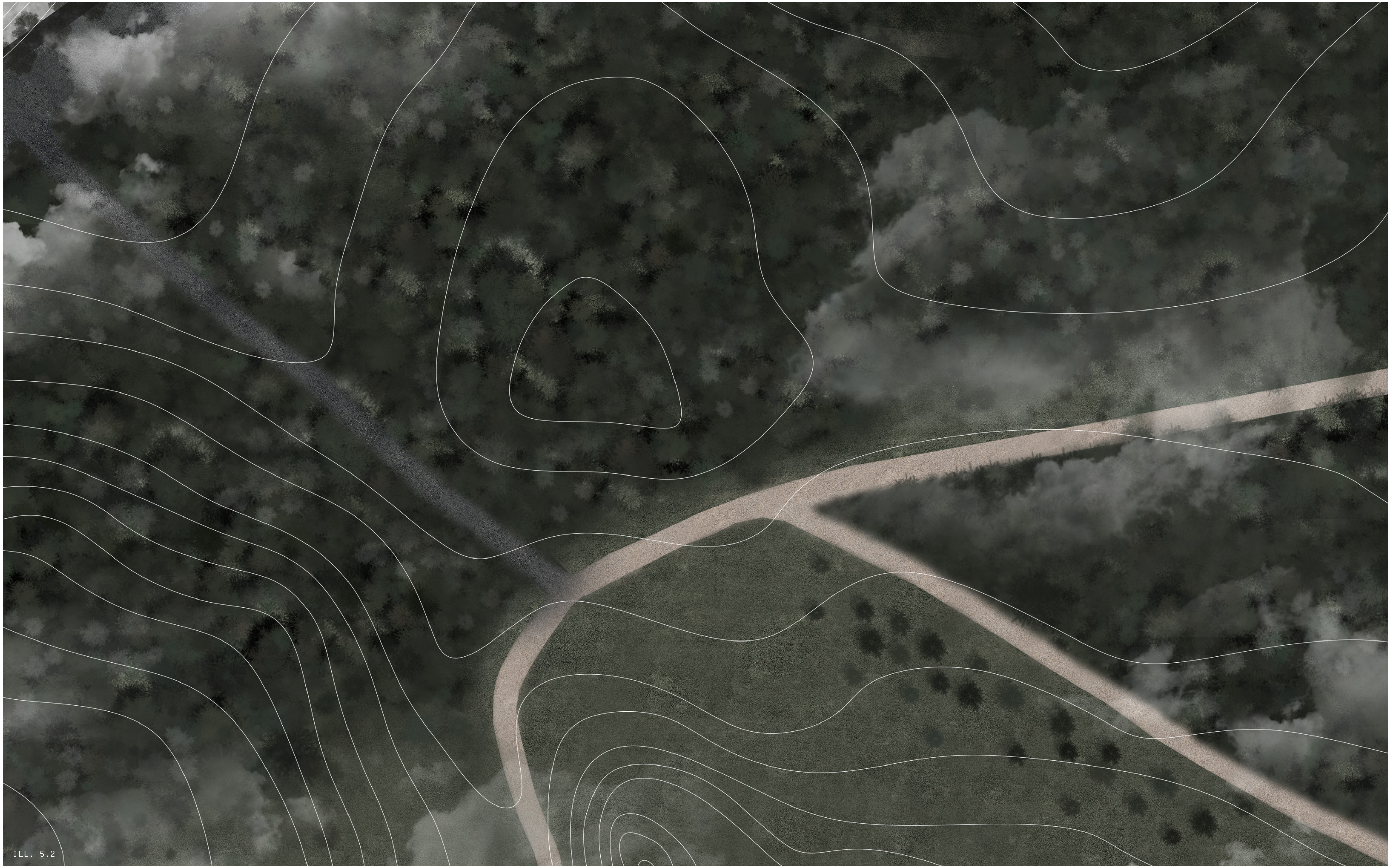
The Woodland House of Recomposition, and in general the Houses of Recomposition, focus on this new way of interment to be a sublime, ceremonial, spiritual, and important last goodbye of a loved one held in divine, safe, and embracing frames. It is important in the design of the House of Recomposition to create a holistic building for the process of a loss and death in general regardless of religious affiliation or the lack of it. Therefore, the design of the Woodland House of Recomposition uses the light as a spiritual symbol and the nature as a healing element in all its rooms designed for bereaved and mourners.

The rooms of the house seeks to accommodate all aspects of death - and life as well - for people to talk about and see the beauty in: The counselling rooms for guiding people through a recent death or in the planning of the interment; the three chapels for the interment and last goodbye of the deceased; the Mourning Hall and Memorial Garden for remembrance and honouring of a lost loved one; and the Life Room for processing a loss together with other people whether it being a recent or a past loss. All these rooms are connected by two halls in the House of Recomposition: the hallway placed between the main functions and the Memorial Garden to create a common space for all the visitors in close connecting to nature; and the staff hall on the back connecting the function of the Back of House with the main functions in between the two halls. In this way the staff flow and visitor flow are connected to the main functions and each other while still being seperated and allowing for clear logistics and a simple flow.

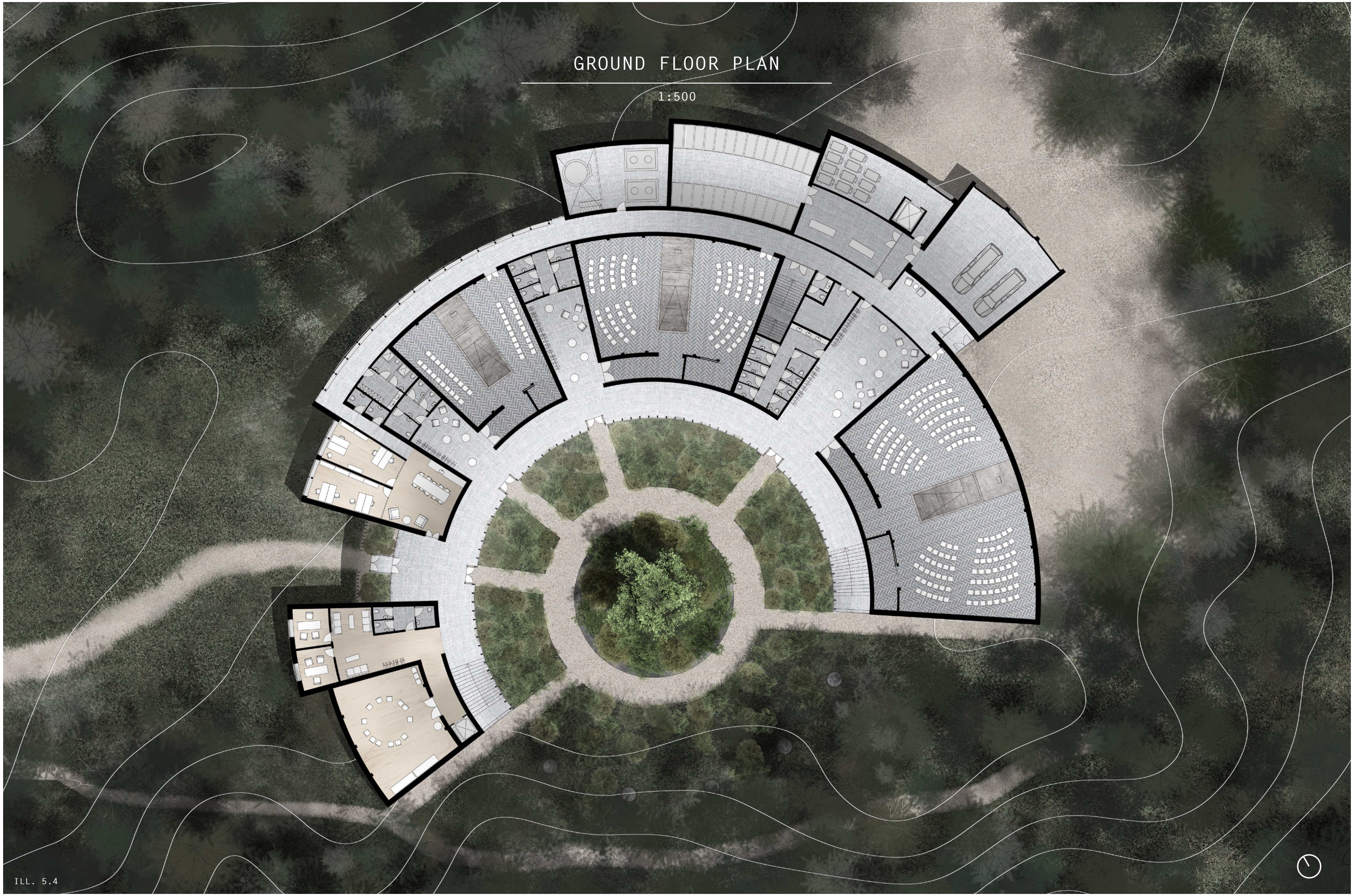
In the Houses of Recomposition, the shared chamber takes care of the decomposition process of deceased in a controlled ecosystem for the body in the duration of only six weeks. Hereafter, the compost is gently moved to the Woodland Forest or other areas in need of nutritious soil. In this way, by building a shared chamber in a shared house, the House of Recomposition eliminates the need for thousands of individual graves and areas only dedicated to death, taking up precious space on earth. The vision for the Woodland Cemetery is with time to slowly fade out its 100,000 graves to create not just a forest but actual nature and biodiversity in the middle of the city - a green spot that even more so than today allows for both death and life to be present together.

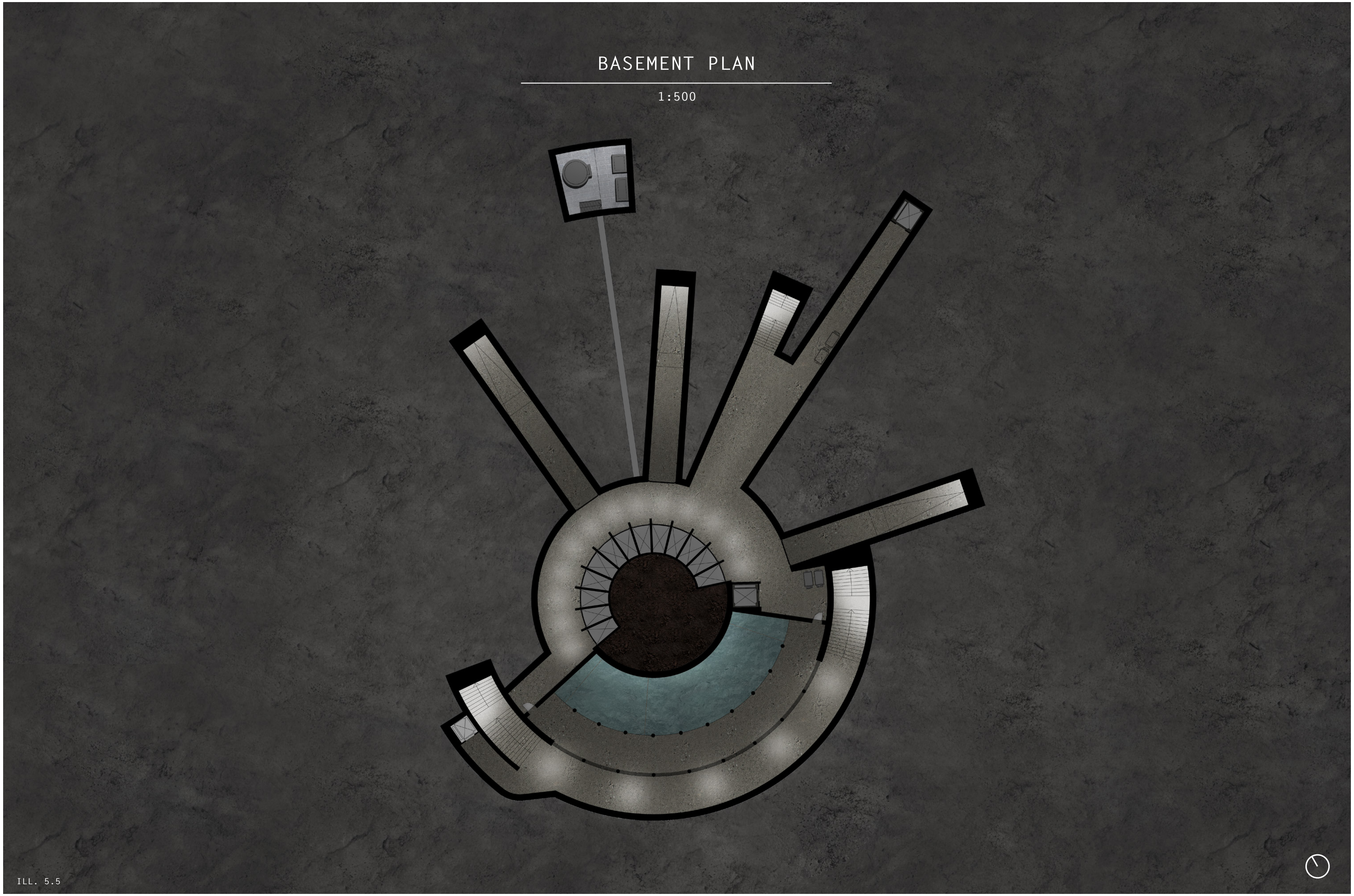
As the function of the building (the decomposition of the deceased) is sustainable and regenerative, the House of Recomposition itself must be as well. Therefore, the building is designed for being a sustainable and regenerative building from the very start. This through integrating passive strategies early in the design to lower the energy consumption, choosing sustainable materials with the knowledge of life cycle properties, and utilizing the energy and heat the house produces itself.

The whole building centers around the Decomposition Chamber and the Memorial Garden. The two are placed on top of each other to symbolise the nature growing from our lost loved ones – in this way telling the story of how both the building and the trees strongly hold down the memory of all who are and will be laid to rest in the Woodland House of Recomposition.


ILL. 5.2

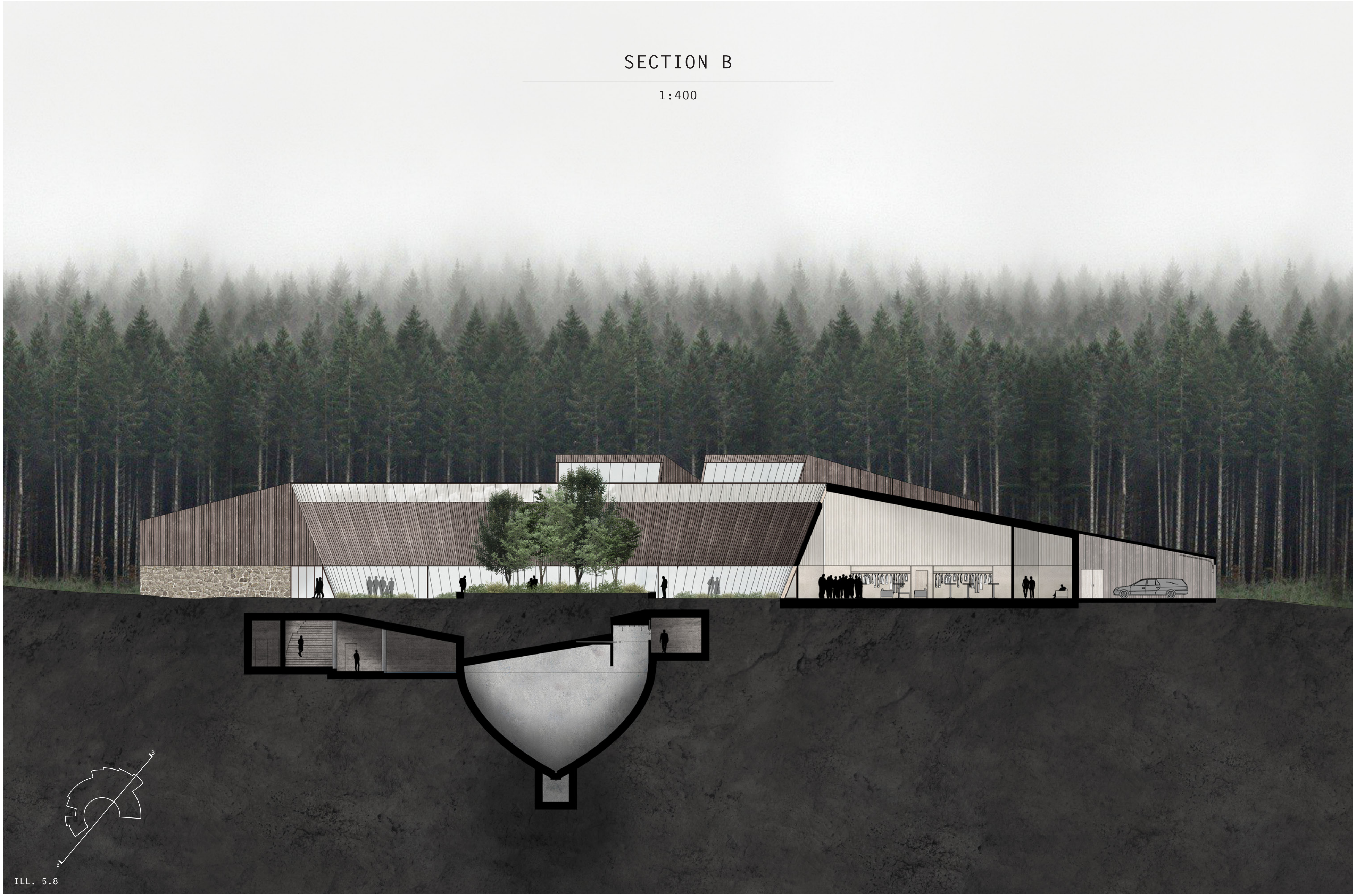

SITE PLAN
1:1000

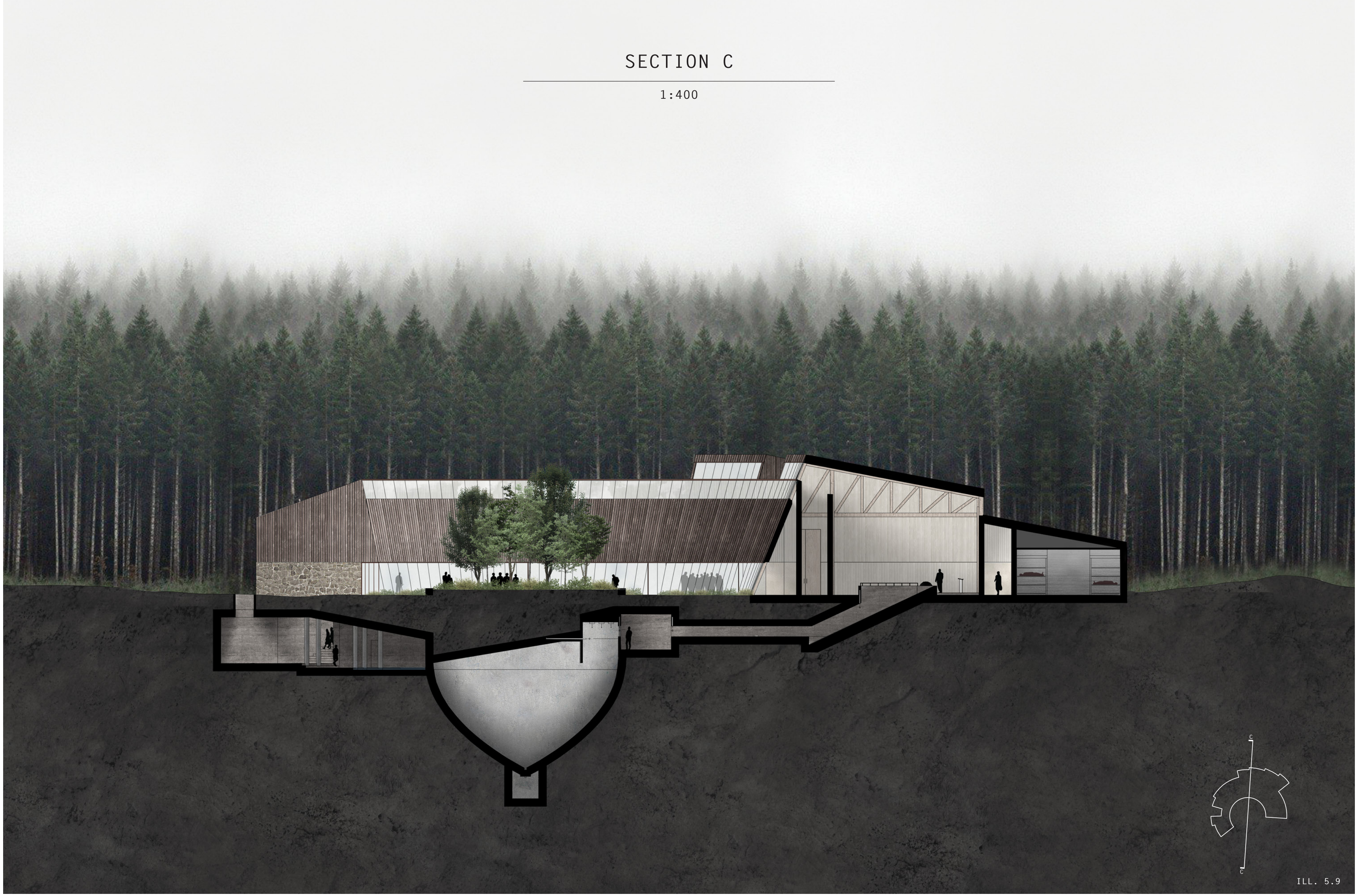

GROUND FLOOR PLAN
1:500
ILL. 5.4


BASEMENT PLAN
1:500
ILL. 5.5


NORTH WEST ELEVATION
1:400
ILL. 5.6


SECTION A
1:400
ILL. 5.7


SECTION B
1:400
ILL. 5.8


SECTION C
1:400
C
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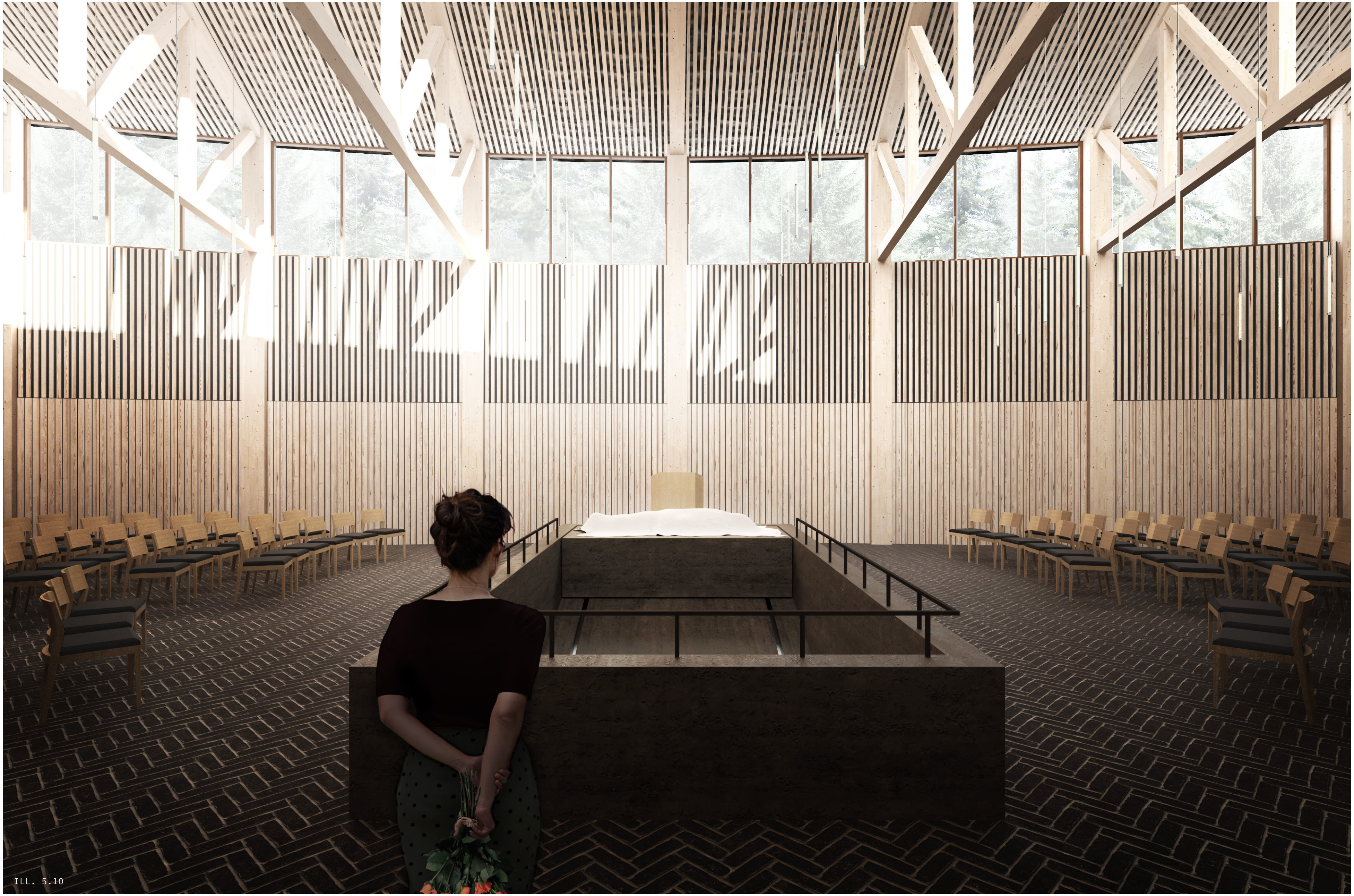
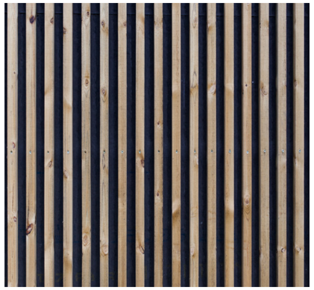
ILL. 5.9


ILL. 5.10



ILL. 5.11-5.13

## THE THREE CHAPELS

In the Woodland House of Recomposition three chapels are designed for the ceremony of the interments. The three chapels are in three different sizes to accommodate various amounts of people attending a ceremony - in this way offering a filled, intimate ceremony even though only few are attending and allowing enough space for large ceremonies. Having three chapels provides for a larger capacity meeting the increasing number of inhabitants and secular people of Stockholm. Additionally the three chapels sends a reference to the old Woodland Crematorium by Gunnar Asplund.

All three chapels placed next to each other follow the shape of the building with its circular plan layout but creates a contrast in each of their symmetrical axis. These axes have their origin in the center of the Decomposition Chamber and Memorial Garden - the center for the whole building layout in general - continuing through the mid of the chapels and out. The axes symbolize the journey of the deceased from the chapel into the Decomposition Chamber underground (death) and the journey of the bereaved from the chapel out to the Memorial Garden above ground (life).

The main gesture of the chapels is the light which creates a sentimental but uplifting sensation of the beauty that is honoring and saying goodbye to a loved one. Therefore, the daylight coming from South behind the assemblage symbolizes a divine, undefinable light while the diffuse light in front from North opens up towards nature in an undisturbed view to the conifer treetops. This, to bring in the healing effect of nature to the chapels.

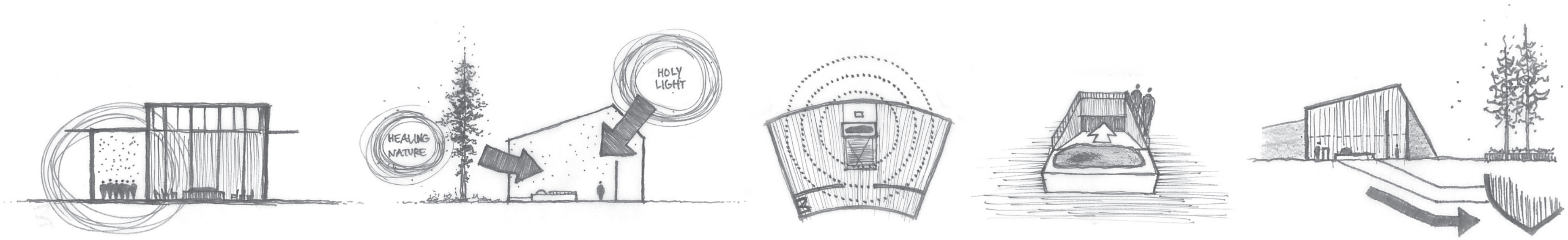
The entrance to the chapels seeks to give time for the bereaved to slowly move from the gathering niche into the ceremonial space. This, through a narrow hallway along the circle of the building, leading into the middle, and turning around at the symmetry axis, looking towards the deceased. This small hallway is designed as a contrast to the open, light chapel with it being narrow and dark. After the ceremony this hallway also allows for the bereaved to gently enter outside into the real world again.

The materiality of the chapels is kept very simple in its choices of only wood and clay stone chosen for their sustainable properties. The wood is chosen to be light in contrast to the earthbound, robust, and darker claystone, as well as referencing to the place of the building being located in the middle of a woodland. As the rest of the building, the interior walls of the chapel is divided in two at 2.5 m to symbolize the division between the divine and unreachable, and the earthbound and human. The materials for the chapels specifically are chosen to be the same under and above the dividing line to illustrate how these two worlds meet during the ceremony. For acoustic matters the wood cladding above the line have a larger gab with sound absorbing material behind.

The claystones are laid in a herringbone pattern on the floor of the chapels to add details to the homogene wood cladding.

In the symbiose of light, materiality, spatiality, symmetry, structure, and transition, the wholeness of the chapels is completed.


ILL. 5.14




ILL. 5.15

## THE CEREMONY OF RECOMPOSITION

While most of the building functions centers around the bereaved, mourners, or the staff, the chapels solely centers around the deceased.

From the side of the chapels the bereaved enters from the gathering niche, through a large door, further along the narrow hallway behind a large wall to enter out into the chapel room. From here the deceased lays in the very middle of the room on a bed of wood chips and sawdust under a cloth on a plinth. The cloth gently hides away the deceased while still revealing a true silhouette in a wish to make the ceremony more personal and real. The plinth is made of stabilized rammed earth as a symbol of what the physical body will soon become. On the plinth, flowers can be placed by the bereaved.

As part of the ceremony a larger piece of compostable cloth is wrapped around the composting material and the deceased and secured, letting the bereaved witness how their loved one is gentle taken care of and protected.

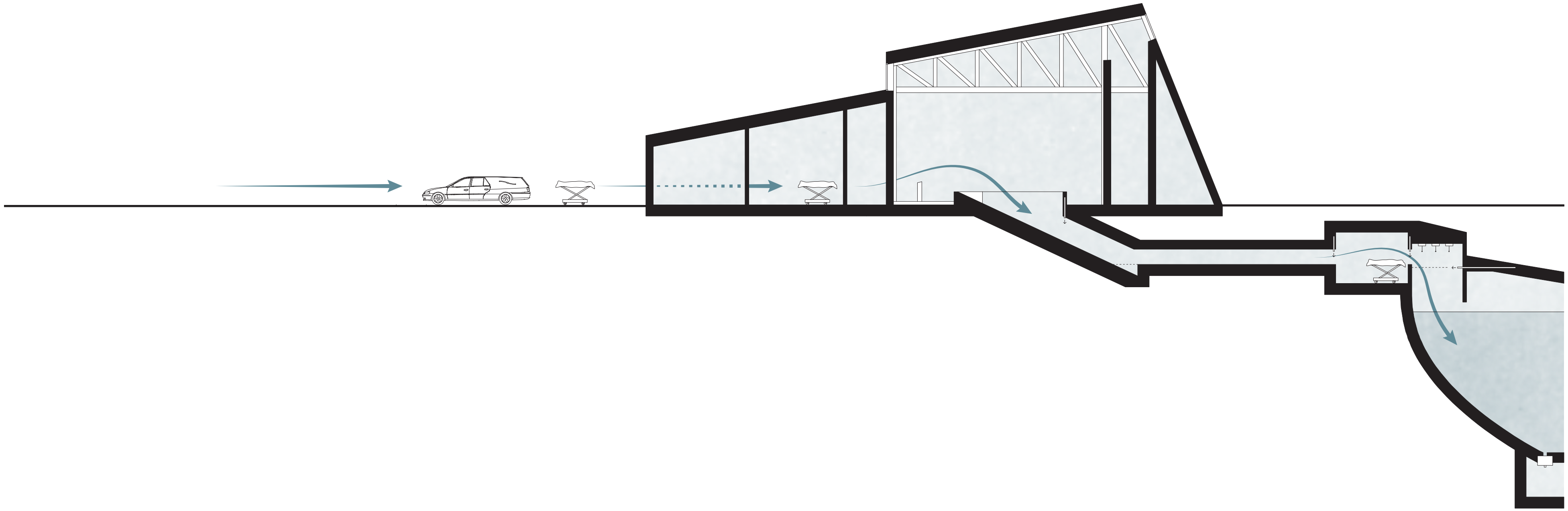
For the last transition it has been important to design for a clear, simple transfer of the deceased telling an honest story of where the deceased is transferred to: towards the Decomposition Chamber to decompose. In this way, the deceased is leaving the room and thereby the bereaved rather than the bereaved leaving the dead behind. It is the body that transits into a new state or life.

The deceased is lowered down the ramp while the bereaved says goodbye to the physical remains that with time will become unpersonalized compost while the soul and the memories of the person stays within the Woodland House of Recomposition. To enhance this, the bereaved can enter out to the Memorial Garden or down into the Mourning Hall while the body enters further into the transfer hall and Decomposition Chamber.

Before and after the ceremony the bereaved can gather in the niches affiliated to each chapels. These niches are designed to offer a semi-private space creating a safe and embracing atmosphere. Here the bereaved can take their time before and after to mourn and remember the deceased in undisturbed frames.The niches are still open out to the main hallway to integrate the space and people in the building - letting all visitors of the building join in their sorrow and mourning of their loved ones.

The ceremony is held by a ritual manager, priest, or other spokesman, and can be accommodated with music if wished. In general the ceremony is structured individually by the bereaved beforehand in collaboration with the staff.

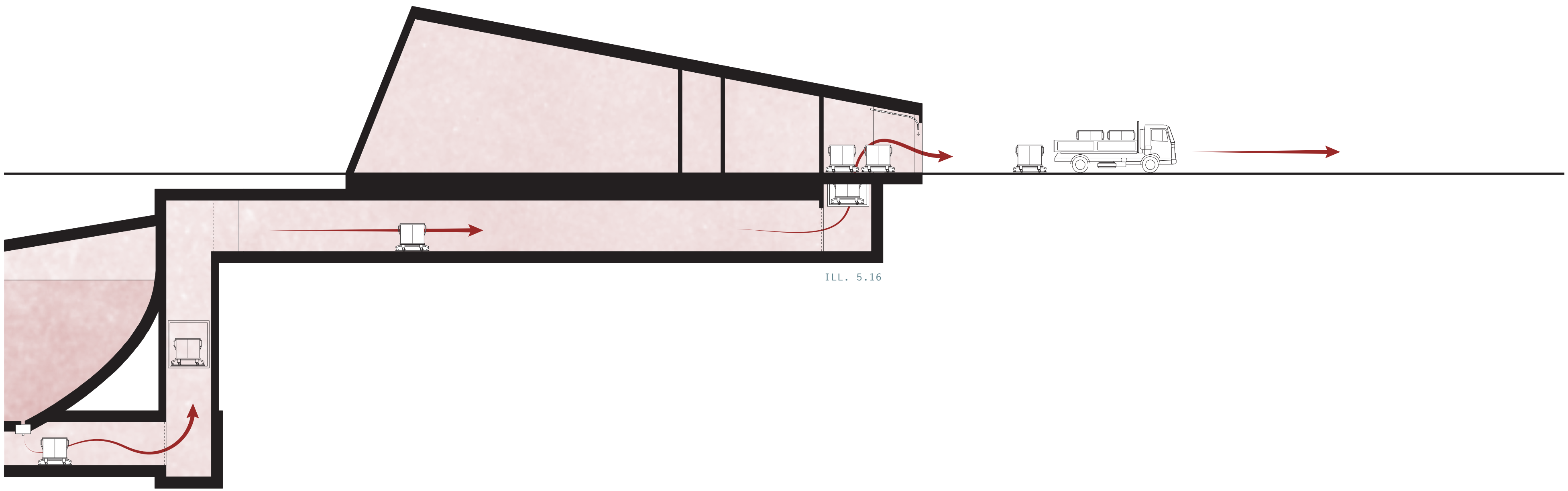
## JOURNEY



### FROM BODY TO COMPOST

As the body descends through the floor of the chapel, the staff is preparing to receive it in the transfer hall and send is further in its journey. The transfer hall is located directly adjacent to the Decomposition Chamber and shares the chamber wall with the Mourning Hall located opposite. The function of this room is the preparation of the body before entering the decomposition chamber as well as the transport route for the extracted compost at the bottom of the chamber.

When the body has arrived at the outer wall of the transfer hall from the chapels, the staff will place it on a stretcher and clean any flowers and objects sent with the body for non-compostable materials. The body is then moved to an available chamber shaft. All shafts in the transfer hall is fitted with two sealed hatches to avoid the escape of gases from the decomposition chamber, so as when the body is placed in the shaft, it is still isolated from the chamber itself. Additional wood chips that has been soaked in water is placed along the body and will aid the decomposition process. After the front hatch has been sealed, the bottom hatch will open, and the body and additional compost material will be lowered down by motored hoists in the shaft ceiling. As the hoist is retracted, the bottom hatch will seal itself and the shaft will be ventilated for unwanted gases.

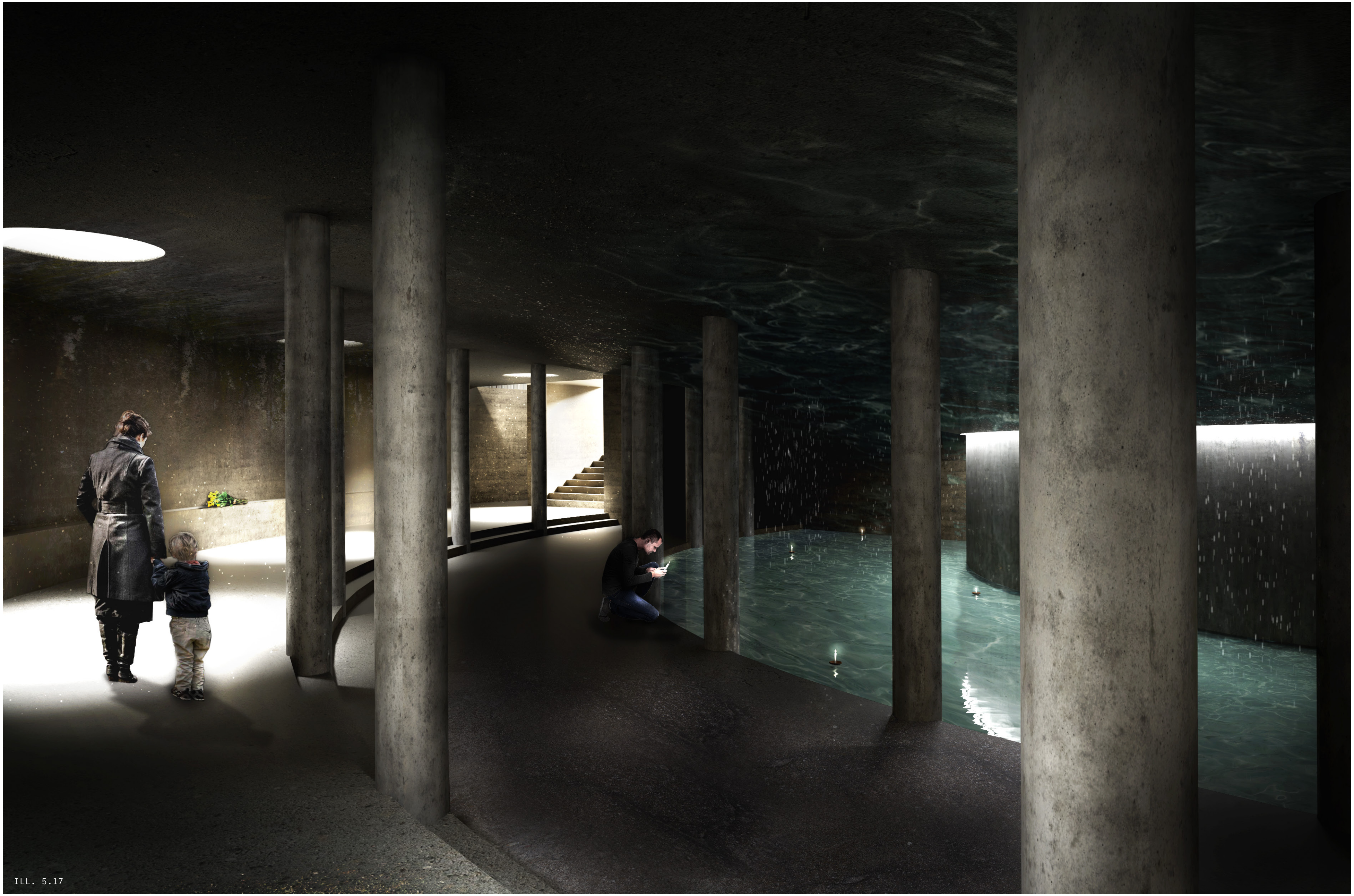


ILL. 5.16

The body - now wrapped in a thick layer of wood chips and sawdust - will remain physically isolated from the rest of the chamber content for the first few weeks during the first steps of the decomposition process. However, it will still share the warmth and humidity with the remaining bodies. Not before the remains of the body has entered the liquidizing phase along with its enclosure will it join the chamber content and transform into a homogenous nutrient rich compost.

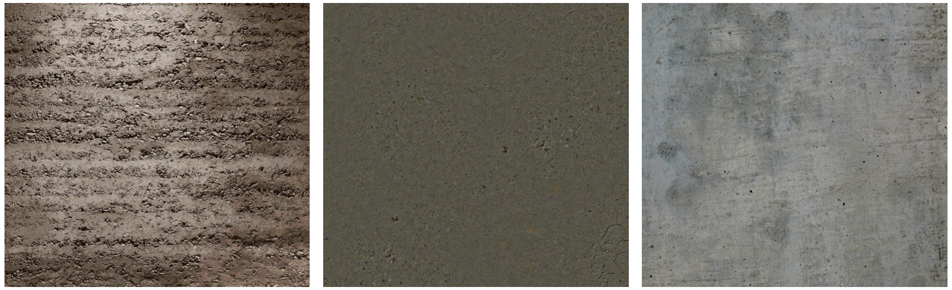
With the same rate as the deceased are being laid to rest in the top of the chamber, the chamber must also be continuously emptied at the bottom. For this, a room is built which houses an industrial screw extractor and an elevator. Here, AGVs (Automated Guided Vehicles - see appendix 06) will collect the finished compost in containers and seal them before taking the elevator back to the transfer hall. A hallway leads the compost to another elevator which will bring the AGV and container to the compost room from where it will be collected by truck.

At an off-site facility, the compost will then be filtered for plastic and metal prosthesis which were not removed in the preparation before the interment ceremony. The compost will then be distributed to various parks and forests to contribute to improving the biodiversity of the place.



ILL. 5.17

# MOURNING



ILL. 5.18-5.20

## MOURNING HALL

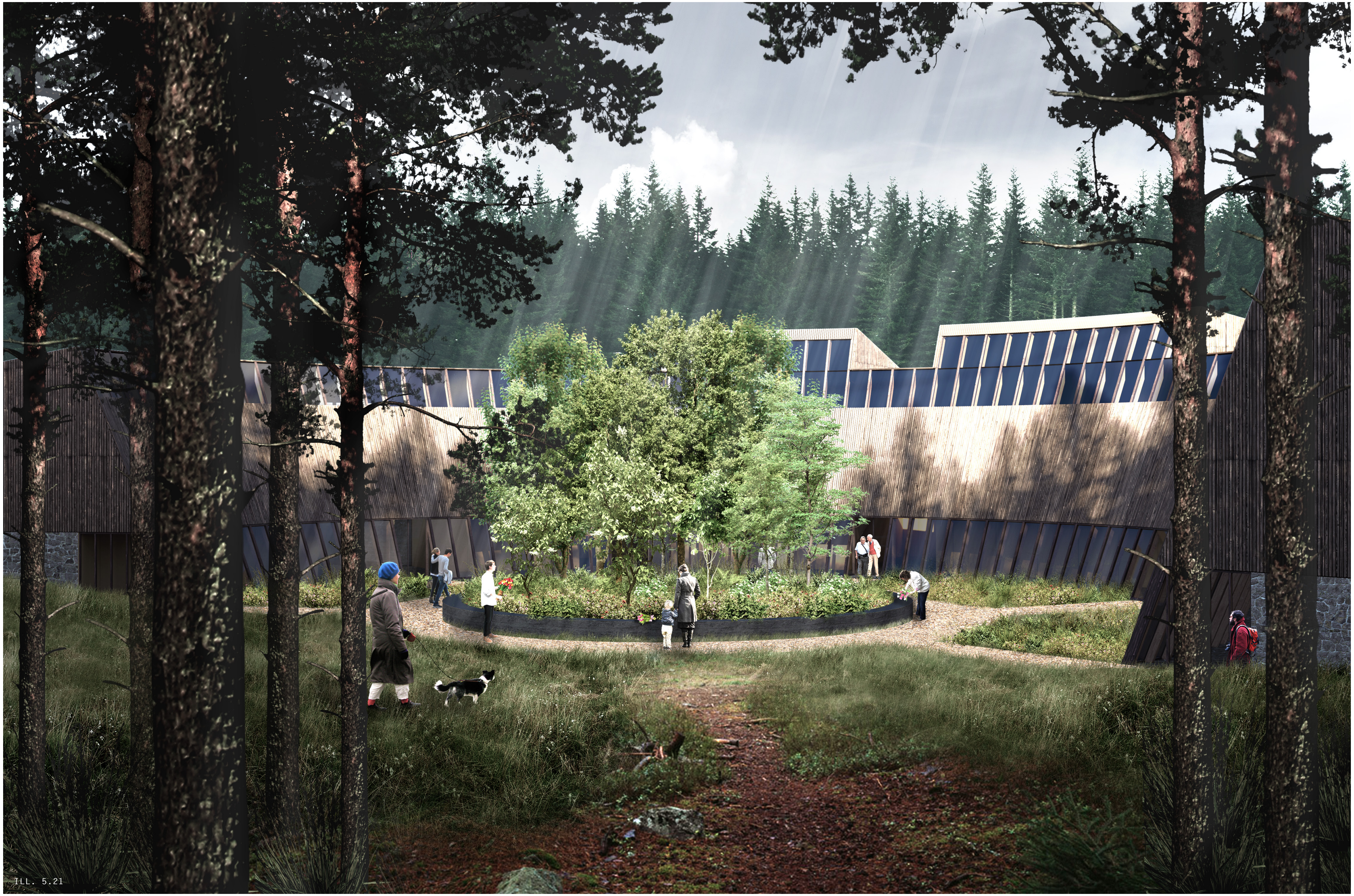
The Mourning Hall continues the circle of the building going underground via the stairs at each end of the main hallway. Down here there is a strongly emotional and dimly lit atmosphere evoking all senses: The visual sense through the high contrast in light and darkness and the water reflection on the ceiling; the olfactory sense noticing the water in the air; the haptic sense on the rough and inhomogeneous rammed earth material; and the auditory sense evoked by the water drops falling from the ceiling to break down the silence as well as symbolizing tears. The room is designed to bring out feelings, sad or happy, to compel the mourners to open up and face a loss - a safe space to address death. It is a place to cry, to scold, to talk, to grief, to think, to remember - a place for people, regardless of the stages of grief they are in.

The Mourning Hall is the room closest to the Decomposition Chamber for the visitors and seeks to create a space in between life and death for mourners to be close to the memory or spirit of their loved ones. To address the need for a specific place to visit without offering people a personal grave to mourn at, the Mourning Hall seeks to create a room in between the individual gravestone and shared memorial architecture.

The main corridor, which is a continuation of the main hallway, is the area lit the most. As one moves towards the chamber, a change in level with two steps down and a dense row of columns encloses another corridor with no direct lighting where people can stand privately and undisturbed to set out a candle on the water while another person is standing by one self to privately talk to the wall as a symbol of the deceased. In the water, candles or other messages can be send out towards the chamber wall, in this way allowing mourners to reach out for the bereaved even though the water physically separates them from the chamber and the dead.

Along the hallway in the Mourning Hall opposite of the chamber wall a shelf in the wall is made for people to leave flowers.

The materials in the mourning consist of rammed earth and concrete. The rammed earth is applied on both walls and floor, but in different finishes. The walls are raw and highly tactile rammed earth to symbolize the layers of soil given a feeling of being underground with the soil right on the other side of the wall. The floor is rammed earth with a smooth finish as a contrast to the walls - the man made versus the natural. The Decomposition Chamber is constructed of concrete with a wall revealed in the Mourning Hall, where the the concrete is left exposed to be honest and clearly stand out.



ILL. 5.21


ILL. 5.22

**Memorial Garden** // On the top of the Decomposition Chamber in the very center of the building, the Memorial Garden is placed acting as a symbolic gesture on what will become of those who are laid to rest in the Woodland House of Recomposition.

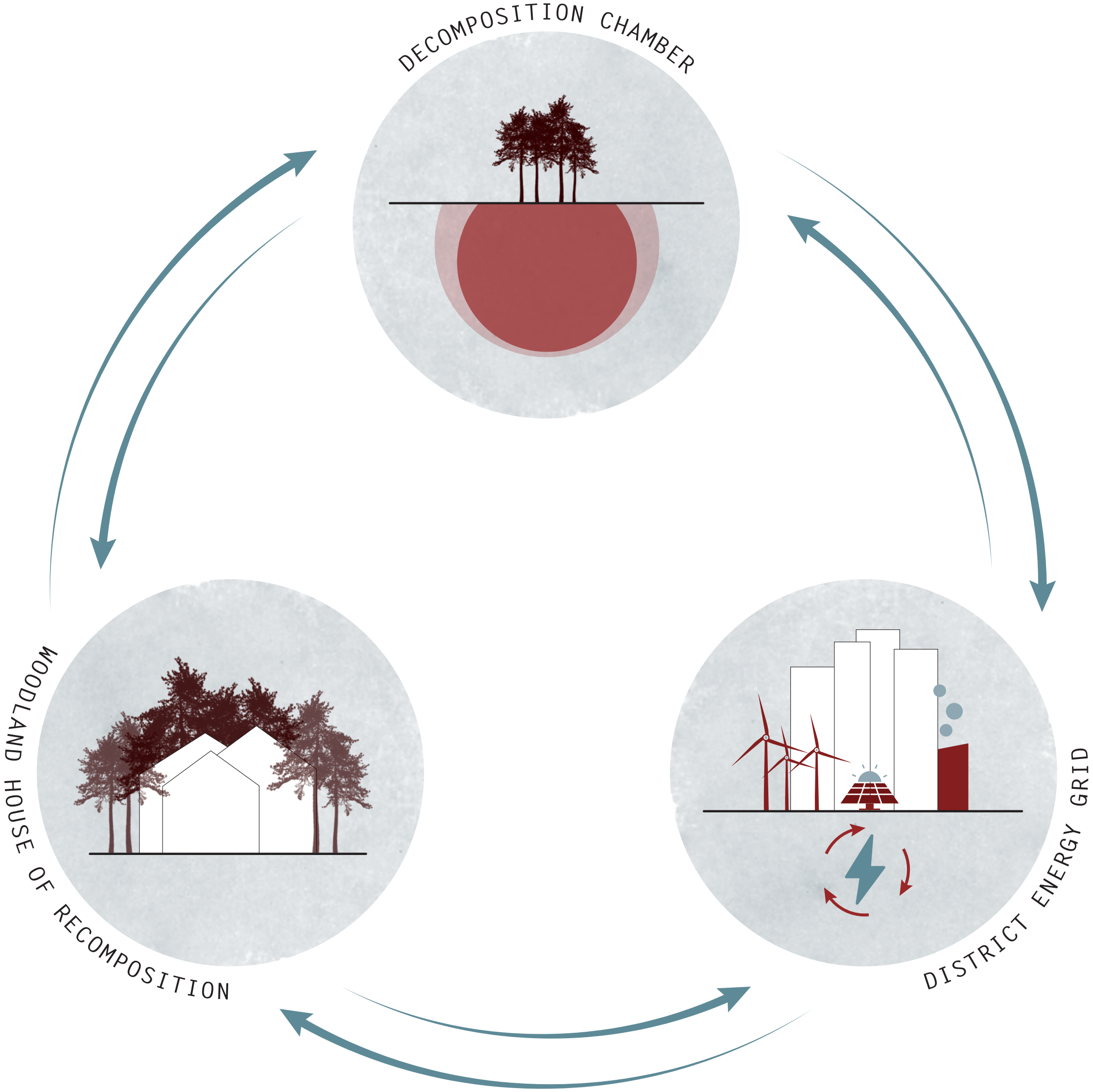
The garden consist of a varied range of trees and bushes in contrast to the homogeneous conifer forest of the Woodland Cemetery surrounding the building. From the warmth produced in the chamber and the compost from the same, the garden will stand lush and bright in the middle of the forest.

Around the central garden bed, a path is established from where smaller paths connects to the building and the interior main hallway. In between the smaller paths, nature grows wild with dense bushes and undergrowth against the path edges and the inner facade to further blur the line between building and nature. The large window areas of the hallway allows a view from inside to the garden at all times while the windows reflects the gardens trees and the sky when view upon from outside. Furthermore, the hallway facade is inclined to open up towards the garden and sky.

**Life Room** // When entering the building through the main entrance, all three chapels - honouring death - are placed to the left while the functions for life is placed to the right. Here in the end of the hallway, the Life Room is placed. The Life Room functions as a gathering room for groups to come and process a loss together. It is inspired by the principle of 'Livsrum' (Life room) by the Danish Cancer Society manifested in seven buildings around the country to provide support, counseling, and guidance.

The Life Room has a larger undisturbed window area facing the top of the tree of the forest to utilize nature in the healing process of a loss. Same as the chapels, the Life Room interior is cladded with wood slats but has wood flooring instead of the heavy claystone floor found in the chapels to separate the functions of death and life and to add warmth and softness to the atmosphere of the room.

**Counseling rooms** // In the gathering niche of the Life Room, two counseling rooms are placed undisturbed - each with a view to the forest. The counseling rooms are for the bereaved seeking guidance in connection with a recent death of a love one and in connection with the planning of the ceremonies. Therefore, the counseling rooms are placed closely to the offices so that the staff can easily and quickly be available for the needing. The small rooms cladded with wood offers a homely, safe, and intimate atmosphere for people in a difficult situation.


DECOMPOSITION CHAMBER
WOODLAND HOUSE OF RECOMPOSITION
DISTRICT ENERGY GRID

ILL. 5.23

Building energy consumption:
15.2 kWh/m$^2$ year

Danish Building Energy Standard 2020:
25 kWh/m$^2$ year

Required energy for heating:
14.7 kWh/m$^2$ year

Recovered heat energy from the chamber:
298 kWh/m$^2$ year

Recovered natural gas from the chamber:
111 kWh/m$^2$ year

Total excess energy sent to grid:
394.3 kWh/m$^2$ year

The building is designed to compose a circular energy flow with all functions and elements within the house contributing to and relying on each other in an effort to lower its energy consumption. Integrating passive strategies and a well designed indoor climate, the building has taken a step in the strategy defined towards being a Zero Energy Building. (see appendix 04 and 05 for indoor climate and energy - ventilation, BSim, and Be18 - calculations)

The LCA of decomposition process, found in appendix 02, has confirmed the presumption of interment by decomposition to be a environmentally better option in comparison to the crematorium benchmark as presented in chapter 02: not only is the carbon footprint significantly lower pr. interment, but both the energy consumption and greenhouse gas emissions is reduced with the decomposition process.

Additionally, the LCA has produced data on the large amount of continuously flowing energy from the decomposition chamber: The heat produced in the chamber as well as the heat recovered from the B.O.H. (morgue refrigeration cabinets, ventilation systems, etc.) will be utilized for heating the building during cold days and in that way reducing the energy consumption greatly.

The remaining heat created in the chamber by the decomposition process, will be sent to the grid as district heating to warm nearby houses. Likewise, the methane produced by the decomposition process, filtered from the flue gases, will be sold to local natural gas power plants. With both of these systems established, the Woodland House of Recomposition completes is Zero Energy Strategy: Reduce, Optimize, Produce, and Grid Balance as defined in Chapter 04.

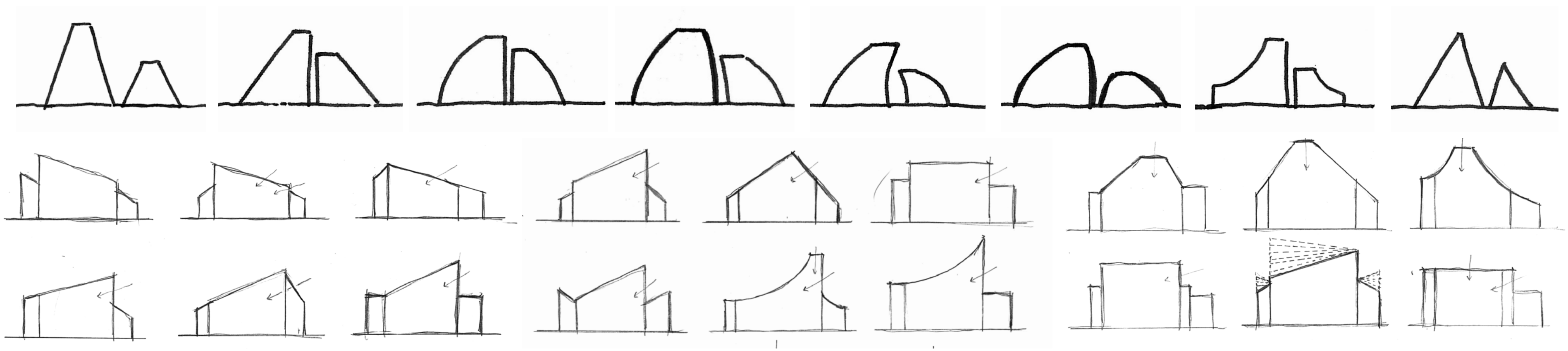
As a result the Woodland House of Recomposition has created the opportunity for contributing to both internal and external energy flows.

# 06

DESIGN PROCESS
SKETCHING PHASE

The sketching phase, the first phase of the design process, is presented in this chapter. The sketching phase is planned and illustrated in the workshops that has taken place: from the Layout Workshop, the Ritual Workshop, and the Light & Acoustics Workshop.

# SKETCHING PHASE



ILL. 6.1

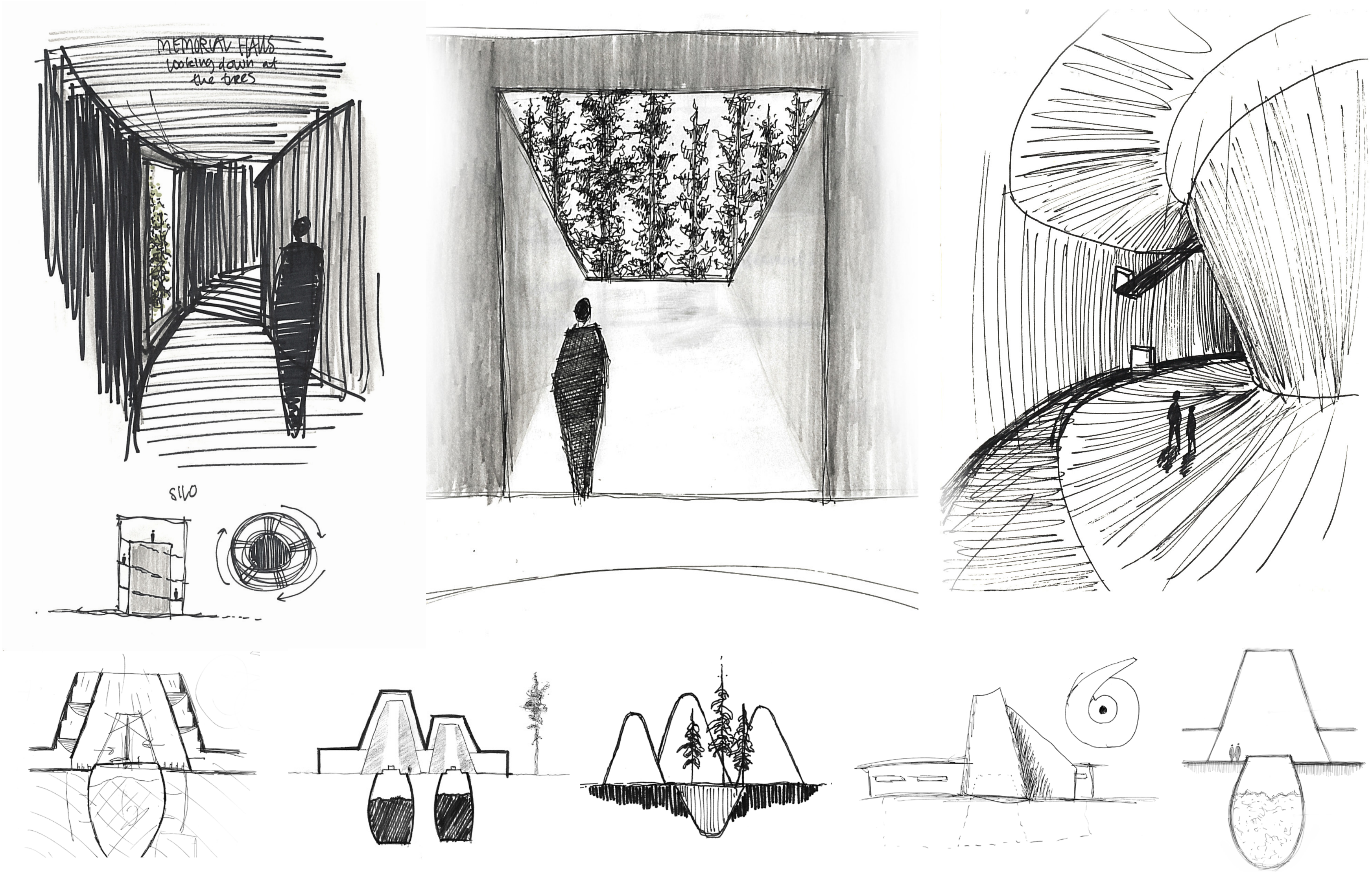
The sketching phase is structured in three workshops to catalyze the design phase from start and guide it throughout an often chaotic, iterative process which especially is the case for the sketching phase.

The sketching phase starts with the plan layout workshop - workshop 01 - focusing on the flow and room program of the building and especially how the front of house and back of house can work together aesthetically, logistically, narratively, and technically.

Workshop 02 is concentrated around the ceremonial aspects and functions of the building. Sketches of the memorial garden, the memorial halls, the transition of the deceased, as well as how to physically and spiritually mourn have been made. Here, there has been a strong focus on the smaller, human scale with the bereaved and the visitors strongly in mind. Both logistics as well as aesthetics, senses, and atmosphere has been guiding this workshop.

Workshop 03 concerns light and acoustic analyses. Though these are two very different aspects, they both affects and interference with each other and must equally shape the building volume. The acoustic analyses have been made as ray tracing in Grasshopper and the light studies have been made on the basis of sun angle throughout the year - both as quantitative analyses. These are made much more detailed and qualitative in the synthesis phase - Workshop 03, part 02.

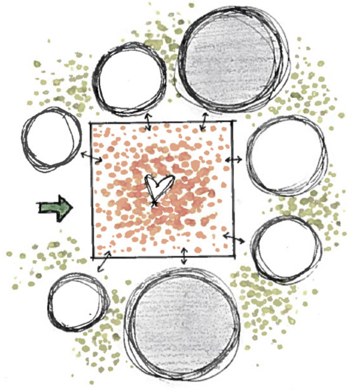
The three workshops may have started chronologically one after another but have with time overlapped each other when iterations were made and new knowledge were gained throughout the design process. In this way interacting with each other as well as guiding each other towards more a holistic design.




ILL. 6.2-6.9

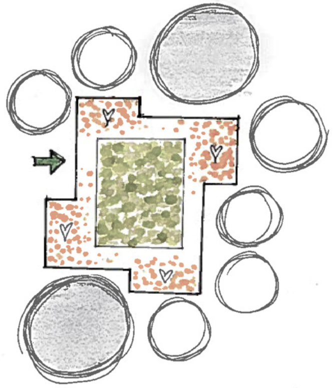
## WORKSHOP 01

PLAN LAYOUT



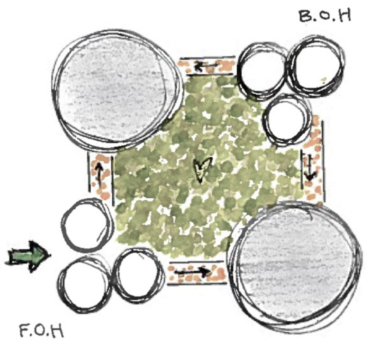
LAYOUT CONCEPT 01

THE CENTRAL
one common room



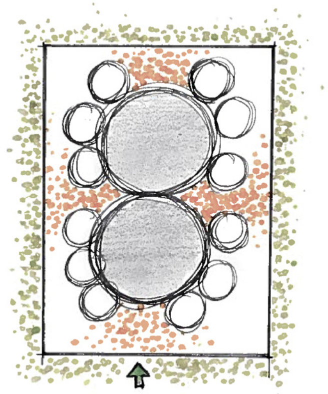
LAYOUT CONCEPT 02

THE COURTYARD
common halls + common niches




LAYOUT CONCEPT 03

THE DECENTRAL
clusters + corridors



LAYOUT CONCEPT 04

THE INNER CORE
centralized rooms + outer skin

### WORKSHOP 01

In the beginning of Workshop 01, four plan layout concepts were formed and categorised on the basis of earlier sketches and iterations. The four concepts aimed to set the foundations, guidelines, and starting point for a focused sketching workshop integrating strong aspects while still providing freedom and variation within the many plan iterations.

After several iterations upon the four concepts, the iterations started merging with the various possibilities and strengths found in them each and thereby creating new and more holistic designs. The plan layout workshop continued alongside the other workshops in the sketching phase up until midterm exam where a final plan concept was selected.

### CONCEPTS

The four concepts are, as seen above: The Central, The Courtyard, The Decentral, and The Inner Core.

The central has one central common room from where other functions all connects to and are distributed from. Thereby, it creates a clear heart of the building, though it may ignore a need of niches and semi-private areas for bereaved people to feel safe in a troubled situation.

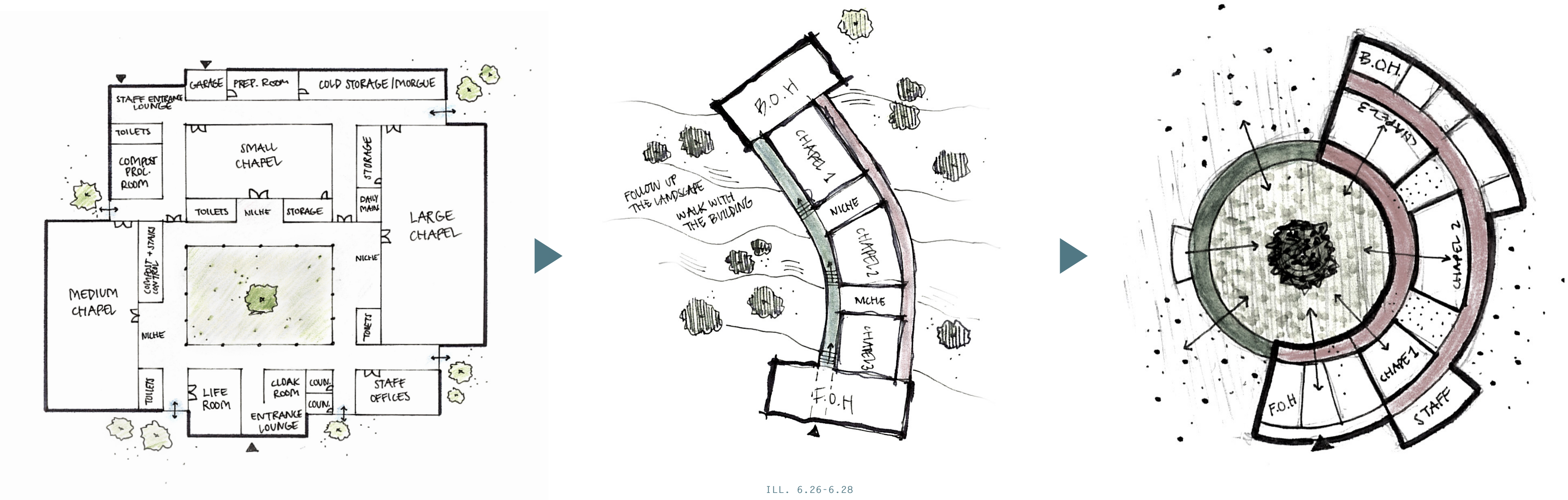
The latter is the base of The Courtyard concept, focusing on the many and smaller common areas creating semi-private niches for the different visitor groups inspired by the plan of Utzon Center. Here nature can be the heart of the building - a common shared courtyard to look towards.

The Courtyard concept is in The Decentral concept taken even further in a wish to create smaller building volumes nestled in nature rather than one large building. Here the four clusters are connected with outdoor corridors activating the visitors both in the building and in nature while minimizing heated area.

The activating hallway creating a flow around the building is also the case of the last concept, The Inner Core. Rather than placing an open space for people to gather in the center, the functions of the building is bundled in the heart of the building - thereby letting people walk around the functions with nature opposite at any time.

01 02 03 04


ILL. 6.10-6.25



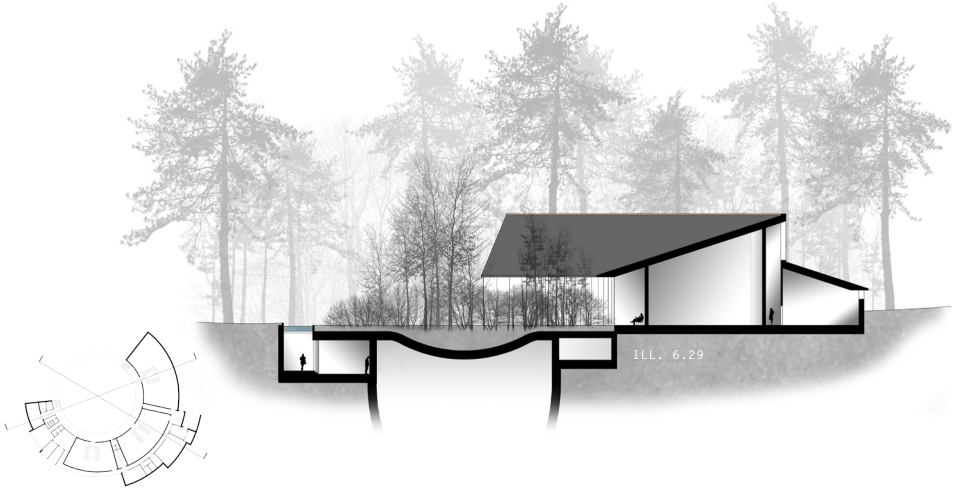

ILL. 6.26-6.28

## NEW CONCEPT // MIDTERM EXAM

Up until the midterm exam, the concept development and plan layout continued in many directions since no concept had been created to satisfaction. The plan layout developed more and more back in the direction of the concept of The Courtyard which from the beginning focused on the niches besides the chapels. At this point, the building included a small, medium, and large chapel instead of one main or two chapels as was the case of earlier iterations. The three chapels created a reference to the old Woodland Crematorium by Gunnar Asplund next to the buildings site with its three chapels: Faith, Hope, and the Holy Cross - the trinity.

The iterations designed close to the midterm exam all ended up being too much of a compressed building, lying too heavily and closed off in the boreal landscape. In an effort to open up and stretch the building along the landscape, a new concept emerged: from a square, compact building, a curved and centric building arose as seen illustrated above.

This new concept kept the nature as a main role in the centered courtyard while managing to open both the building and courtyard towards nature. The flow around a courtyard seen from earlier iterations and interior logistics found its balance in the circle - half of it inside in the hallways and half of it continuing outside around the central garden. A concept solving and integrating all the important elements set earlier while at the same time opening of for new ways of seeing the design and flexible enough for allowing changes along the way.



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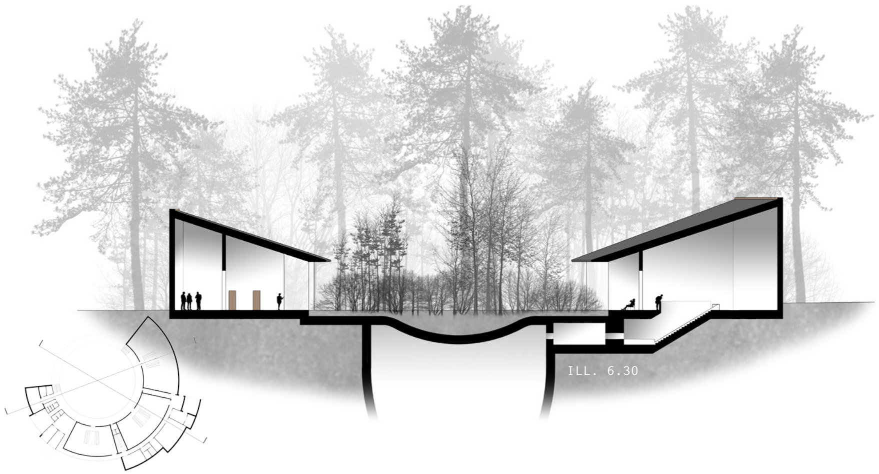

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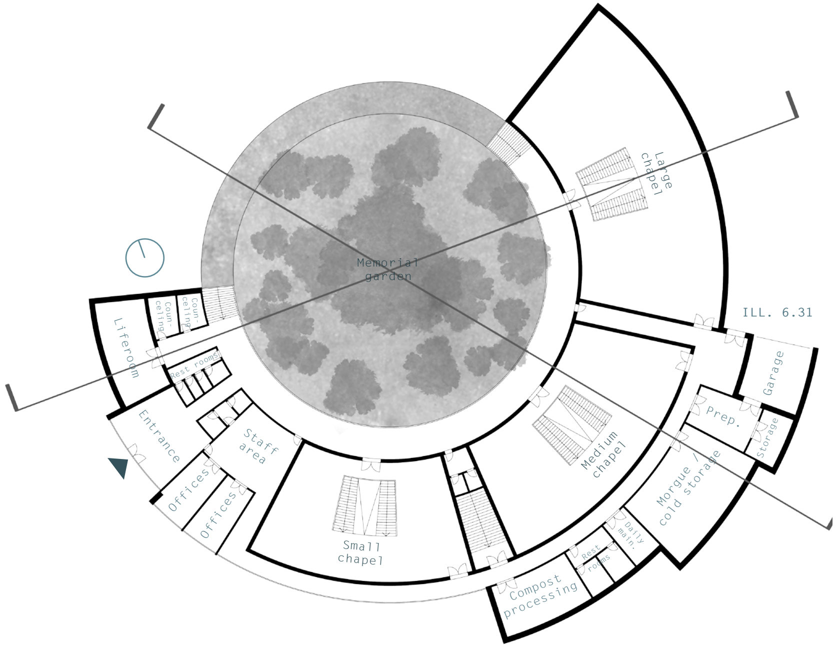


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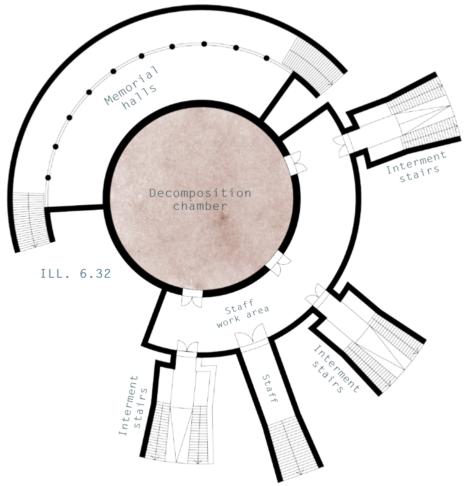


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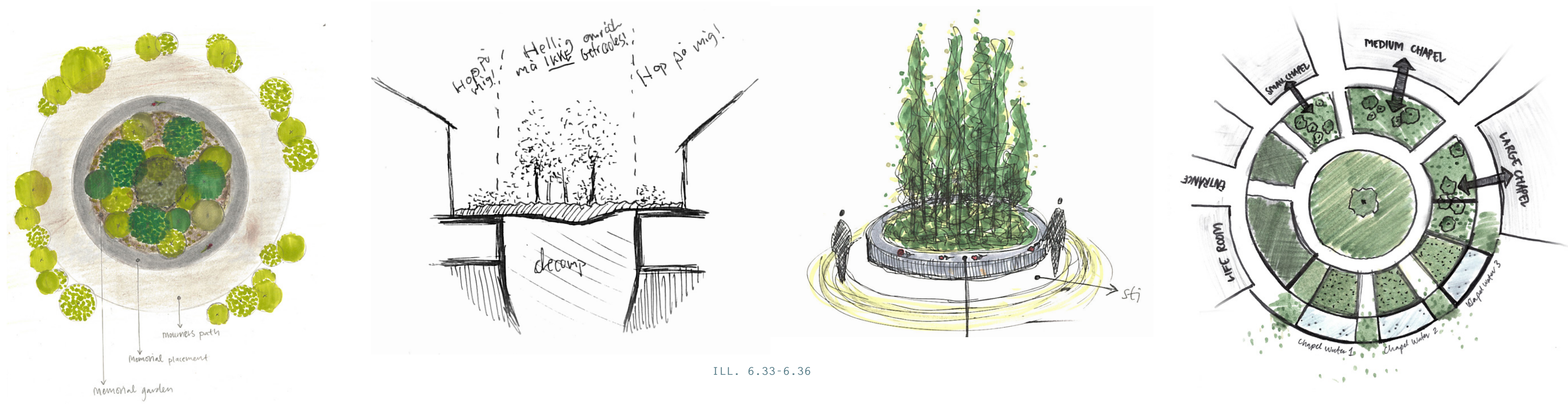



ILL. 6.33-6.36

## WORKSHOP 02

The aim of Workshop 02 is to integrate rituals and the ceremonial aspect affiliated with interment, death, and mourning into the building. Besides a need for these ceremonial aspects to be integrated in the overall architectural design, a special focus in this workshop is on the memorial garden, the mourning hall, and the chapels.

Elements such as light, darkness, materials, details, water, etc. is thought of in the sketches of the functions above and to the right. Furthermore, contrast between these functions must be great to create a strong, specific sensation and address a certain feeling - be it sad, uplifting, divine, or healing.

## MEMORIAL GARDEN

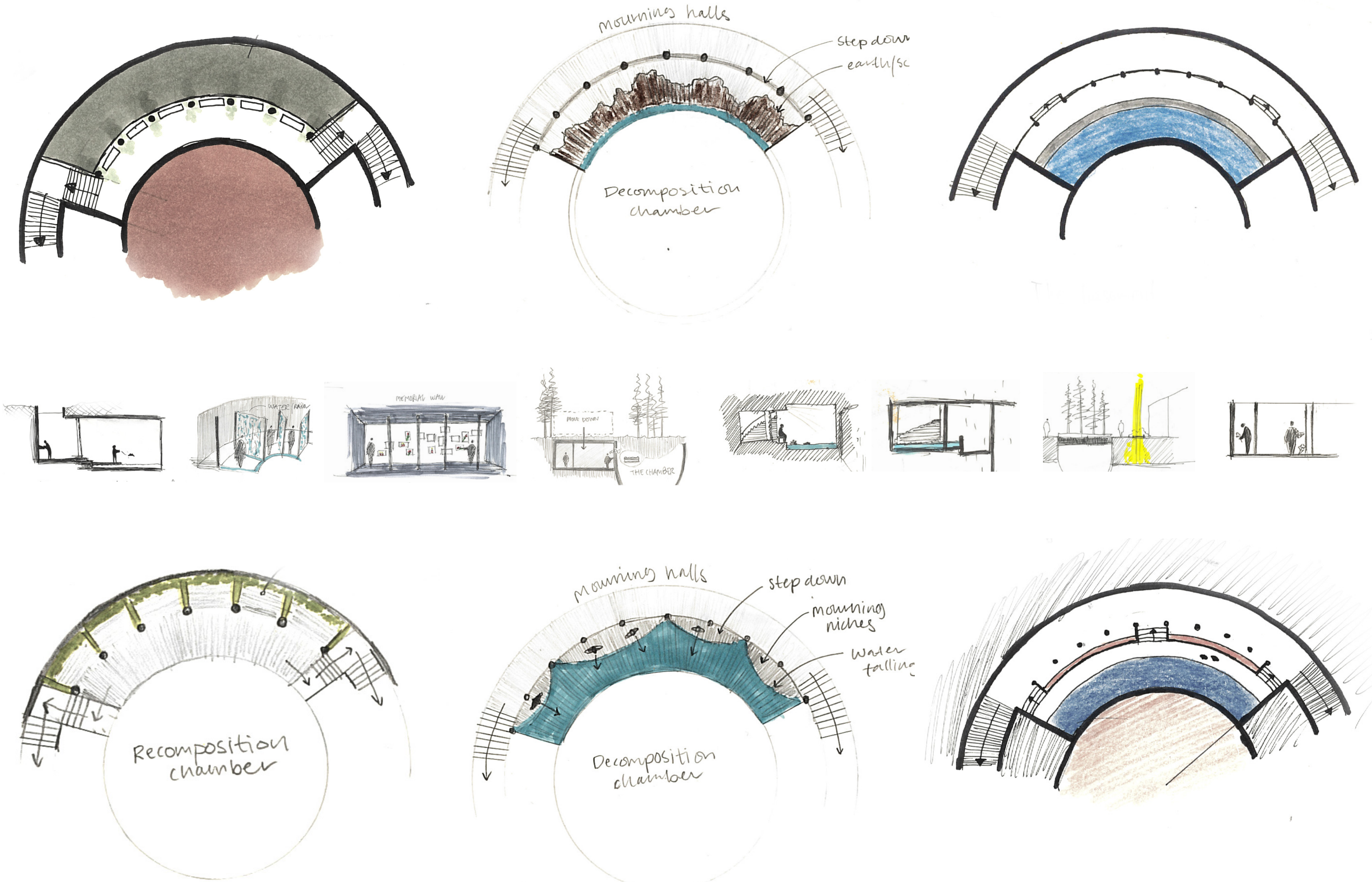
The memorial garden is the heart of the building and a place for all visitors to walk in and enjoy - regardless of target group. It seeks to be a wild garden yet still different from the forest next to by being more versatile and lush. The memorial garden is the symbol of the people who has chosen to be composted and thereby returning to earth and nature. Therefore, the decomposition chamber is placed right under the garden as if the garden was growing from the chamber - nurtured by our loved ones.

The memorial garden could also be a place for the flowers brought for a interment to be placed afterwards. In this way showing and honoring the deceased in the days after the last ceremonial farewell.

## MOURNING HALL

As a contrast to the outside, light memorial garden connected to nature, the mourning hall is placed under ground in close connection to the decomposition chamber - or figuratively: to death. The mourning hall should be dark, calm, divine, and emotional with elements such as water and candles to create a strong atmosphere. From here, people can come to privately mourn a lost loved one by setting out a lighted candle or talking to the deceased.

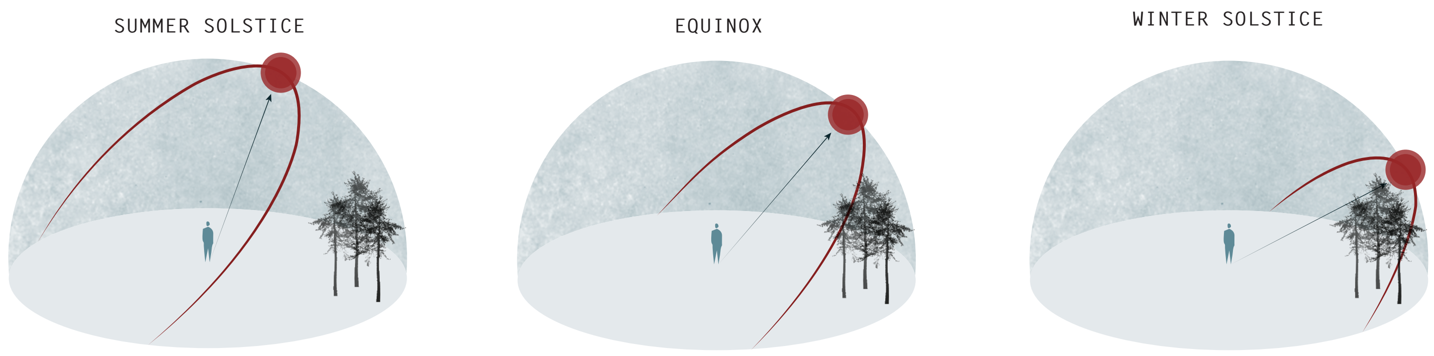
The mourning hall is placed along the decomposition chamber underground with the entrance along the stairs from the internal hallway of the building. The hallway on ground level and the mourning hall underground forms together the circle of the building.


mourning halls
Decomposition chamber
THE CHAMBER
Recomposition chamber
mourning halls
step down
mourning niches
Decomposition chamber

ILL. 6.37-50

# WORKSHOP 03

ACOUSTICS & LIGHT - PART 01




ILL. 6.51

## WORKSHOP 03

The semicircular plan layout itself is a strong principle and the building volume must compliment it.

A simple cross section, swept along the plan, can not only promote the narrative of the 'circle' but also allow for flexibility and adjustment to a hierarchy between the various functions of the building. Of this hierarchy, the three chapels are the main functions in direct use by the visitors of the site and also the one most sensitive to the design of light and acoustics.

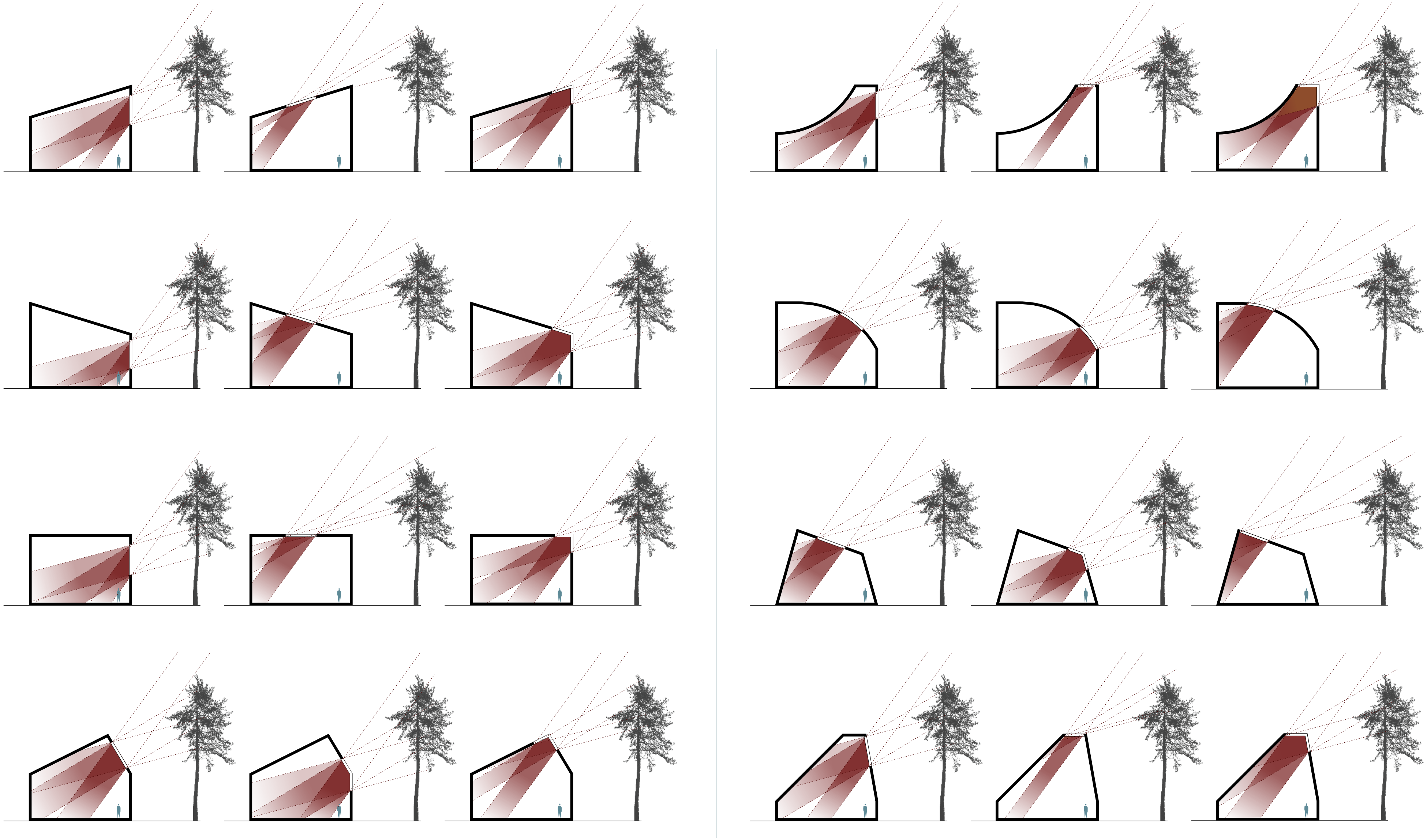
In this workshop, various cross section is tried for acoustic potential and the role of daylight as a narrative element as well as an continuous evaluation of the spatial perception.

## LIGHT STUDIES

The chapels of the building must be perceived as the most sacred and spiritual rooms - this is to be created mainly by light. For this project a focus will be on the daylight in a wish to create a narrative towards nature. By using the daylight as a symbol from above, a divine atmosphere can be achieved by playing with contrasts of darkness and light as a guiding element for the chapels. Daylight as a symbol seeks to connect with bereaved, atheists as well as religious people, by allowing them to interpret the light in their own spiritual, non-religious, or religious way.

Therefore, light studies have been made to get an understanding of the light setting in the chapels in relation to the placement of a speaker, the bereaved, and the deceased. Light rays for the winter solstice, equinox, and summer solstice for Stockholm has been added to all the iterations to get an understanding of the light input throughout the year. The different llight settings from summer to winter allows for some iterations to have a much varying light during the year, giving visitors different perceptions affiliated to the specific time of the year. On the other hand, other iterations focus the light towards the same area regardless of seasons.

An important challenge for this workshop is to ensure a divine and illuminated interment atmosphere regardless of it being a winter day or summer day.



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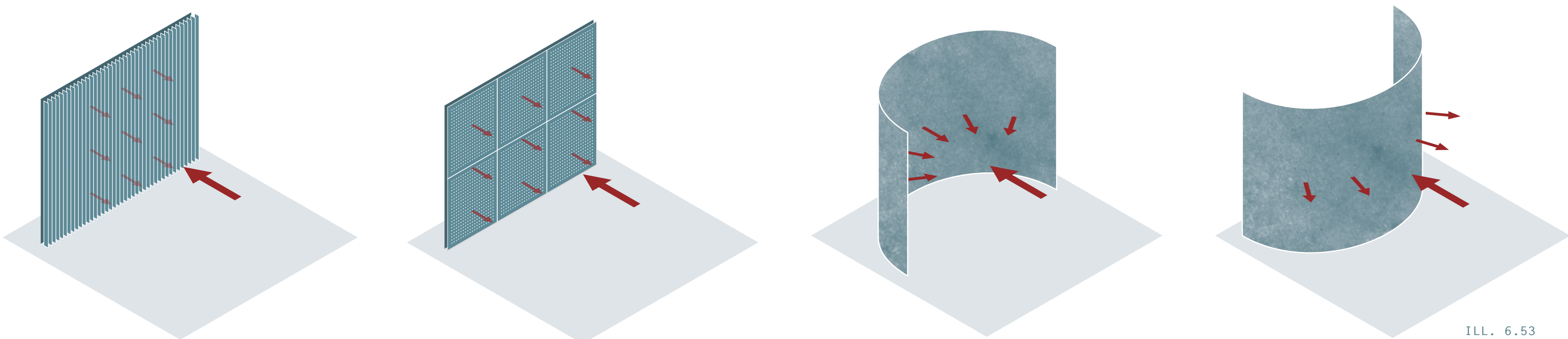


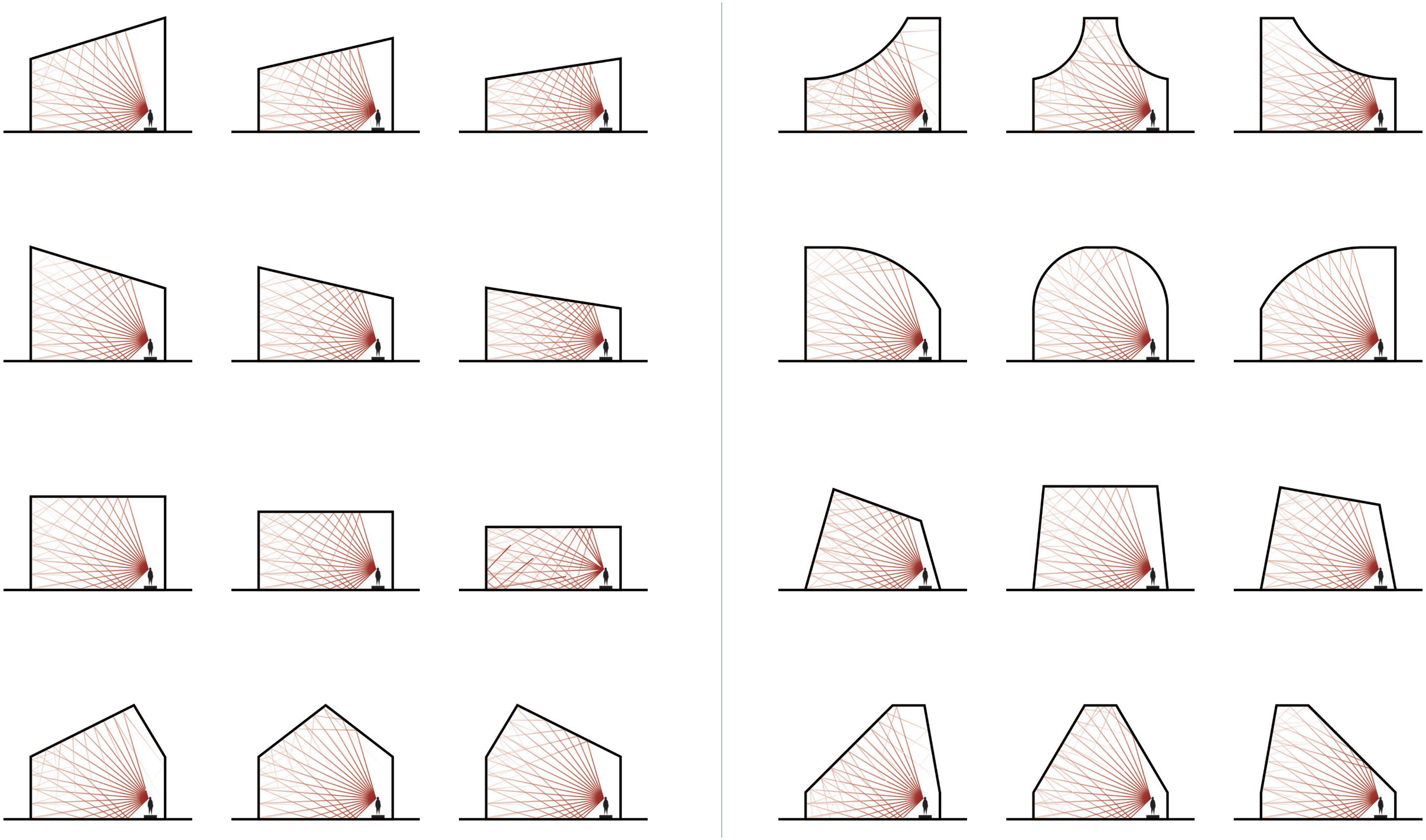
ILL. 6.53

## ACOUSTICS

While the chapels in the building will not have a built-in organ as in christian churches, we do expect people to want to sing and listen to music as part of the interment rituals. This creates a challenge for designing the acoustics, as the optimal room shape and surface materials for music is very different from those of speech. There are many examples of such 'multi-function' auditoriums which suit both theatre and concerts but more often than not they solve this by finding a middle ground and compromise.

Designing acoustics has two levels: shape and materials. The shape of a room has a considerable role in the reverberation of the sound and thereby also the intelligibility of speech. Furthermore, the shape of the room is also responsible for distributing the sound evenly so that everyone will receive the same sound characteristics. The surface materials, on the other hand, has the potential to be more or less absorbent or reflective as well as a potential to scatter the sound to further distribute it evenly throughout the room. In this sense, you can often design the materials to address the limits of the room shape.

The music expected to fill the chapels are neither particularly loud or a central part of the rituals, as we deem the speeches and preachings to be more important for the acoustics. In this regard, We have a greater opportunity to focus more on one sound profile. Therefore, in this first part of the workshop, only the shape of the cross section was analyzed with ray tracing to create for us a sense of the rooms potential and its ability to distribute the speech evenly. As a result, there is a tendency of the acoustics to fit better in a smaller room size as well as either the flat ceiling or the outwards tilted ceiling (row 3 and 2 on the left, respectively).

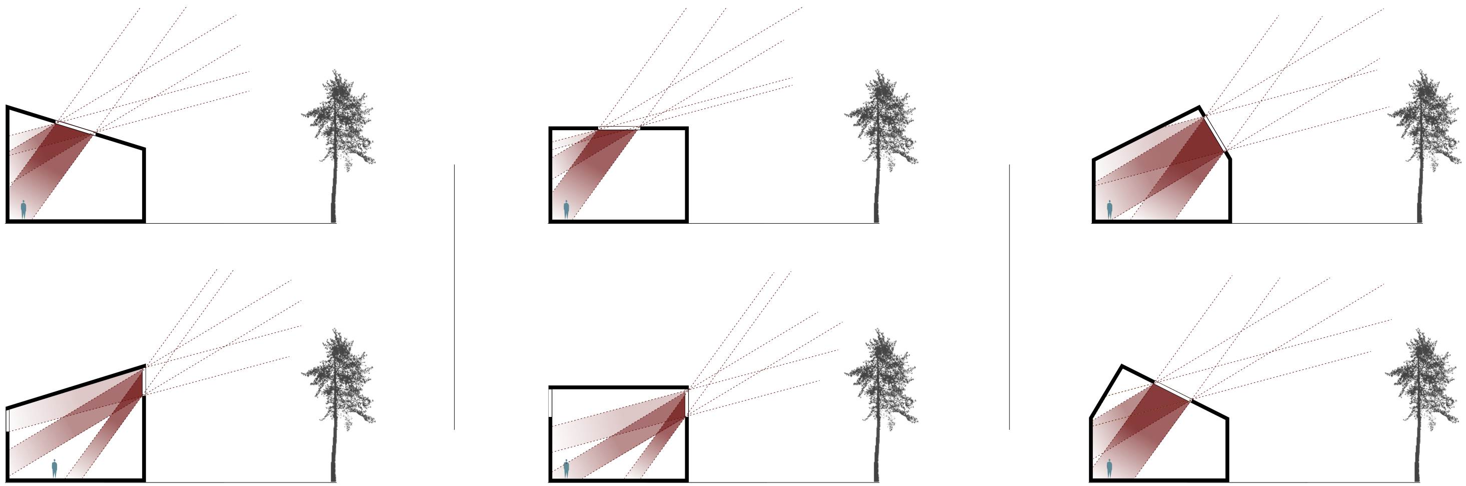


ILL. 6.54

# 07

DESIGN PROCESS
SYNTHESIS PHASE

A concept and a *flip* was the stepping stone into the synthesis phase. As the previous chapter this chapter is planned and illustrated in its workshops. Workshops such as Light & Acoustics (Part 2), Materials, Energy & Indoor Climate and a Detailing.



ILL. 7.1

## FLIP IT

The synthesis phase starts from the design concept presented at the midterm exam. After many iterations of the plan layout, the 'flipping' point for the final overall plan concept was the mirroring of the plan. This allowing more sunlight to enter the building in general and especially the hallways allowing to utilize the sunlight for passive heating. While the original building plan before 'the flip' followed the slow incline of the landscape several more pros besides the daylight and passive heat were to be found for the mirrored building plan: The building now shields the memorial garden from the road to the North, the building respects and preserve the existing forest path along the South side of the site, the memorial garden gets more framed within the landscape, and the staff offices now have view towards and light from North.

The synthesis phase, like the sketching phase, is structured in workshops. For the synthesis phase, these workshops are as following: Workshop 03 part two, Workshop 04, Workshop 05, and Workshop 06.

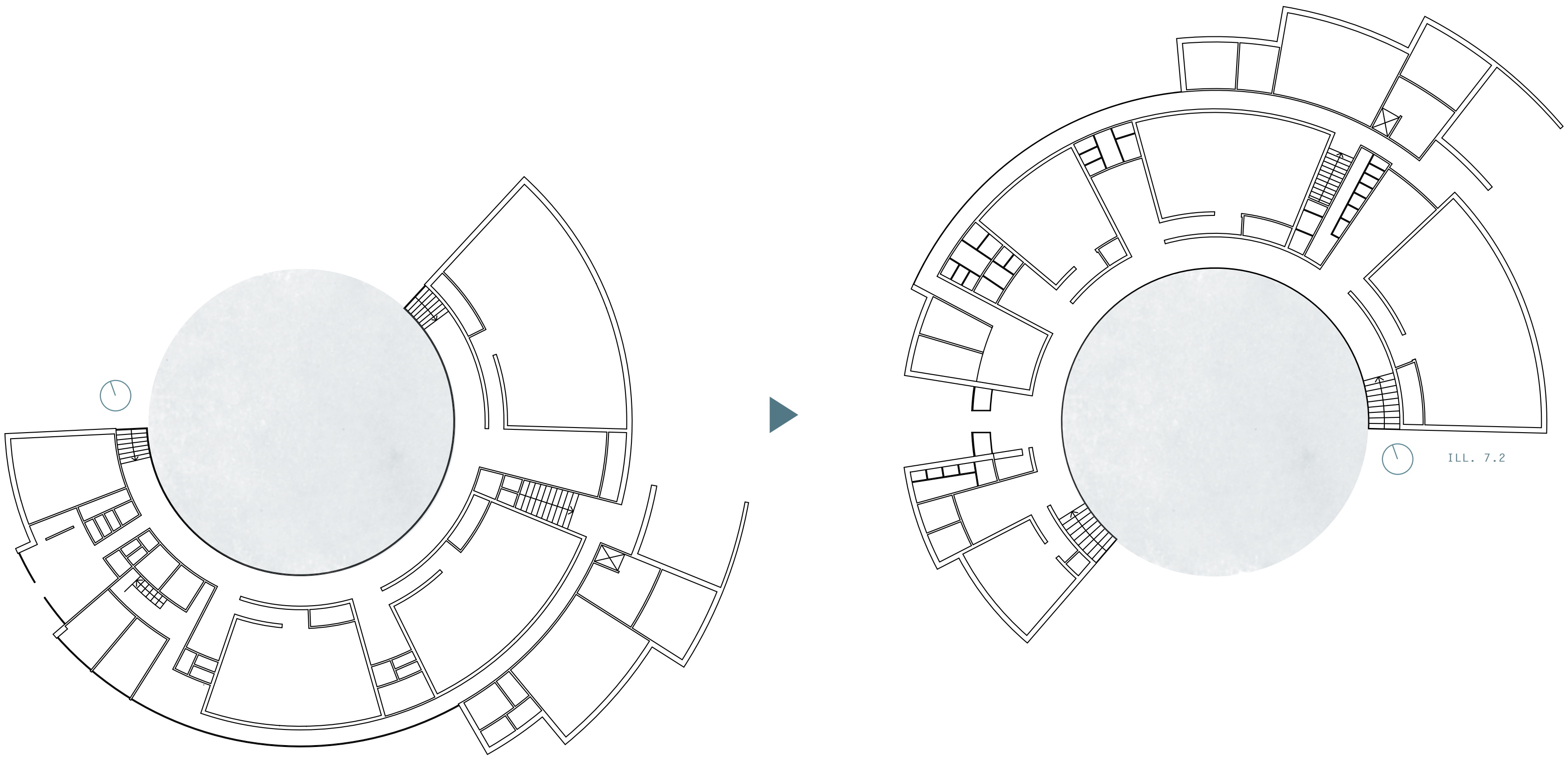
Workshop 03 part two continues the many analyses of light and acoustics, now making them more qualitative and detailed. Analyses and simple studies mainly in section and plan evolves into simulations and renders of 3D building volumes. The workshop focus mainly on the chapels with a goal of creating a divine atmosphere by utilizing daylight.

Workshop 04 investigates the possibilities of materials in general from local materials to waste materials and upcycled material. Further, the workshop looks into specific material choices for the different building elements. Combinations of materials on the exterior and interior are made as well.

Workshop 05 concerns energy strategy and indoor climate. Here the building design is built in BSim to analyse critical thermal zones. In this way using BSim in the iterative and holistic process of creating an acceptable and balanced indoor climate. Furthermore, the LCA process is presented - an analysis made upon the decomposition process itself to investigate whether this process in fact is sustainable and better in comparison with cremation.

Workshop 06 looks into the detailing of different aspects of the building design. That means, detailed sketches and models of the construction as well as of the plinth of where the deceased lays upon during the ceremony.

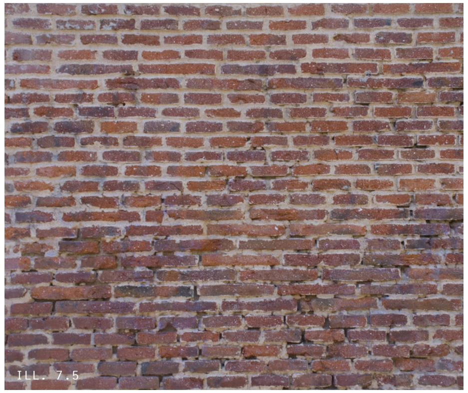
Along with all the workshops, the overall design has been designed, adapted, modified, and grown in a holistic and very much iterative process. Here the workshops, as seen in the sketching phase, has overlapped and benefited from each other in many ways.



ILL. 7.2


FALU RED WOOD


STONE




BRICK

## WORKSHOP 04

The material workshop seeks to widen the perspective and knowledge of materials in an effort to go beyond typically non-sustainable materials such as reinforced concrete. While looking towards innovative materials, a need for understanding the local traditions of materials is vital as well and a balance between these must be maintained. The tactile characteristics as well as a sustainable, life-cycle perspective is a focus of the selected materials from facade cladding, interior materials, floor materials, to materials for the decomposition chamber.

## LOCAL, SUSTAINABLE MATERIALS

Using local materials is a key part of addressing sustainable buildings in an effort to lower emission, connected to transport. Here, local and vernacular materials in Stockholm is investigated. Stockholm is - as most of Sweden's cities - surrounded by forests and mountains, so it was a natural choice that most early architecture was made of timber and stone. The towns would grow from locally sourced wood, typically with a stone foundation and with wood board cladding. Stone, however, was difficult to manipulate so it was more often used for castles and fortresses, which demanded a stronger material than timber (Visit Stockholm, 2016). At some point in the 1700s, many people were looking for a durable paint to extend the lifespan of their timber houses. The traditional Falu Red colour of the Swedish townscape was from this period and made from a by-product of the copper mining in the town of Falun (Bade, 2017). It was only later in the industrialization period that Sweden also joined in the effort to introduce bricks and concrete - both of which could be sourced somewhat locally in Stokhholm's outer suburbs (National Heritage Board, 2013).


EEL GRASS WASTE TO FACADE OR INSULATION

STRAW WASTE TO BUILDING BOARD

OLD CONCRETE TO NEW CONCRETE MATERIAL

OLD WINDOW FRAMES TO UPCYCLED WOOD PANELS

PLASTIC BOTTLES TO ACOUSTIC FELT MATERIAL

OLD DENIM MATERIAL TO INSULATION

## UPCYCLING AND WASTE MATERIALS

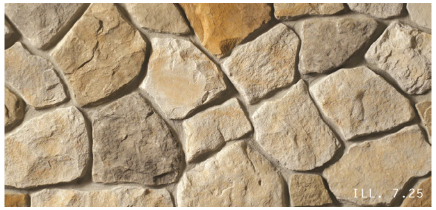
In the effort to create a sustainable, regenerative building, waste materials and upcycled materials have been investigated. This to be able to regenerate what we already have that are more or less carelessly produced to use it in new ways through the new architecture we create.

As an example in Danish context: *"In Denmark alone approximately 2,8 mio. tonnes of waste straw from the wheat production is produced. New technology can process these waste materials transforming them into valuable resources in the form of ecological building materials. Thereby, large amounts of carbon can be embodied in buildings, saving the environment from emission of CO2."* (Miljøstyrelsen, 2017)

The investigated material in this workshop are not limited to only waste materials from the building sector but also from others such as the agriculture sector: Here, waste materials from e.g. the tomato production, eel grass production, and straw production can be made into new building materials such as plywood boards and insolation. Furthermore, these waste materials - straw, tomato stems, sawdust, etc. - can be utilized for the decomposition process in the Decomposition House, where there is a need for extra carbon dioxide-rich material when decomposing a dead body - in this way downcycling or reusing the waste materials already produced. (Miljøstyrelsen, 2017)

From the building industry, concrete can be demolished, crushed and reused as gravel in new concrete, bricks can be reused as single bricks or larger cut-outs, and old window frames can be disassembled and upcycled into an interior wood panel wall as seen above.


ILL. 7.24


ILL. 7.25


ILL. 7.26


ILL. 7.27


ILL. 7.28


ILL. 7.29


ILL. 7.30


ILL. 7.31


ILL. 7.32

## FACADE

For the facade materials, Kebony Wood, local stones, and slate shingles from Comproment has been investigated. The technology of Kebony Wood is developed in Norway by processing the local non-durable softwood to give it long-lasting and robust properties of hardwood. This process is done without chemicals using the bi-product from the sugarcane production as natural impregnation and in that way saturating the wood. (Kebony Wood, 2018). Natural slate could give a historical reference and has sustainable properties such as low CO2 emission, easy disassembly, and low maintenance.

## INTERIOR WALLS

The interior walls has been investigated for materials that can express local, nordic building traditions and create a change in atmosphere between outside and inside. Here, birch wood panels and upcycled wood slats can provide the association to the timber structure within as well as the change from the harder materials in the basement to the lighter and warmer materials at ground level. Stone has equally been considered for its expression of strength, solidity, and durability - both physically and as a narrative element.

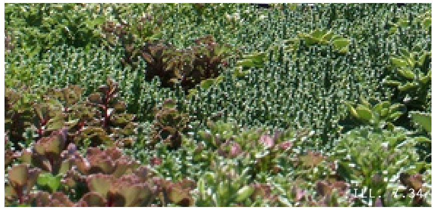
## CONSTRUCTION

Designing for disassembly has been in mind when investigating solutions for the construction of the building. With a wooden structure, the assembly and disassembly could be managed quite easily and even more so by choosing a post-and-beam system. However, with little thermal mass in a skeleton system, CLT might be a better choice. Lastly, rammed earth was considered for its indoor climate properties, thermal mass, and aesthetics but it may be a challenge with the wet and humed Swedish climate.

# WORKSHOP 04

MATERIALS

ILL. 7.33



ILL. 7.34

ILL. 7.35

## ROOF

For the roof, a material with high durability for the Swedish weather and a possibility of being used in a low incline is prefered. From local traditional architecture, slate is an obvious choice for its long lifespan and easy disassembly. A green roof may address the high amount of precipitation as well as generate a small amount of oxygen. Furthermore, green roofs can create an association to traditional grass-covered huts. Lastly, thatched roof also provides for a great insulator but requires a steep angled roof.

ILL. 7.36

ILL. 7.37

ILL. 7.38

## FLOOR

To create a perception of a robust, heavy, and earthbound floor, clay brick and stone has been looked upon as floor material. The stone as a reference to the uncontrolled nature and the local historical architecture. In contrast the unburned clay bricks can provide a simple, controlled, and calm expression, a heavy expression as a contrast to eg. a wooden inner cladding. On the other hand, a wooden floor may provide a warmer atmosphere and better acoustic properties.

ILL. 7.39

ILL. 7.40

ILL. 7.41

## PAVEMENT

For the outside pavement, a material with clear connection to nature and easy accessibility is prefered. A stone pavement might further express the difference between ground and building and the blurred line between nature and the built environment. These properties can also be applied to gravel as well as an association to traditional cemetery pavement. However, gravel will not work well with wheelchairs and stretchers. A wooden plank floor will be a less durable choice but can create a stronger connection to the building and even a seamless transition from terrain to facade.


ILL. 7.42


ILL. 7.43


ILL. 7.44

## INSULATION

Eelgrass and wood fibre has been chosen as possible solutions for sustainable and non-toxic insulation materials. Eelgrass is naturally fire resistant due to the high concentration of salt while the wood fibre insulation is treated with biological fire resistant material keeping it as a C2C-certified product (KKS Wood Fibre, 2017).

To find a sustainable rigid insulation material for the foundation of the building, much research has been conducted to finally find a product by Foamglas who upcycles old glass into cellular glass blocks (Foamglas, 2018).


ILL. 7.45


ILL. 7.46


ILL. 7.47

## CHAMBER

For the basement, mainly concrete have been considered as the structure, as other materials do not have the structural properties to match. However, for the decomposition chamber, a steel shell might be more sustainable as it requires less material. In the mourning hall and the transfer hall - both placed in the basement - a more ceremonial and clean material is prefered that, too, will express the heaviness of the basement and its connection to the decomposition chamber. Here, a smooth stone such as locally sourced granite or slate has been investigated.

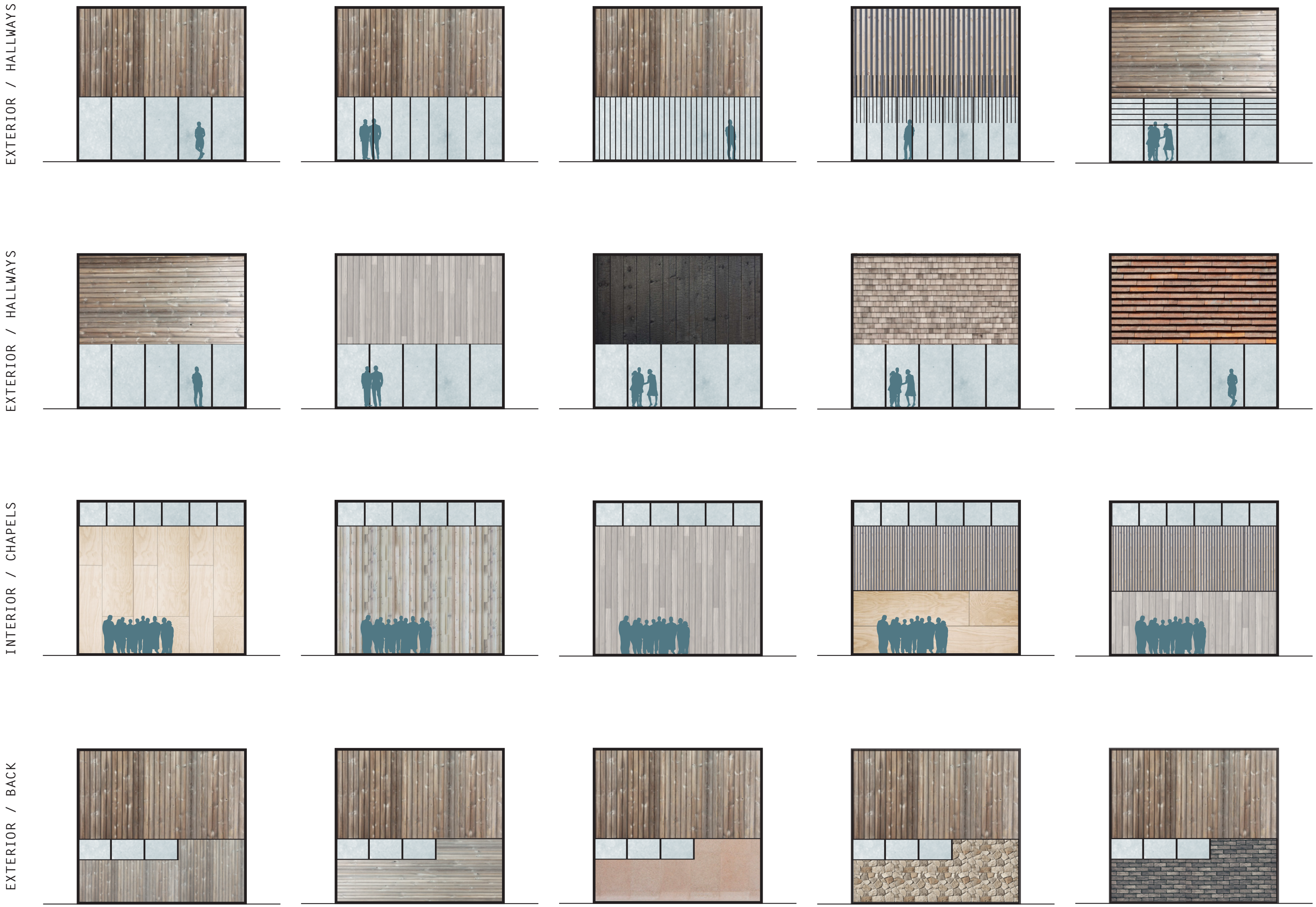

ILL. 7.48


ILL. 7.49

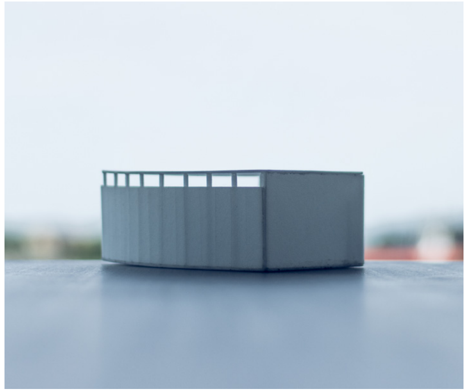

ILL. 7.50

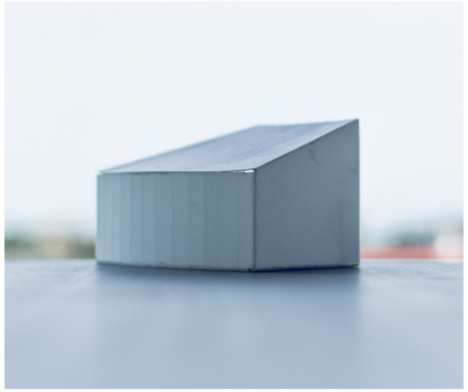
## COMPOST MATERIAL

For the decomposition process, organic and biodegradable materials rich on carbon dioxide is needed. These materials should preferably be bi-products or waste materials to avoid choosing materials that will be produced specifically for this purpose, since these material are to have a short lifespan and needed in large amounts for every interment. Bi-products such as tomato stems, straw, and eelgrass are all waste materials that the agriculture sector has too much of without an optimal solution for utilizing it.


EXTERIOR / HALLWAYS
EXTERIOR / HALLWAYS
INTERIOR / CHAPELS
EXTERIOR / BACK

ILL. 7.51





ILL. 7.52-7.54

## ACOUSTIC STUDIES - PART TWO

Based on the previous ray tracing, four iterations was chosen to thoroughly analyse as they showed good results as well as potential for approaching the desired spatial and visual perception. The acoustic analysis was first made on the simplest of the four - the flat ceiling - to find a set of materials to apply to all iterations: The ceiling was analysed as wood wool panels, the walls perforated plywood, and the floor as bricks (the bricks was a part of the concept at the time and thought to persist as a material through all iterations). The analysis was based on the size of the large chapel.

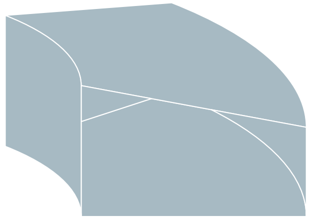
The numbers by the diagram on the left shows the minimum and maximum values of reverberation time as well as the average measured definition of the sound. The first two iterations on the left - tilted and flat - are very similar in numbers, while the last two on the left have either good reverberation and bad definition or too low reverberation but good definition. Furthermore, the last two iterations have generally a larger gap between min.- and max.-values meaning that some people might get a very different sound perception than others.

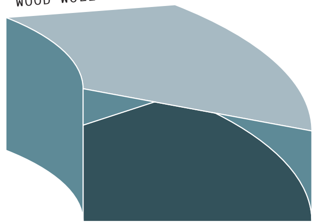
Based on this comparison, the inclined ceiling was chosen, as it generally was one of the closest to the prefered values. It also had the flexibility and a strong relation to the concept of earth and sky (body and spirit) through its ceiling oriented towards the center of the building above the decomposition chamber and memorial garden.

Following this decision came the detailing of materials of the chapel. Here, several materials and combinations were tested to further heighten the quality of the acoustics. On the right side are four selected of the ten material iterations (the remaining can be seen in appendix 03). Of these four, the last has the best reverberation time values as well as an acceptable definition. Though the definition was not the highest among the ten iterations, it had the least amount of spread in both reverberation time and definition which was prefered over correct values.

REVERBERATION:
1.16s - 2.76s

DEFINITION:
49% - 78%



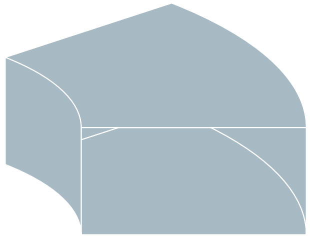


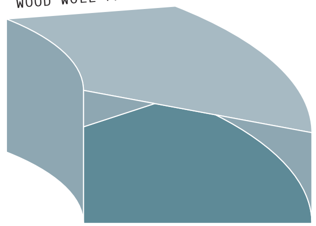

REVERBERATION:
0.39s - 1.98s

DEFINITION:
34% - 95%

REVERBERATION:
1.22s - 2.65s

DEFINITION:
50% - 79%



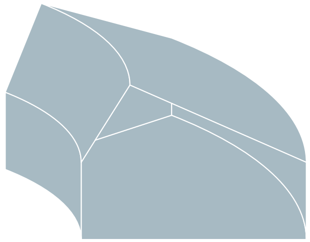


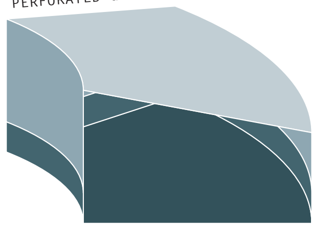

REVERBERATION:
1.10s - 3.92s

DEFINITION:
38% - 79%

REVERBERATION:
1.15s - 2.73s

DEFINITION:
37% - 77%



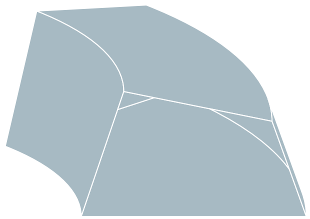


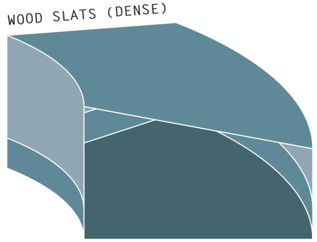

REVERBERATION:
0.55s - 2.15s

DEFINITION:
44% - 93%

REVERBERATION:
0.49s - 1.24s

DEFINITION:
40% - 89%





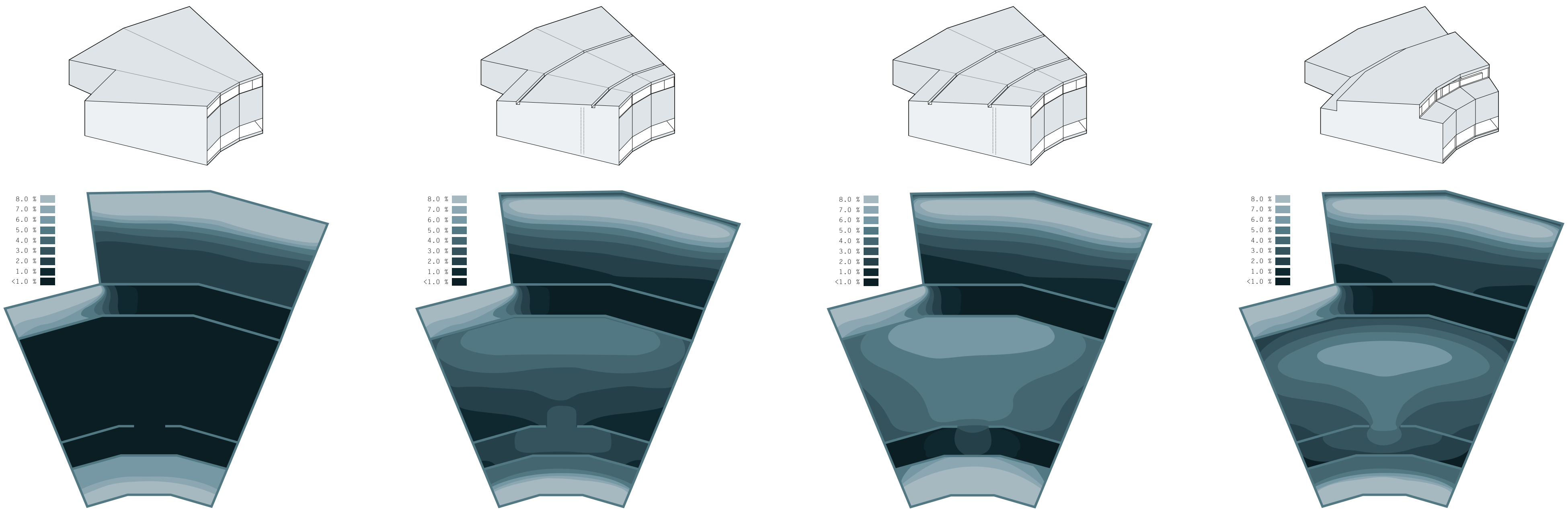

REVERBERATION:
0.75s - 1.88s

DEFINITION:
42% - 79%

ILL. 7.55

## WORKSHOP 03

ACOUSTICS & LIGHT - PART 02




ITERATION 1 // CONTINUED ROOF    ITERATION 2 // ROOF WINDOWS A    ITERATION 2 // ROOF WINDOWS B    ITERATION 4 // SEPERATED ROOF

ILL. 7.56

### LIGHT STUDIES - PART TWO

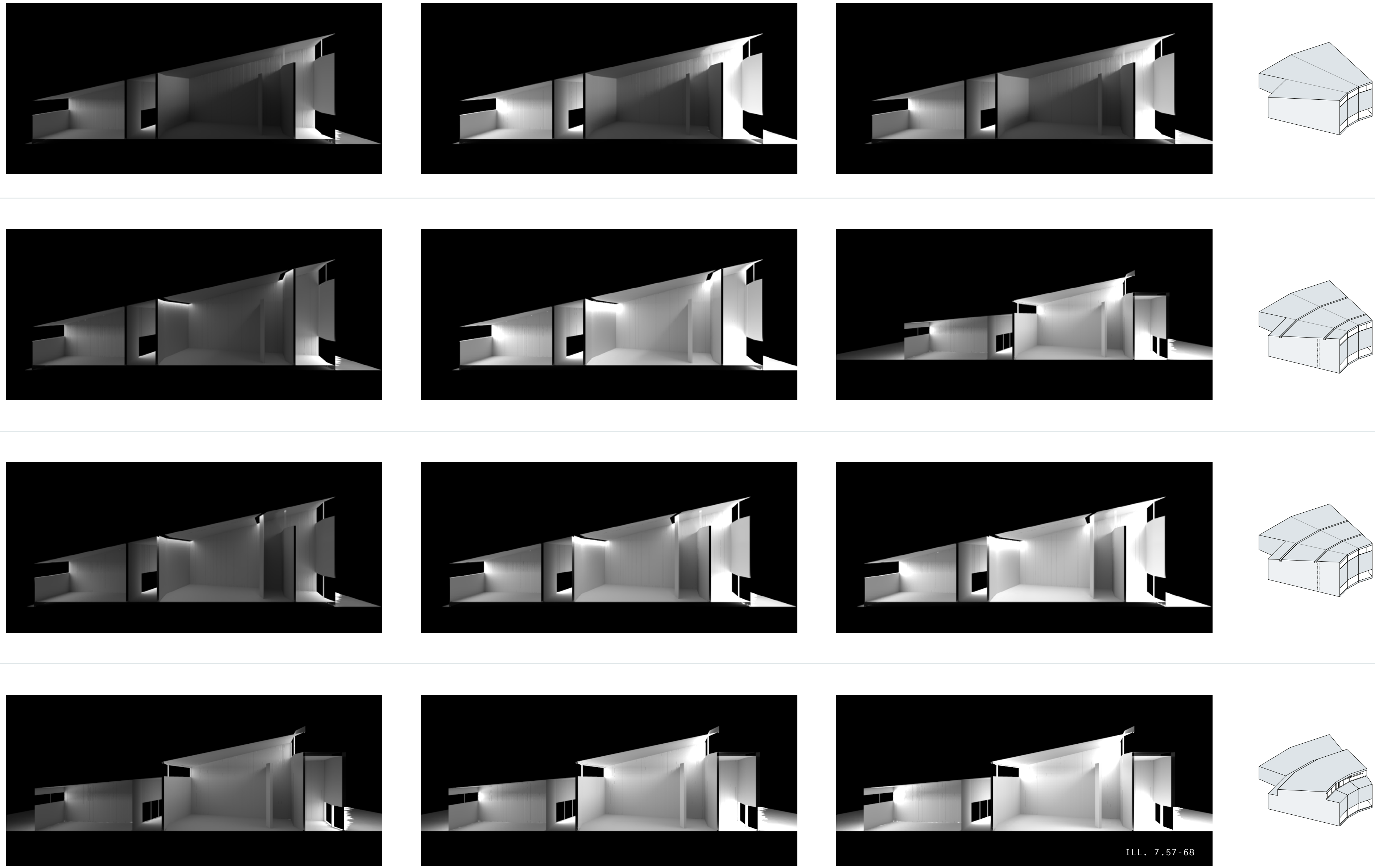
Entering the synthesis phase more actual and detailed light studies has been made. For the further light studies simulations and renders have been made of four iterations using the program Velux Daylight Visualizer. Simulations and renders have been made for both plan and section as well as for illuminance and daylight factor.

The first iteration proved not to be sufficient enough with a daylight factor too low for the bereaved, being able to perceive the chapel as wanted as well as being able to read songs properly during a ceremony. Adding to the daylight factor simulation, the light was further shown in the illuminance renders of a section view. This making it clear again how the light, windows, and the daylight factor (DF) is not acceptable.

This forced the design to change to be much more optimal and integrated in the matter of light and indoor climate in general. Therefore, simulations of three other iterations were made in this workshop and continued being made along with the iterative design process.

Changes were made to the first iteration by adding different skylight windows. This provided the right amount of daylight but did not meet the aesthetical demands, the perception of the chapels, or the overall architectural expression.

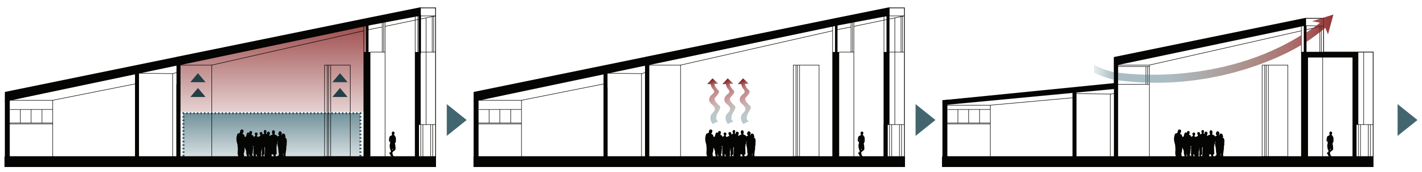
The last of the four iterations detaches the chapel roof from the rest of the building, allowing light to enter directly into the chapel from South and North. In this way giving more flexibility and freedom to the overall design without devaluing the overall concept.



ILL. 7.57-68

# WORKSHOP 05

ENERGY & INDOOR CLIMATE



ILL. 7.69

FINAL ITERATIONS:
IMPROVED VENTILATION,
HEATING, INFILTRATION

HOURS >27$^{o}$C: 40
HOURS >28$^{o}$C: 19

HALLWAY
SET POINT
VENTING:
23$^{o}$C

HALLWAY
SET POINT
HEATING:
17$^{o}$C

HALLWAY
MAX PEOPLE
LOAD:
200

HALLWAY
CALCULATED
AIR CHANGE:
3,02

CHAPEL
SET POINT
VENTING:
25$^{o}$C, 850 PPM

CHAPEL
SET POINT
HEATING:
22$^{o}$C

CHAPEL
MAX PEOPLE
LOAD:
150

CHAPEL
CALCULATED AIR
CHANGE: 1.06,
1.42, 1.73

## WORKSHOP 05

Workshop 05 aims to integrate aspects of energy and indoor climate into the design process early on. With the tool BSim, the aim of this one part of the workshop it to guide the building design to have a optimal indoor climate on the basis of our requirements. To secure a proper air quality for the thermal zones of the buildings, calculations have been made to find the needed air change. These calculations can be seen in appendix 04 and have been used in BSim and Be18. Additionally, Be18 results can be found in appendix 05 - a program used to secure a low energy consumption to meet the requirements of a ZEB.

Lastly an LCA of the decomposition process have been made to state whether the process is a sustainable alternative to cremation.

## INDOOR CLIMATE

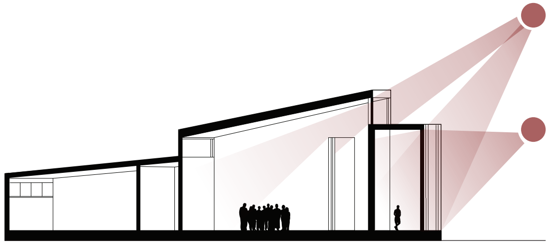
The building has been built in the program BSim and divided into thermal zones on the basis of the wanted indoor climate. Two critical thermal zones has been selected for indoor climate analysis with the main focus on thermal comfort: the hallway and the medium chapel with windows directly towards South and North.

Firstly, for the hallway, two different designs were analyzed: one with heating and one without heating in an effort to lower the energy consumption and give the desired atmosphere of being in contact with the constantly changing nature. Simulations of the unheated hallway revealed a thermal comfort too far under our minimum criteria of 12 degrees in the cold months and too high temperatures in July and August. The latter was also the case for the heated hallway which therefore had to be the base of change for the iterations to come. With a critical look into venting, ventilation, construction of building envelope, heating, infiltration, heat loss, shading, window area and design, etc., an acceptable indoor climate has finally been realized in the simulations of the heated hallways.

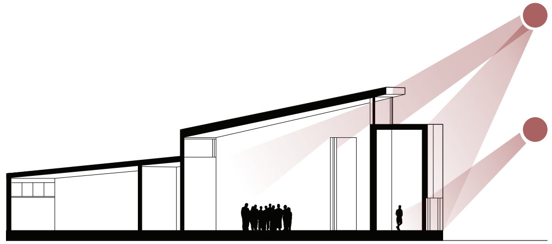
For the chapels, a stable thermal indoor climate is prefered as a contrast to the hallway. With the large and sudden people-load many times during the day when ceremonies are taking place, the comfort of the room could be critical in both thermal and atmospheric comfort. With a building design that has a better potential for natural ventilation with windows towards both south and north, larger volume to dilute the air pollution, and change in window area and design, an acceptable indoor climate has been achieved that fits our demands.

IT. 01: HALLWAY
NO SOLAR SHADING

HOURS >27°C: 195
HOURS >28°C: 108



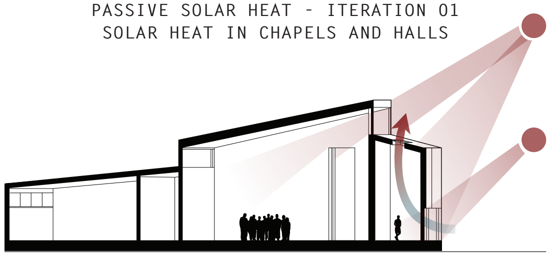
PASSIVE SOLAR HEAT - ITERATION 01
SOLAR HEAT IN CHAPELS AND HALLS



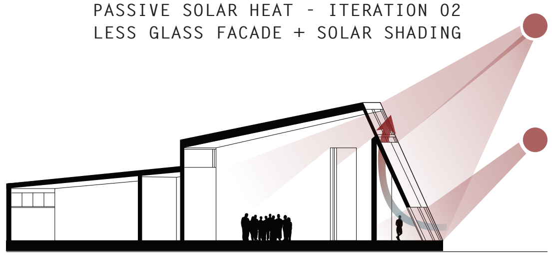
PASSIVE SOLAR HEAT - ITERATION 02
LESS GLASS FACADE + SOLAR SHADING

IT. 02: HALLWAY
W/ SOLAR SHADING

HOURS >27°C: 102
HOURS >28°C: 41



PASSIVE SOLAR HEAT - ITERATION 03

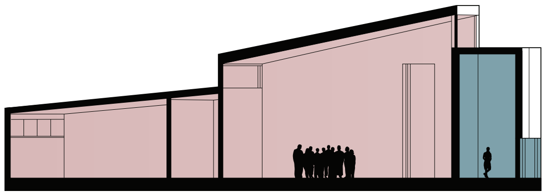


PASSIVE SOLAR HEAT - ITERATION 03

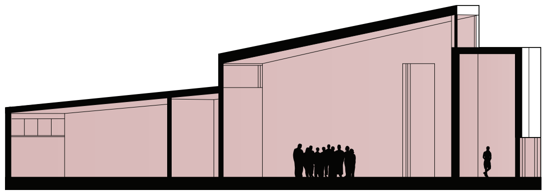
ILL. 7.70

IT. 03: HALLWAY
NOT HEATED

MAX. TEMP: 27°C
MEAN TEMP.: 10°C
MIN. TEMP.: -12°C
HOURS <20°C: 7396



HEATED - UNHEATED



HEATED

IT. 04: HALLWAY
HEATED

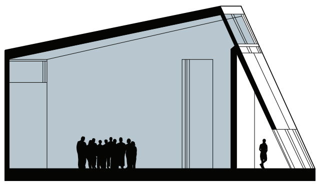
MAX. TEMP: 30°C
MEAN TEMP.: 18°C
MIN. TEMP.: 6°C
HOURS <20°C: 5693

ILL. 7.71

---

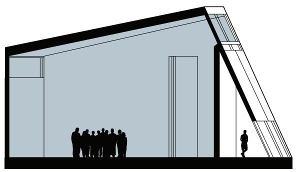
LARGE CHAPEL

HOURS >27°C: 77
HOURS >28°C: 24
MEAN TEMP.: 22.9°C



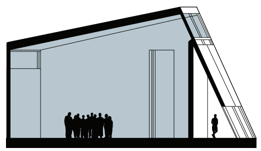
MEDIUM CHAPEL

HOURS >27°C: 41
HOURS >28°C: 11
MEAN TEMP.: 22.8°C



SMALL CHAPEL

HOURS >27°C: 29
HOURS >28°C: 8
MEAN TEMP.: 22.6°C



ILL. 7.72

REINFORCED CONCRETE:
24,069 $kgCO_2eg$

STEEL:
62,423 $kgCO_2eg$

ILL. 7.73

## LCA

The elements and system boundaries included in the decomposition LCA has been chosen based on the analysis of the decomposition process, ecosystem, and the method of inserting bodies and extracting compost, all investigated during the previous workshops. Therefore, in addition to the operational energy and flue gas emissions, the LCA will include equipment such as the ventilation system, shaft lifts and hatches, and compost extractor.

Aside from establishing whether interment by decomposition can be considered a sustainable option unlike current methods, the LCA has two sub-goals: to calculate the required decomposition chamber volume with regards to the building design and to calculate energy recovery as part of the energy strategy of the building.

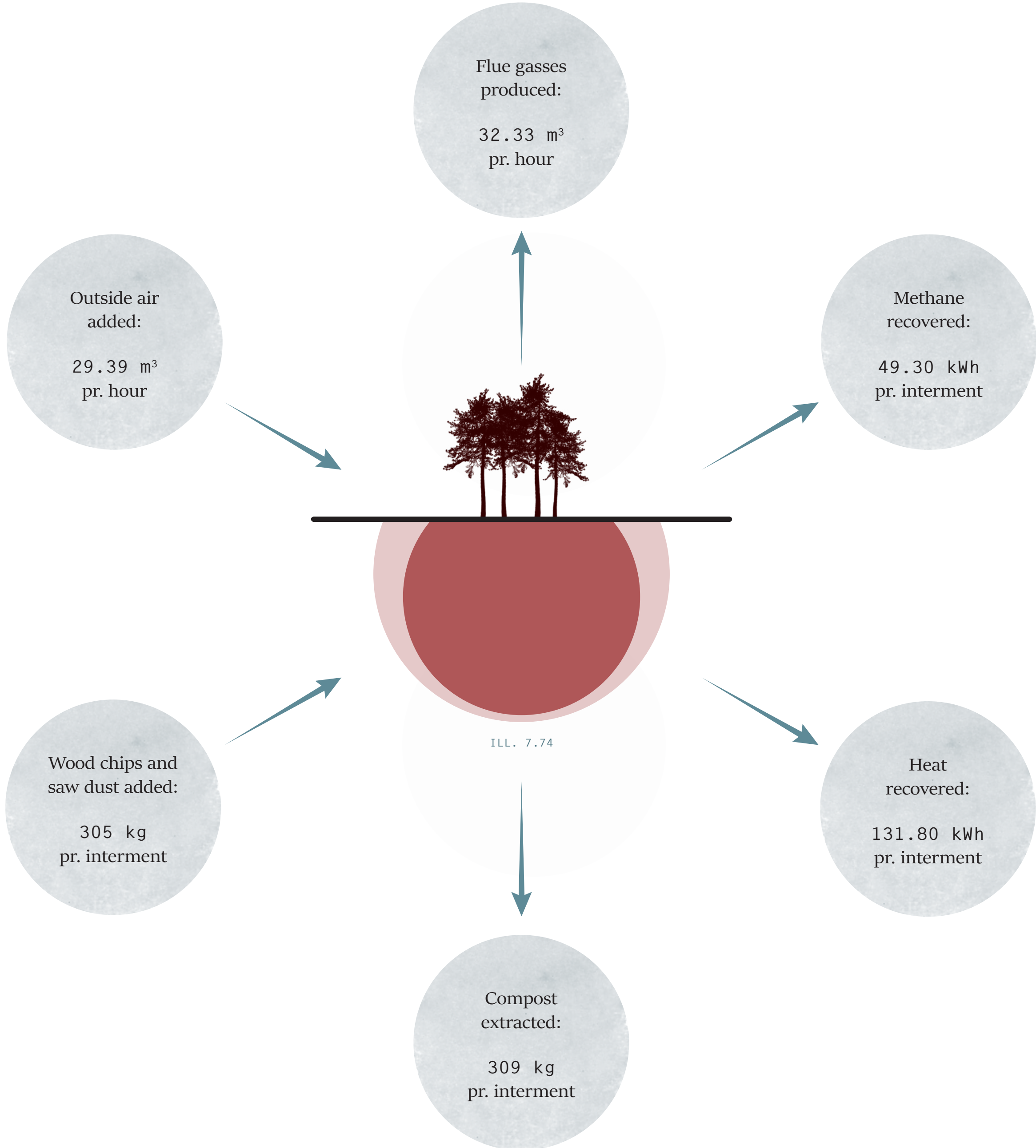
The chamber volume is calculated based on the expected 20 daily interments (maximum) and the amount of added composting materials required for the process. From this, the flue gas emissions can be calculated, leading to dimensioning the ventilation system and air compressor connected to the decomposition process as well as the loss of mass during the six weeks: with a total mass decrease of 66 kg for every interment, the required chamber volume ends at 596 m3.

With the finished design of the chamber found via the Rhino plug-in Grasshopper as a concave funnel, the chambers materials can be investigated. Here, concrete and steel are tested for their GWP based on the chamber surface area and construction thickness. With the concrete having 39 % the footprint of the steel, concrete is chosen and included in the LCA.

Lastly, the energy contribution from the process is calculated - first from the heat recovery of the ventilated flue gases and secondly from the methane gas production in the chamber:

The recovered heat energy is calculated from a study of heat recovery potential from municipal composting. From this data, the potential transmission loss through the chamber walls can be calculated to also estimate the required chamber insulation thickness. The methane production contribution is calculated by data from natural gas energy as the methane is expected to be sold to an off-site facility and thereby negated in both the process LCA and building energy strategy.

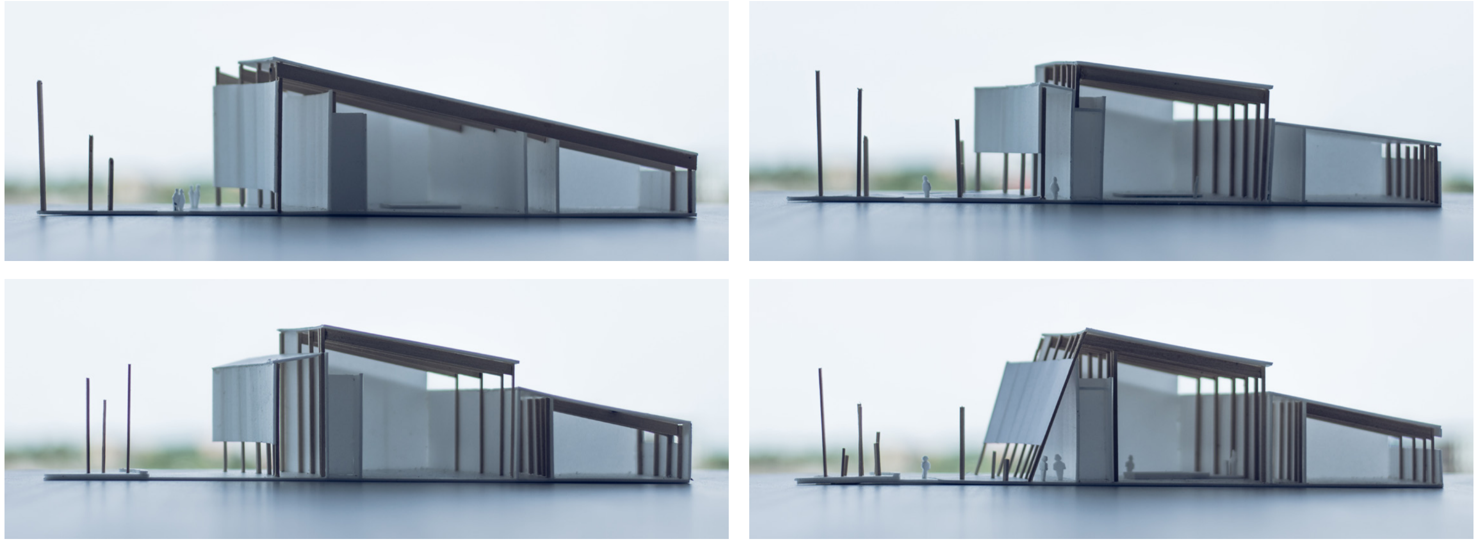
For the full LCA with all data and sources, see appendix 02.


Flue gasses produced:
32.33 m³ pr. hour
Outside air added:
29.39 m³ pr. hour
Methane recovered:
49.30 kWh pr. interment
Wood chips and saw dust added:
305 kg pr. interment
Heat recovered:
131.80 kWh pr. interment
Compost extracted:
309 kg pr. interment

ILL. 7.74

## WORKSHOP 06

DETAILING



ILL. 7.75-7.78

### WORKSHOP 06

The last workshop of the synthesis phase and the design process in general zooms in to look at various details of the building. Details such as the entrance to the chapels, chapel construction, chapel lighting, Mourning Hall lighting, and the main entrance of the building.

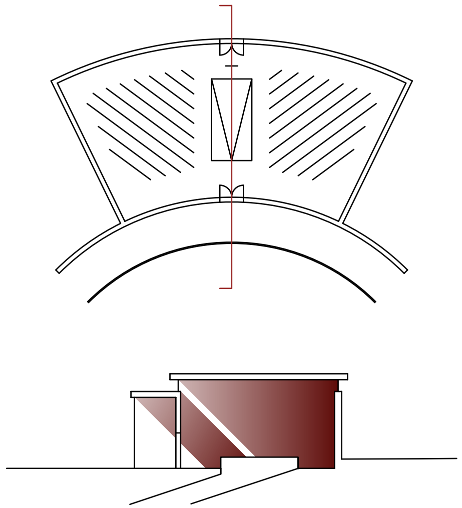
In this workshop both sketches, several models, and renders have been created in a aim to make the right final decisions.

### CHAPELS - ENTRANCE AND TRANSITION

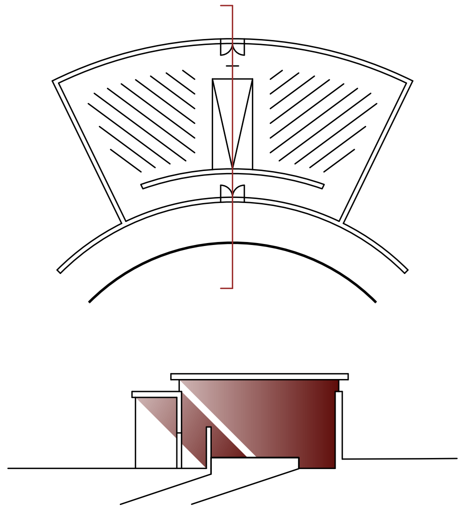
Different iterations are made for the plan layout of the chapels focusing on the seating of the bereaved, the entrance of the chapels, and the transition of the deceased being moved from the chapel to the chamber. The latter seeks to create an honest farewell that clearly represents the transition of the body to the chamber and the soul towards the Memorial Garden. In this way the bereaved can follow the deceased out - the deceased ending in the chamber (death) and the bereaved in the garden (life).

The first iteration focuses on creating a community-feeling viewing inwards from the chairs. However, this iteration lacks a niche for people to gather before and after as well as nearby a cloakroom and restrooms. Furthermore, it can be questioned whether the bereaved will feel as if they walk 'on top' of the deceased, disappearing under them. This last obstacle is prevented in iterations 2, 3, and 4 where a wall separates the entrance and chapel room. Although, this may create a too complicated way of entering and leaving the chapels with the two doors. Also, the wall might break with the idea of the deceased disappearing into the building.

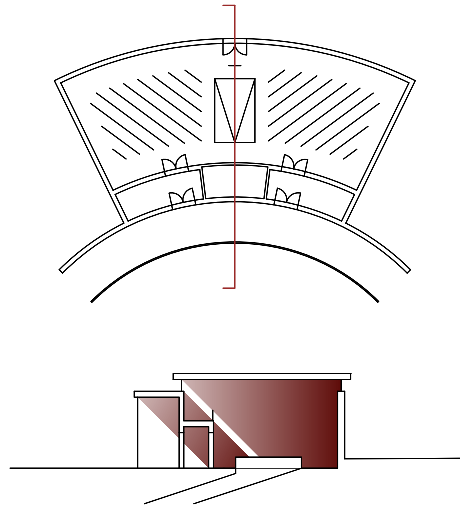
Iteration 5 and 6 fulfill the need of a private gathering space releasing the main hallway from being too crowded. A combination of iteration 1 and 5 creates the last iteration with the desired sensations.



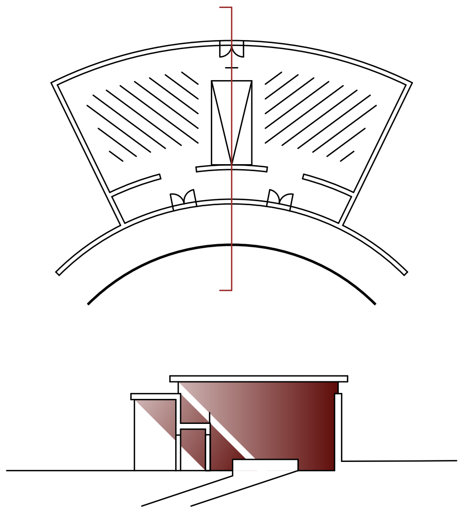
ITERATION 1 // SYMMETRIC ORIG.



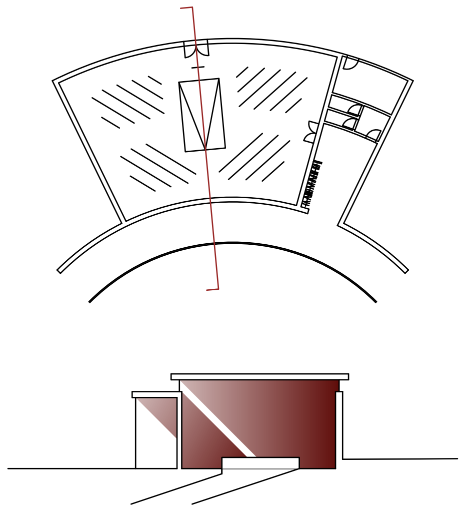
ITERATION 2 // SYMMETRIC WALL



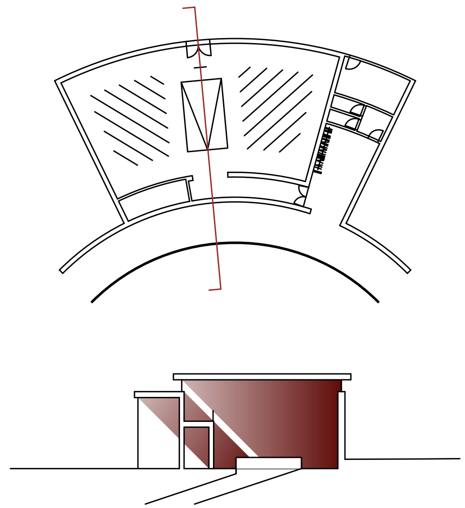
ITERATION 3 // CLOSED BOXES



ITERATION 4 // OPEN BOX



ITERATION 5 // NICHE W. SIDE DOOR



ITERATION 6 // NICHE W. FRONT DOOR

ILL. 7.79

ILL. 7.80

ILL. 7.81

ILL. 7.82

ILL. 7.83

## CHAPEL CONSTRUCTION

For the design of the construction, iterations have been made primarily for the chapels. For these, the role of the construction is to support the large roof span as well as integrating a tectonic utilization for aesthetics means - in this way the structure becomes a vital part of the spatial perception, adding to the grandness of the room.

The first iteration is post-and-beams in its most simple form, inspired by the auditoriums of the Utzon Center, demanding for very large wood elements. But the simplicity in shape of the chapels in contrast to the Utzon Center gives the possibility to create a more intricate and conceptually stronger structure, making the room more detailed and finished. Therefore, inspired by the architecture of Danish architects Exner, further iterations were made with different designs of trusses. The iterations have been made in Rhino and VRAY to investigate the atmosphere and expression of the room with a structure that, in different manners, interacts with the light and spatial perception.



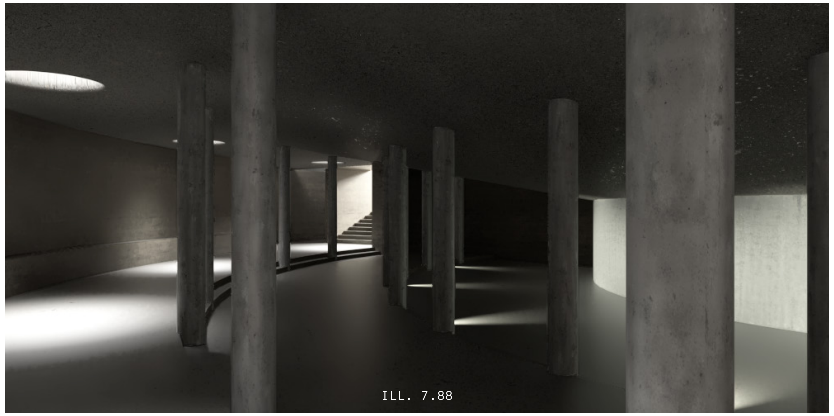


## CHAPELS: ARTIFICIAL LIGHTING

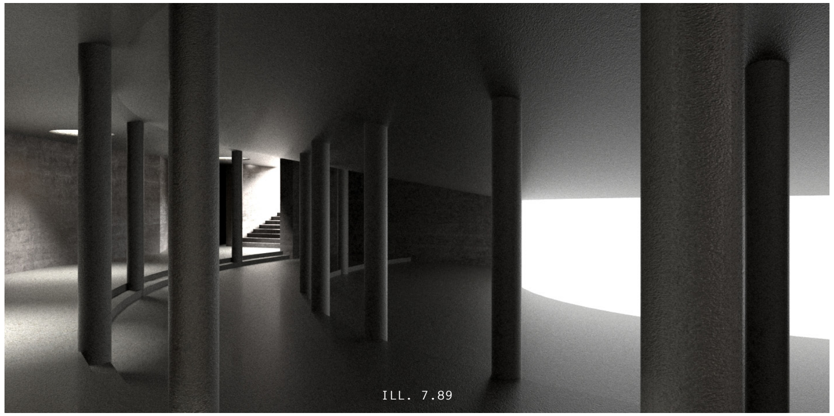
The chapels are design to be filled with daylight from South and North, but the short days during winter demands for artificial lighting. Therefore, several iterations have been created with different artificial lighting.

In order to not interfere in an undesired way with the spatiality created by the chapel structure, the first two iterations - Ill. 7.84 & 7.85 - is designed with spots placed in the walls pointing towards the ceiling or in the ceiling pointing towards the floor, respectively. But these iterations created a too large focus on the upper parts of the room, leaving the floor without the sense of divinity and spirituality seen during the daytime and generally a flat atmosphere.

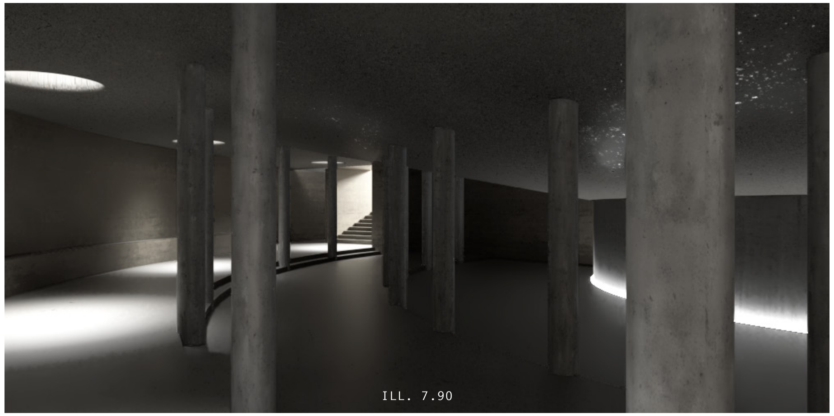
In illustrations 7.86 and 7.87, two variations of pendants were tested. These with the idea of a third element along with the furniture and the structure, addressing the separation between human space and divine space in the chapels. These proved to create the desired effect, creating a greater focus on the ceremony during low-light hours



ILL. 7.88



ILL. 7.89



ILL. 7.90

ILL. 7.91

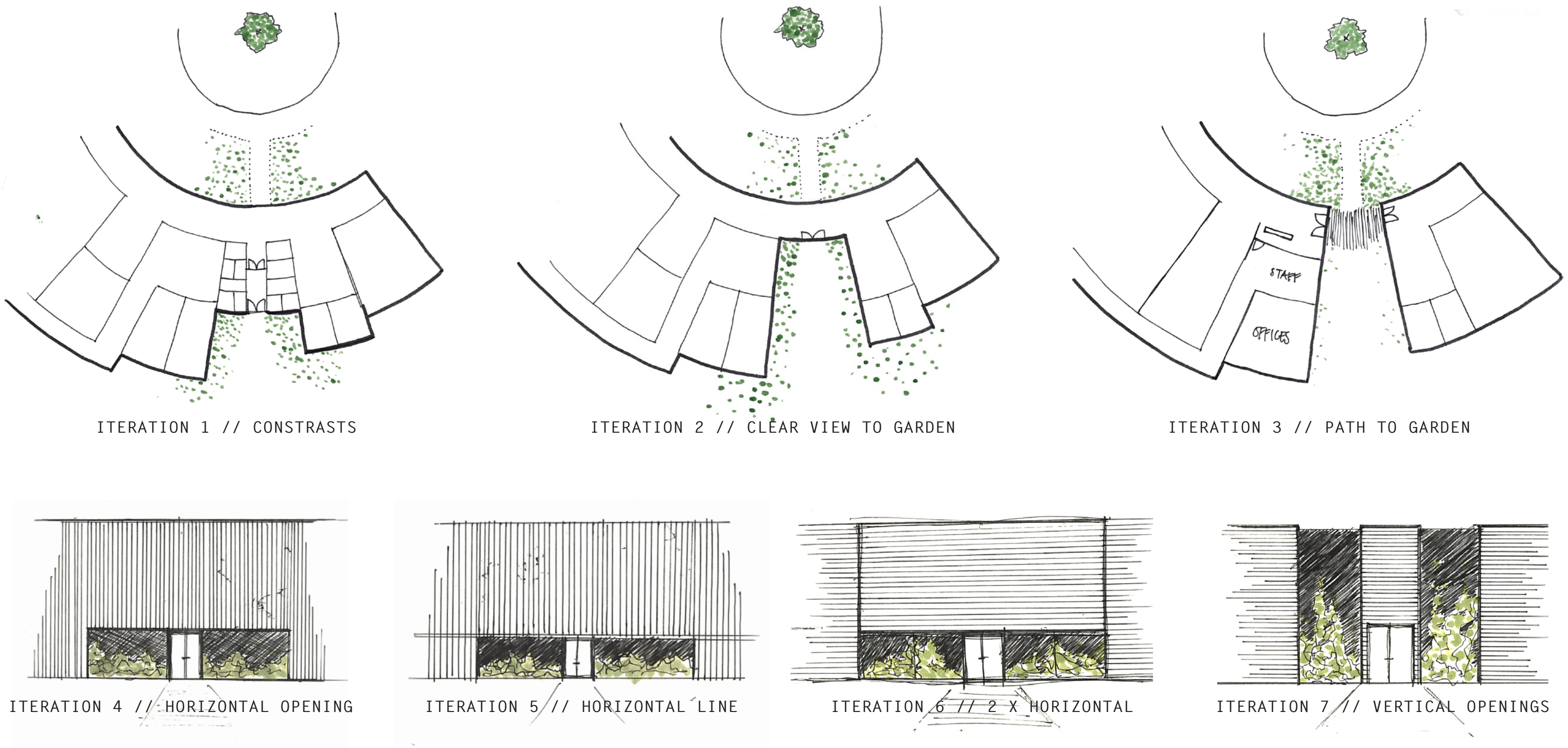
## MOURNING HALL LIGHTING

Since little daylight enters the Mourning Hall, artificial lighting is essential in creating the right atmosphere. The daylight will be limited to only the outer corridor that is connected to the circular hallway above. As a contrast to this, the atmosphere closer to the decomposition chamber wall must be very dimmed still with some light to allow for reading and lighting a candle. This principle would speak well with a light that emphasizes the importance of the chamber, which was first investigated as seen in ill. 7.88. Here, spots in the floor makes the chamber wall appear to be illuminated - an idea taken further in the second iteration (ill. 7.89). Both of these iterations overplayed the wall, thereby neglecting the area opposite the water where people would stand.

The following iterations investigates an idea of a narrow slit of light by either the bottom of the chamber wall or the top. These would give the impression that the chamber wall continues beyond the room and connects to the realm of the dead - be it below or above the realm of life.

# WORKSHOP 06

DETAILING




ILL. 7.92

## MAIN ENTRANCE

From the very start, in both the sketching phase and synthesis phase, iterations have been made towards a clear distinguished and inviting entrance - an entrance that makes it easy for mourners to find their way into the building and for curious to feel welcome to enter. Iterations have been made with a wish of creating a contrasting, slender, and darker entrance that enhances the bright hallway with a view to the Memorial Garden. This, creating a gesture of denial and reward (iteration 1 & 4-7). In an effort to investigate the opposite, iteration 2 og 3 creates a light, transparent view or path, directly towards the memorial garden. These iterations blurs the border of the entrance, creating a much stronger inside-outside perception and a stronger integration with nature.

For the facade design of the entrance, iterations have been made focusing on either a horizontal, human scale design or a vertical, grand design as seen in iteration 4-7. Here, both shape and materials have been implemented to enhance or break down a vertical or horizontal expression.

# 08

EPILOGUE

The last chapter of the thesis report counts the conclusions and reflection upon the master thesis. Lastly a bibliography and illustration list can be found in this chapter.

## PROBLEM STATEMENT

*By designing a sustainable building for a new way of parting with our deceased based upon decomposition of our dead bodies, can we then offer a holistic, sustainable, and spiritual way - both in architecture and function - of interment for the future?"*

In a clearing of the dense conifer forest of the historical Woodland Cemetery, a new, innovative architecture for interment of the future lies: *The Woodland House of Recomposition* - a sustainable building, housing a new way of parting with our deceased by composting the dead body to give back to and regenerate nature.

The house offers a holistic, sustainable and spiritual way of dealing with death and parting with our loved ones. This through an integration of three Ceremony Chapels, a Memorial Garden, a Life Room, Counseling Rooms, and a Mourning Hall. These main functions are specifically created and designed on the basis of the research and analyses conducted in this master thesis, to fulfill the many aspects of designing for death. In this way the Woodland House of Recomposition creates a space with safe frames for spirituality, contemplation, and death to be part of the lives of, primarily, the many secular people of Sweden. A growing group of people in the North European countries, who lacks a guiding force in the questions of life and death. In general, the building is designed both for bereaved attending a ceremony as well as mourners coming to mourn, honour, and remember the ones who spiritually are laid to rest in the Woodland House of Recomposition.

The Decomposition Chamber placed in the origin of the circular plan layout of the Woodland House of Recomposition constructs a closed ecosystem for the decomposition to progress safely and efficiently, taking only six weeks. Underground closely together with this chamber the Mourning Hall is placed open to all visitors.

By decomposing our deceased the House of Recomposition eliminates the many, large, and in many cases full graveyards that takes up precious land around the world; it eliminates the need of environmentally harmful caskets and embalming of the deceased; and most importantly: the House of Recomposition offers an alternative way of interment that is different from burial and cremation, currently being the only common options.

While the soul or memory of the deceased stays within the building, the soil itself - no longer affiliated to the person - will after the six weeks be collected to contribute to the Memorial Garden, the Woodland Cemetery, and other areas in need of nutritious soil.

Through a detailed LCA conducted in this master thesis, the actual process of decomposition of dead human bodies has been proven in fact to be a sustainable choice compared to cremation. Thereby, the house itself together with the function of the house, the decomposition process, give the world a new, innovative, and holistically sustainable way of parting with, honour, and remember our loved ones.

*The House of Recomposition* does not have an existing typology neither an established building program. This meant that most of the aspects of both the design process and design in this master thesis, had to be created from scratch and from the basis of vaguely similar examples. A testament to this is the research group Recompose that, after four years of research into interments by decomposition, still has not begun to thoroughly investigate the architecture to house the process. As with this example, our project theme would might be more suited for exclusively developing a thoroughly compiled building program with more in-depth sociologist, anthropological, and architectural studies, thereby limiting the actual designs. However, the underlying aim of this thesis was not to only investigate the process of human decomposition, but instead to challenge ourselves, and the world, with an actual architecture as a pilot project. Additionally, to widen the boundaries for what could be possible for interments through a specific and actual architectural design. In this regard, the combination of knowledge from a wide range of disciplines, and attempting to create a design of both strong emotional value in close connection to its technical aspects, proved to be the right challenge for this master thesis and an important steppingstone.

While current buildings addressing death can rely on a strong traditional connection, as in the case of churches or an already socially accepted status as with crematoriums, the House of Recomposition must, to a greater extent, address the challenge of designing something that is innovative and transparent and simultaneously controversial and bound by traditions. For our design to fully express its intention and to persuade its users of its potential, it must deliver a gentle atmosphere with the right amount of authority and spiritual significance. Thereby, this architecture must be all about state of mind and subconscious architectural mechanisms - something that we did not anticipate the importance of when starting the project. As a result, the Woodland House of Recomposition is not a case of people arriving to utilize a function with the bonus of abstract and provocative architecture. Instead, this building is designed to give a first-impression that offers simplicity and recognizability to calm the bereaved and enable them to focus inwards and towards each other. However, during their stay, the architecture aids in understanding death - its meaning and consequences - as well as aiding the mourning. Here, the subconscious is in focus: the constant hints of life in a house of death through vegetation, light, and warmth.  At the end, the bereaved will hopefully maintain a respect and acceptance towards death and leave with a less heavy heart due to the architecture and placement of the house.

Sustainability has been a key driving force of this thesis from the very beginning but it has also proved to be a difficult concept to manage with its many and different definitions as well as it containing so many aspects that not always benefits from each other. Therefore, apart from the challenge of creating our own definition and strategy of sustainable design, together with the many calculations regarding whether we achieved it, we had to thoroughly evaluate our many design iterations against more abstract ideals. This, to be able to balance pros and cons with a sustainable mindset, not just based on raw data and carbon-footprint but also with the mindset of social sustainability with the architectural quality and people in mind. The latter being a very specific and different way of designing for social sustainability, when designing for death, life, mourning, and memorial. Therefore, while the reduction of glass area in the hallway and the volume of the chapels could have been reduced even more, this would simple not be optimal for the perception and social sustainability of the project. Looking back at the design process, sustainability have been a complex driving force, constantly in need for choosing, within the definition of sustainability, what is most important for the specific design issue. Being it less glass areas, more daylight, larger volumes, robust materials, or local materials.

While the constant evaluation between architectural and technical arguments have sometimes been a huge challenge during previous semester projects at Aalborg University, the Woodland House of Recomposition has seemed to only gain in quality from every decision, iteration, and modification. In this design process, tied so strictly to its research, many of the initial presumptions proved unsound: Early ideas and thoughts were continuously substituted for holistic principles, and design elements more closely connected to both the contextual architecture and the needs of both the decomposition process and the target users. The sketching phase especially, which ran parallel to the research, is full of examples of this: amongst others the various shapes of the chapels investigated, as well as the idea of the chapels having individual chambers. However, some decisions in the early design process still proved as an obstacle in later detailing, where the architecture was put before the technical needs: the largest of these being the placement of the Decomposition Chamber: In spite of the chamber designs from Katrina Spade/Recompose being above ground, we decided that a chamber placed underground would be better for the Woodland House of Recomposition to reflect the narrative of returning to nature as soil. This narrative and spiritual representation later evolved into the Memorial Garden placed on top of the Decomposition Chamber. However, placing the chamber underground resulted in the need for active systems to aid the decomposition process where Spade's designs - to some degree - could utilize the wind to ventilate the compost. On the other hand, the thermal properties of the ground could be beneficially utilized in the cold climate of Sweden - limiting the need for insulation and active climate control.

Without a recognizable typology to work from, the early decision in the sketching phase was primarily logistics-based. Here, the flow of people - both visitors and staff - were continuously evaluated in all design concepts, resulting in most of the concepts being investigated as building layouts as seen in Chapter 06. This method proved well to work with but it created unforeseen problems in later stages: While the whole building was detailed in plan drawings, only few rooms were drawn in section and 3D. As a result, some functions in the building were left with disproportionate room heights as seen in for example the restrooms and counseling rooms. In both examples, the problem could be justified to some extent as there is still a need for placing the ventilation systems and pipes. But in the end, this was still a problem that could have been reduced or foreseen. A solution to this would be to either use the space above the niche and restrooms for extra gathering space or to relocate the meeting and counseling rooms - or simply, to generally optimize the building layout. Due to the many important aspects of the master thesis within time, neither option was investigated to a point where the problem was truly solved.

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# APPENDICES

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## DIRECT EXTRACTS FROM THE BRIEF

*”The history of Skogskyrkogården, the Woodland Cemetery dates back to the opening years of the 20th century, when it became clear that Stockholm was short of burial space.*

*In 1914 the City Cemeteries Board announced an international architecture competition. First prize went to the young architects Gunnar Asplund and Sigurd Lewerentz. Their entry, “Tallum”, was alone in making the Nordic forest the principal experience. The Skogskyrkogården crematorium has been in use since the 1920s. Its architecture and landscaping have been a great support to people in their bereavement and in their leave-taking of loved ones. The Woodland Cemetery has been cherished and used by the people of Stockholm with great reverence for the uniqueness and magnificence of the place.”* [on page 5 of the full competition brief]

*”The new building will carry on the tradition and be of the same architectural stature as the original work. It will be a part of the City’s Vision 2030, “a Stockholm of world class”. This being so, it seems natural that the City should once more arrange an international architecture competition. The appended programme for the new Skogskrematoriet has been drawn up by the Cemeteries Board with the utmost respect for the history of the burial ground but also with the aim of creativity.”* [on page 5 of the full competition brief]

*”The* [new, red.] *building, its positioning and surroundings are to be designed with the same care and architectural awareness as were devoted to The Woodland Cemetery by Asplund and Lewerentz, meet the functional requirements on a limited budget and to conform to the preconditions determined by both the cemetery and World Heritage site listing.”* [on page 6 of the full competition brief]

*”The competition brief is to propose a crematory building and its immediate surroundings within the competition site. The focus of the architectural and design-related brief is on designing a building which can enter into the holistic composition which Gunnar Asplund and Sigurd Lewerentz evolved at the Woodland Cemetery with the passing years. In its encounter with family and mourners, the crematory must have a symbolic and sacred impact distinguished by tranquillity and dignity. The new crematory will take over the present crematory functions of the Woodland Crematorium, in keeping with the technical and logistical programme which the Cemeteries Administration has defined for those functions and on the site, next to the Woodland Crematorium, which the programme indicates.”* [on page 6-7 of the full competition brief]

*”The Woodland Cemetery is included on the UNESCO World Heritage list and ranks as an artistic masterpiece and a unique example of the integration of architecture and landscape into a single composition.*

*In their design of buildings and landscape, the architects Gunnar Asplund and Sigurd Lewerentz have shown great skill in acting on the principle of directing the mourners’ attention to nature, as a source of support and strength in life’s difficult moments. Even today, the landscape and buildings are experienced as highly authentic in relation to the original composition. With the passage of time, minor changes have been made compared with the architects’ original scheme, but these were not found to have adversely affected the overall concept when the Woodland Cemetery was inscribed on the World Heritage List in December 1994. The interplay between the buildings, with their meticulous detailing, and the landscape attracted both national and international attention.*

*The technical facilities at the Woodland Crematorium have been upgraded several times over the years. The existing crematory cannot be renewed any further.”* [on page 7 of the full competition brief]

*”The building must also support a dignified treatment of the dead. People of many different creeds and nationalities will be given opportunities of taking part in certain crematory acts. The work environment must be designed with special consideration for the personnel having the crematory as their daily workplace.”* [on page 8 of the full competition brief]

*”The Woodland Crematorium was proportioned according to the apparent and foreseeable situation in 1940. Today some 7,500 Stockholmers die annually and the proportion cremated exceeds 90 per cent. The City of Stockholm is planning for an additional 150,000 new residents during the period ending in 2030. The City is also responsible for Råcksta Crematorium, Vällingby, which was inaugurated in 1965 and thoroughly modernised in 2003.”* [on page 9 of the full competition brief]

*”By the beginning of the 20th century it was clear that Stockholm’s existing burial grounds would not suffice for much longer. Two major cemeteries existed at the time, namely Norra Begravningsplatsen and Sandsborg Cemetery, Enskede, and it was decided to enlarge the latter, which was 12 hectares in area. In 1912 the City Council resolved to augment Sandsborg Cemetery by adding an area of land to the south of it. The new addition, amounting to 96 hectares, consisted mainly of the conifer-clad Stockholm Ridge with strata*

*of gravel and sand."* [on page 10 of the full competition brief

*"The Woodland Cemetery is laid out in a pre-existing pine wood. The burial areas consist of lofty pillared halls with grass "floors". The large areas of natural woodland in the centre convey a genuine sylvan atmosphere. From the main entrance in the north, in contrast to the dense woodland, there opens up a magnificent landscape which Lewerentz and Asplund created through a major redistribution of the gravel deposits existing along the original ridge with its two large gravel pits. Starting with the original positioning of the Woodland Crematorium on the central axis from the entrance, the architects jointly devised its present offset position in the landscape. There is a clear distinction between the sparse but lofty pine trees of the regularised grave sections and the core of untamed woodland from the pristine ridge located between the Woodland Crematorium and the northernmost grave sections in the lee of the cemetery wall. The dense, untamed woodland fringe behind the Woodland Crematorium is an indispensable backcloth from which the entire Woodland Cemetery derives much of its character."* [on page 12-13 of the full competition brief]

*"The creation of the Woodland Cemetery testifies to a drastic transformation of funeral practices at the turn of the previous century. Interment was paramount at that time and had been so since the Middle Ages. A new conception of humanity was one reason for the idea of cremation now being broached. The insanitary conditions which were becoming increasingly rife in the cemeteries and churchyards of the period were a contributory cause, and population growth meant congestion in the existing burial grounds. A first crematory chapel was built at the Sandsborg Cemetery in 1895 with two incinerators from the 1897 Stockholm Exhibition, but these were not commissioned until 1931. Stockholm acquired its first crematorium, at Norra Begravningsplatsen, in 1909. The Woodland Crematorium, when completed in 1940, was the largest and most up-to-date facility of its kind in Sweden."* [on page 14 of the full competition brief]

*"The crematory in itself provides a highly instructive illustration of how the handling of a dead person proceeds. Arriving in a coffin transported by a hearse, the deceased is taken to a cold store pending the ceremony and subsequent cremation. If the funeral is to take place in one of the Woodland Crematorium chapels, the coffin is decorated before being taken to the chapel, sometimes preceded by a viewing of the deceased. It is then returned to cold storage pending cremation, after which the ashes are transferred to an urn. This is later released to the next of kin or interred in the Woodland Cemetery. Originally there were also facilities for post-mortem examination, embalming and shrouding of the deceased."* [on page 15 of the full competition brief]

*"The northern part of the Woodland Cemetery touches the boulder ridge extending from north to south and traversing the centre of Stockholm. Most of the land in the Woodland Cemetery is glaciofluvial sand and gravel from the formation of the ridge following the melting of the inland ice cap. In the northeastern part of the area which includes the competition site, there are thinner strata of glaciolacustrine sand mingled with underlying clay and also with outcrops of rock at the highest points. The site of the new crematory is located in a woodland area which is the largest expanse of unspoiled country in the whole of the Woodland Cemetery. This woodland constitutes a visible eastern boundary to the open landscape inside the main Woodland Cemetery entrance. On the inside of its west-facing edge of tall, ancient pine trees there is mixed conifer woodland, dense in places.*

*When the Woodland Cemetery was first laid out, there was a pine forest there, tall by the standards of the time and constituting one of the unusual features of the place. Forests in and around 1900 were as a general rule badly scarred by grazing livestock and heavy timber extraction. Probably, therefore, one reason for the presence of unusually ancient and large pine trees between 200 and 300 years old within the competition site is that the former owner of Enskede Gård, Axel Odelberg, realised already in the mid-19th century that the forest was of value and took good care to preserve it. Woodlands that ancient are a rarity in the Stockholm area nowadays. One reason why this greenfield site was not utilised for grave sections was probably that the land consists partly of outcrops and the soil strata are too shallow for interment of coffins to be feasible. An even stronger reason was the preservation of the woods as a visual frame surrounding the open landscape. Thus the woodlands were a deliberate part of the composition of the open entrance area.*

*The woodland area today consists of dense mixed conifers of more or less the same age, sparsely interspersed with taller and older pine trees between 150 and 250 years old. One or two pine trees may be up to about 300 years old. Beneath this there is younger woodland growing, consisting mainly of spruce and pine as well as scattered broadleaf trees. There are small pine trees growing in the outcrop areas. Otherwise the younger generation of trees is dominated by spruce, which is capable of growing up in the shade and ousting the* *light-hungry pine trees. Many old pine trees in the area are under pressure from growing spruce trees.*

*Along Kapellslingan there are many beautiful old pine trees on the western edge of the woods. The undergrowth consist of mosses and shrub vegetation such as blueberry and lingonberry. The natural ground vegetation is an important element of the sylvan ambience and should be safeguarded in a woodland cemetery. In principle, no silviculture is believed to have occurred in this area since it became a burial ground. In particular, the eastern part of the woods within the competition site rather resembles a primeval forest, with large numbers of old pine trees and fallen dead wood. The woodlands are also the habitat of the goshawk and black woodpecker, both of which are dependent on old trees.*

*The western edge of the woods facing Kapellslingan is generally considered fairly storm-proof and the old pine trees at the front have withstood exposure to the prevailing western and southerly storm winds.”* [on page 16-17 of the full competition brief]

*”The starting point of the competition is the preservation of the Woodland Crematorium’s unique setting with the forest edge behind, out of respect for the World Heritage Site. The competition site, therefore, has been pulled back in section 41 from the existing car park there, so as to extend south-eastwards into the glade formed on the inside of the eminence overlooking Kapellslingan and the Woodland Crematorium. The glade and traces of a footpath leading to it are probably the remains of an old building site. The eminence provides a natural screen secluding the new crematory from Asplund’s building. The level of the competition site varies between +37m and +39m above sea level. The eminence is +44m and the forecourt of Heliga Korsets Kapell (the Chapel of the Holy Cross) +46m.”* [on page 17 of the full competition brief]

*”To minimise interference with the natural forest, therefore, the competition site makes use of the existing open spaces in the form of the closed parking lot and the glade further in. The relation between the new building and adjoining natural woodlands is a fundamental quality to be preserved, in the spirit of Asplund and Lewerentz, in the design of the new crematory.”* [on page 18 of the full competition brief]

*”Conveyance of coffins to the new crematory will take place both from the present crematorium and also, to a great extent, directly from other ceremonial venues away from the Woodland Cemetery. In addition to the road connections already existing at the parking lot, a further connection will probably need to be provided for the conveyance of coffins etc., but preferably towards east. This must be closely tested in the landscape. Both Kapellslingan and Östanvindsvägen can be used for vehicular traffic.*

*The competition brief also includes studying how mourners can in various ways move about and experience the new creamtory, both in itself and in relation to Asplund´s building.”* [on page 19 of the full competition brief]

*”Both Gunnar Asplund’s and Sigurd Lewerentz’s unique works at the Woodland Cemetery are distinguished by great artistic empathy and compassion for the situation and experience of the individual mourner in connection with funeral rituals. For this they created, over the years, a magnificent wholeness of original natural scenery, newly created and dramatised landscape and buildings of widely varying expression and location. As architects they were capable of creating timeless form out of limited resources, with simplicity of materials and consummate detailing. The present brief is to be seen in this context. Thus the neat measurements and proportion of the existing crematorium are to be regarded as a prototype of the new crematory, and over and above the technical arrangements the focus of the competition brief will be on creating a high level of architectural quality in the spatial design, especially at the meeting point between outdoor and indoor spaces.*

*The new crematory is to be integrated as a perfectly natural addition to this internationally unique ensemble without disrupting the delicate spatial balance between landscape and buildings which characterises the Woodland Cemetery.”* [on page 19 of the full competition brief]

*”The new building must interact with its surroundings harmoniously, not only architecturally but also as regards the choice of materials and design, daylighting etc. The indoor environment should be characterised by light, airiness, aesthetic and space. The beautiful natural surroundings should be taken advantage through the windows, the size and alignment of which are important.*

*Given that Stockholm is a multicultural city with many creeds represented, allowance must be made for neutrality in the choice of adornments. Peace, tranquillity and the possibility of privacy for mourners while waiting must also characterise the design of the building, so that funeral parties and mourners can enjoy privacy while at the same time being able to view the natural surroundings.*

*The work environment must be of optimal technical design, the aim being for the logistics to facilitate all handling and* *moving of coffins from reception for conveyance to incinerators and from incinerators to urn storage. The personnel facilities planned should conform to the same guidelines as the above regarding the indoor environment.”* [on page 20 of the full competition brief]

*”For administrative purposes there is to be a terminal for registration and reception for urn collection, combined with a workstation and a manager’s office, plus a lunch room with seating for at least six persons. An office and a small staff room are also to be provided in conjunction with registration and reception. The crematory staff comprise a crematory manager and a workforce of three or four technicians who are to have appropriate personnel facilities of their own (two changing rooms with showers) in the new crematory.*

*Health and safety considerations are very important in a modern crematory. Heavy lifting is to be done with trucks. Noise must fall short of current limit values by a generous margin. The working premises must be well-lit, properly ventilated and suitably decorated.*

*A separate space for recharging and overnight parking of three electrically powered trucks is to be provided within the building. In or adjoining the new crematory there are to be lock-up garages with recharging stations for an electrically powered vehicle which will be used for conveying coffins between the new and the existing crematories and for two smaller electrically powered vehicles.*

*Provision is to be made for the possibility of a future enlargement. The incinerators and cleaning equipment are to be replaceable should the need arise.”* [on page 22-23 of the full competition brief]

*”All spaces where coffins are handled, from reception to ash collection, should be on the same level together with other facilities. Technical services such as fan room, heat recovery etc. can be installed one storey above or below the crematory spaces. The logistical chart is a guide to the main functional connections. In addition to this, the architect’s brief is to solve the layout of the building in such a way as to provide high-quality spaces both for funeral parties and for the staff whose daily work takes place in the building.*

*The coffins arrive at the Woodland Cemetery mainly by road (funeral contractors). Most deliveries are made directly to the new crematory.”* [on page 24 of the full competition brief]

*”Staff and families are to have a separate entrance to the building, separated from the coffin reception bay. If possible, a separate entrance for families should be considered. Visitor parking space must also be provided there.*

*Families coming to the new crematory may have specially requested to attend the insertion of the coffin into the incinerator or to be present when the urn is released. Those waiting while cremation is in progress will need a private waiting room. For ethical reasons it should be made possible to segregate one of the incinerators on the coffin intake side from the others or possibly to provide an onlooking room from which the incinerator and insertion of the coffin into it can be witnessed. Families wishing to take part in the cremation will not be allowed access to the rear of the incinerator.”* [on page 24-25 of the full competition brief]

*”The building must be adapted to Nordic conditions and low energy losses aimed for. The crematory will be technically very advanced as regards recovery of energy from the processes. The project also includes advanced technical solutions with regard to environmental friendliness and low refrigeration plant costs. The exact cremation, recovery and cooling systems to be used are under investigation and will be indicated in the planning phase following the competition.”* [on page 25 of the full competition brief]

*”In its funding request to the Stockholm City Council, the Cemeteries Administration has quoted a total capital cost for the realisation of a new crematory and certain supplementary works in the existing crematorium. The following figures can be taken as guidelines, to give entrants a financial frame of reference on the financial conditions which the Cemeteries Administration will be working to.*

*- Process works, crematory technology: MSEK 35*
*- Construction costs: MSEK 50*

*Running and maintenance costs have a very important bearing on the long-term economics of the building, which means that care must be devoted to the choice of materials, structure and energy supply and also to generality, space effectiveness and flexibility.”* [on page 25 of the full competition brief]

*”TERMS OF THE COMPETITION*
*Competition promoter:*
*The Cemeteries Administration, Stockholm.*

*Form of the competition: This is a single-stage invited design competition, to be conducted in accordance with Sweden’s Public Procurement Act (Lagen om Offentlig Upphandling, LOU).”* [on page 26 in the full competition brief]

## INTRODUCTION

This appendix is a collection of all calculations related to the systems for the decomposition process as well as the benchmark crematorium LCA and the decomposition process LCA. These calculations are directly related to the circumstances and data of the House of Recomposition project report and hold many assumptions not suited as valid information for other situations. However, all calculations are based on the scenario where the decomposition chamber is not necessarily built underground, which is why some systems and aspects of the design is ignored (e.g. the lift transporting the compost from the extractor room to the transfer room). Furthermore, the calculations are based on and average of 20 interments per day.

The two LCAs will be focused primarily on operational energy (B2) but will still include production emissions (A1-A3) of the oven and decomposition chamber. When available, the LCAs will also include disposal (C4). To compare the two LCAs, we will calculate with a building lifetime of 100 years.

The crematorium oven benchmark will be based on an LCA by Dutch chain analyst and LCA expert from Rijksuniversiteit Groningen in the Netherlands, Elisabeth Keijzer. In this paper called The environmental impact of activities after life: life cycle assessment of funerals she thoroughly compares cremations to burials with all aspects included (material production, transport, disposal, visitor transport, etc.). Though this paper does also include an LCA of burials, only the data from the cremation will be used. Apart from the CO2-emissions from the burning of fuel and the energy won from heat recovery, all data for the benchmark crematorium LCA will be from Keijzer's paper.

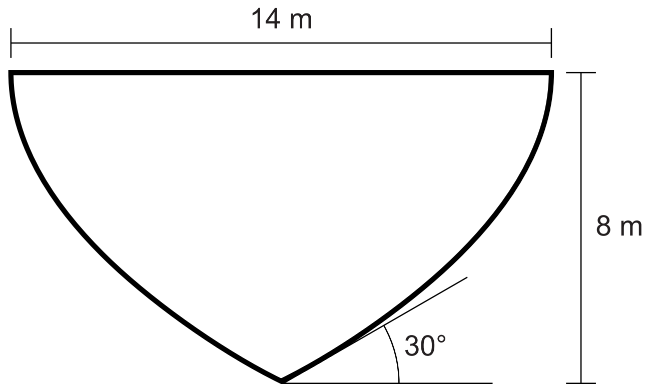
As stated in the report section about zero energy buildings, the energy gain from the methane and heat recovery will also be included in the LCA and factored by the grid emission factors of district electricity and heating.

## CALCULATIONS

**A-01. Carbon Material //** In order to successfully decompose organic material, 11.47 $m^3$ of composting material (sawdust and wood chips) must be added to every ton of bodyweight, as stated in the project report. We estimate an average body weight of 70 kg and a carbon material density of 380 kg/$m^3$ (AVCalc Limited Liability Company, n.d). This adds to 11.47 $m^3$ × 0,07 × 380 kg/$m^3$ = 305 kg composting material needed per interment.

**A-02. Gas and Ventilation //** As stated in the project report, the total emissions of the decomposition process add to 168 kg carbon dioxide, 8.1 kg methane, and 0.19 kg nitrous oxide per ton of composting material. With densities of 1.842 kg/$m^3$, 0.668 kg/$m^3$, and 1.826 kg/$m^3$ (The Engineering Toolbox, n.d.), respectively this adds to 168 kg × 1.842 kg/$m^3$ + 8.1 kg × 0.668 kg/$m^3$ + 0.19 kg × 1.826 kg/$m^3$ = 103.43 $m^3$ of gases per ton of compost, equal to 103,43 $m^3$ × 0.375 t = 38.79 $m^3$ of gas per interment. Our decomposition chamber is estimated to receive 20 new bodies per day and each decomposition chamber will last six weeks. With this knowledge, we can translate the previous amount of gases to 38.79 $m^3$ × 20 interments/d / 24 h/d = 32.33 $m^3$ of gas per hour from the chamber.

With the knowledge of gases produced per hour, the content of oxygen in outside air (21%), and the necessary per-




centage of oxygen in the chamber (10%) we can calculate the hourly supply of outside air via the dilution formula:

C1×V1 = C2×V2

V × 21 % = (V + 32.33 m$^{3)}$ × 10 %

V = 29.39 m$^3$/h

With the oxygen joining in the decomposition process, the remaining air must be ventilated out along with the gases produced by the process. The remaining air is now 79 % the volume of the original supply. Therefore the chamber must ventilate 33.32 m$^3$ + 29.39 m$^3$ × 79 % = 55.55 m$^3$.

**B-01. Chamber Volume** // With a density of the human body to approximately 1010 kg/m3 (The Engineering Toolbox, n.d.), we can calculate the volume of each body along with the added composting material to 70 kg / 1010 kg/m$^3$ + 0.803 m$^3$ = 0.872 m$^3$.

During the decomposition process, we assume that the only material lost is gas. Translating the aforementioned gases from the production into mass per interment, we get 66 kg. This, along with the earlier calculation of composting material, leaves the mass after the six weeks to 305 kg + 70 kg - 66 kg = 309 kg. We assume the density of the end result equal to that of regular compost: 600 kg/m$^3$ (Paul, 2009). This leaves the volume of the end result to 309 kg / 600 kg/m$^3$ = 0.515 m$^3$. Assuming a linear loss of mass over the six weeks and a constant of 20 new bodies added per day, this totals to an minimum chamber volume of 596 m$^3$.

With the requirement that the chamber walls must not slope under 30°, the decomposition chamber will be designed as follows with a volume of 663 m$^3$ and a surface area of 448 m$^2$ (See illustration above).

**B-02. Chamber Material** // Regarding the construction of the decomposition chamber, We will address two scenarios: one where the chamber walls and ceiling is made of concrete and one where it's made of steel:

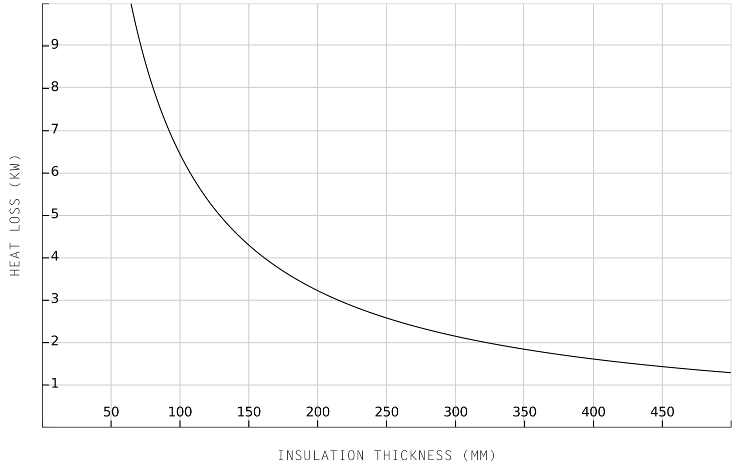
We estimate the thickness of the concrete walls to be the same as typical slurry tanks: 120 mm (Department of Agriculture, Food and the Marine, 2017). This equals to a total reinforced concrete volume of 120 mm × 488 m$^3$ = 53.76 m$^3$. With an emission factor of 447.71 kg$CO_2$eq/m$^3$ (IBU, 2017), this results in a footprint of 24,069 kg$CO_2$eq over 100 years.

For steel, the thickness is estimated equal that of tank trucks: 5 mm (RP-Koneet, 2018) and with a steel density of 7850 kg/m$^3$ (The Engineering Toolbox, n.d) and an emission factor of 3550 kg$CO_2$eq/t (IBU, 2014), the steel construction costs 62,423 kg$CO_2$eq over 100 years.

With the significantly lower emissions from the concrete walls, this is what the chamber will be built from.

**B-03. Chamber Coating** // To ensure that the chamber is completely sealing, an epoxy coating will be applied to the inside of the walls. This is also to ensure, that the compost will not stick to the walls. We estimate that the coating will have the same thickness as water storage tanks: 800 µm (Fischer, n.d.). With an density of 1250 kg/m$^3$ (The Engineering Toolbox, n.d), this equals to 800 µm × 448 m2 × 1250 kg/m$^3$ = 448 kg = 0.61 g/interment.

**C-01. Heat Recovery and Chamber Insulation** // According to the Crematorium Energy Recovery Project from Redditch Borough Council, England from 2011, an average 80 minute cremation generates 300 kW of waste heat (Red




ditch Borough Council, 2011) equal to 400 kWh per interment. With an assumed recovery efficiency in the ventilation system of 80 %, 400 kWh × 0.08 = 320 kWh of heat energy is recovered.

In relation to the decomposition process, a study from the Institute of Heating and Ventilation of Warsaw University of Technology concludes that compost will generate an average of 1136 kJ/kg through all stages of the decomposition (Klejment and Rosiński, 2008). With the previously calculated compost volume of 596 $m^3$ in the chamber and a compost density of 600 kg/$m^3$, 406 GJ is generated for every batch. With a decomposition time of 6 weeks, this translates to 112 kW from the decomposition process.

To calculate the amount of heat that is possible to recover, we must first calculate the heat loss through the chamber walls via Q = U × A × Δt. When calculating the U-value, it is interesting to notice that it is inversely proportional to the thickness of the insulation material. This means that the increase in embedded emissions of the insulation material will at some point outweigh the decrease of heat loss through the chamber.

The area we already know to be 448 $m^2$ as calculated earlier and the temperature will go from 50°C inside (optimal temp.) to 10°C outside in the surrounding earth.

For the chamber wall construction, we use the previously calculated 120mm reinforced concrete with a thermal transmittance of 12 W/m2K (İbrahim, 2015) and a layer of rigid foamglass insulation. This material is made from upcycled waste glass and provides sufficient pressure resistance. It has a thermal transmittance of 0,036 W/mK (Owens Corning, 2018). From here, we can plot the relation between insulation thickness and heat loss as seen above.

Using the foamglass density and emission factors of 115 kg/$m^3$ and 1.33 kg$CO_2$eq/kg respectively (IBU, 2015), we can combine different scenarios:

100 mm insulation = 6.4 kW heat loss = 6.8 t$CO_2$eq
200 mm insulation = 3.2 kW heat loss = 13.7 t$CO_2$eq
300 mm insulation = 2.1 kW heat loss = 27.4 t$CO_2$eq
400 mm insulation = 1.6 kW heat loss = 54.8 t$CO_2$eq

At around 300 mm insulation, the curve has started flattening out. This means that the increase in insulation thickness will have less of an impact on the decrease of heat loss while the increase of the embedded emission of the insulation material will remain proportional. We therefore deem that this thickness will balance the two factors sufficiently.

This results in a total heat recovery of 109.9 kW and total carbon footprint of 300 mm × 448 $m^2$ × 115 kg/$m^3$ × 1.33 kg$CO_2$eq/kg = 20.6 t$CO_2$eq.

**C-02. Methane Energy Production** // From earlier we can calculate that the decomposition process produces 4.55 $m^3$ of Methane per interment and according to the American Environmental Fabrication & supply, Natural gas generates 39 MJ/m3 (American Environmental Fabrication & supply, LLC, n.d.). The energy produced from burning waste Methane is therefore equal to:

4.55 $m^3$ × 39 MJ/$m^3$
= 177.45 MJ = 49.29 kWh

**C-03: Compressor** // The base of this data is an industrial compressor capable of supplying the chamber with the previously calculated required oxygen supply of 29.39 $m^3$/h. The chosen model G7-100 weighs 392 kg, produces an air flow of 43 cfm and has an energy consumption of 7.5 kW (AtlasCopco, 2016). The weight of the model we estimate to have the same ratio of steel vs. electrical components as the cremulator from Keijzers cremation LCA: 91.7 % steel and 8.3 % electrical components (keijzer, 2016). As an average industrial compressor has a lifetime of up to 60,000 hours (Purchasing, n.d.), our compressor is calculated to last for 60,000 h / (29.39 $m^3$/h / 43 cfm) × 24 h/d / 20 interments/d = 124,290 interments. Dividing the compressor material per interment we get:

392 kg × 91.7 % / 124.290 interments = 2.89 g steel per interment

392 kg × 8.3 % / 124.290 interments = 0.29 g electrical components per interment

As the minimum hourly supply of the compressor is higher than the required, we expect it to only be active periodically. This leaves an energy consumption per interment at 7.5 kW / (43 cfm / 29.39 $m^3$/h) × 24 h/d / 20 interments/d = 3.62 kWh.

The piping connected to the compressor is estimated to reach a combined length of 300 m and consist of an average cross section of 6.9 $cm^2$. With a steel density of 7850 kg/m3 (The Engineering Toolbox, n.d), this leaves a combined weight of 1.629 kg = 2.22 g/interment.

**C-04: Ventilator //** Same as the compressor, a ventilation system was chosen based on the required ventilation of 55.55 $m^3$/h. The chosen model - the COMPACT Air - weighs 331 kg and consists of 84 % steel, 4 % aluminium, 1 % Polymeric material, 6 % mineral wool, and 4 % electrical components (Swegon, 2009). This translates to:

331 kg × 84 % = 278.04 kg = 1.9 g/interment
331 kg × 4 % = 13.24 kg = 0.09 g/interment
331 kg × 1 % = 3.31 kg = 0.02 g/interment
331 kg × 6 % = 19.86 kg = 0.14 g/interment
331 kg × 4 % = 13.24 kg = 0.09 g/interment

Furthermore, this model uses 0.5 kW (Swegon, 2009).

**C-05: Extractor //** The extractor will be situated at the bottom of the decomposition chamber and work by a screw to controllably extract compost. The base of this data will be an industrial kitchen meat grinder as it work by a screw. The model chosen weighs 65 kg and can push through 7.3 kg per minute with an energy consumption of 1.1 kW (Hobart, 2017). Its lifetime is estimated to be that of the compressor: 60,000 hours. With the final weight of the compost being 309 kg per interment, the extractor will run for 42.3 minutes per composted body. Over the 60,000 hours, this equals 85,049 interments. Again, the ratio between steel and electrical components is estimated to be that of the cremulator: 91.7 % and 8.3 %, respectively. That leaves the weights of steel and electrical components to respectively:

65 kg × 91.7 % / 85,049 interments = 0.70 g/interment
65 kg × 8.3 % / 85,049 interments = 0.06 g/interment

As each extraction takes 42.3 minutes, each interment requires 1.1 kW × 42.3 minutes = 0.78 kWh.

**C-06: Shaft Hatch** // A typical steel hatch large enough to fit a person is estimated to weigh 40 kg (Acudor, n.d.). As out building has 11 opening in the top of the chamber, each with two sets of doors, the combined weight of hatches are 22 hatches × 40 kg = 880 kg = 0,0012 g/interment.

## APPENDIX 02

LIFE CYCLE ASSESMENT

### BENCHMARK CREMATION LCA

| | SOURCE | AMOUNT (PR. PROCESS) | UNIT | REFERENCE | EMISSION FACTOR VALUE | EMISSION FACTOR UNIT | EMISSION FACTOR REFERENCE | $KGCO_2EQ$ (PR. PROCESS) | $KGCO_2EQ$ (PR. 100 YEARS) |
|---|---|---|---|---|---|---|---|---|---|
| OPERATIONAL ENERGY | Cremation | 30 | kWh | (Keijzer, 2016) | 45 | $gCO_2eq/kWh$ | (Tomorrow, 2018) | 1.35 | 986,175 |
| | Ventilation | 25 | kWh | (Keijzer, 2016) | 45 | $gCO_2eq/kWh$ | (Tomorrow, 2018) | 1.13 | 821,813 |
| | Cremulator | 1 | kWh | (Keijzer, 2016) | 45 | $gCO_2eq/kWh$ | (Tomorrow, 2018) | 0.05 | 32,873 |
| | Heat recovery | -320 | kWh | C-01 | 65 | $gCO_2eq/kWh$ | (Stockholm Data Parks, 2017) | -20.88 | -15,252,840 |
| EMISSIONS | $CO_2$ (Body & coffin) | 40 | $g/m^3$ | (Keijzer, 2016) | 2,500 | $m^3$ | (Keijzer, 2016) | 100.00 | 73,050,000 |
| | $CO_2$ (Natural gas) | 32.2 | $m^3$ | (Inciner8, n.d.) | 117 | $lbsCO_2/MBtu$ | (EIA, 2017) | 65.37 | 46,291,785 |
| REPLACEMENT | Oven (steel) | 0.120 | kg | (Keijzer, 2016) | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.43 | 311,193 |
| | Oven (el. comp.) | 0.010 | kg | (Keijzer, 2016) | 10,26 | $kgCO_2eq/kg$ | (IBU, 2016) | 0.10 | 74,962 |
| | Oven (Refactory) | 0.400 | kg | (Keijzer, 2016) | 195,13 | $kgCO_2eq/t$ | (EPDDanmark, 2014) | 0.08 | 57,017 |
| | Ventilation (steel) | 0.416 | kg | (Keijzer, 2016) | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 1.48 | 1,078,802 |
| | Ventilation (copper) | 0.078 | kg | (Keijzer, 2016) | 1,88 | $kgCO_2eq/kg$ | (Ecoinvent, 2014) | 0.15 | 107,121 |
| | Ventilation (pvc) | 0.026 | kg | (Keijzer, 2016) | 2,82 | $kgCO_2eq/kg$ | (IBU, 2015) | 0.07 | 53,503 |
| | Cremulator (steel) | 0.011 | kg | (Keijzer, 2016) | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.04 | 28,526 |
| | Cremulator (el. comp.) | 0.001 | kg | (Keijzer, 2016) | 10,26 | $kgCO_2eq/kg$ | (IBU, 2016) | 0.01 | 7,496 |
| | | | | | | | **Total $kgCO_2eq$:** | **147.36** | **107,648,425,395** |

# APPENDIX 02

LIFE CYCLE ASSESMENT

## DECOMPOSITON LCA

| | SOURCE | AMOUNT | UNIT | REFERENCE | EMISSION FACTOR | | | $KGCO_2EQ$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | (PR. PROCESS) | | | VALUE | UNIT | REFERENCE | (PR. PROCESS) | (PR. 100 YEARS) |
| OPERATIONAL ENERGY | Compressor | 3.62 | kWh | C-03 | 45 | $gCO_2eq/kWh$ | (Tommorow, 2018) | 0.16 | 119,017 |
| | Ventilator | 0.60 | kWh | C-04 | 45 | $gCO_2eq/kWh$ | (Tommorow, 2018) | 0.03 | 19,724 |
| | Extractor | 0.78 | kWh | C-05 | 45 | $gCO_2eq/kWh$ | (Tommorow, 2018) | 0.03 | 25,510 |
| | Methane recovery | -49.29 | kWh | C-02 | 45 | $gCO_2eq/kWh$ | (Tommorow, 2018) | -2.22 | -1,620,342 |
| | Heat recovery | -131.76 | kWh | C-01 | 65 | $gCO_2eq/kWh$ | (Stockholm Data Parks, 2017) | -8.60 | -6,280,315 |
| EMIS-SIONS | $CO_2$ (bio plant) | 117.45 | MJ | C-02 | 117 | $lbsCO_2eq/MBtu$ | (EIA, 2017) | 8.93 | 6,523,365 |
| | $CO_2$ (flue gas) | 63.00 | kg | A-02 | - | - | - | 63.00 | 46,021,500 |
| | $(NO_2)$ | 0.071 | kg | A-02 | 265 | $kgCO_2eq$ | (GHG Protocol, 2016) | 18.88 | 13,792,753 |
| REPLACEMENT | Chamber (concrete) | - | - | B-02 | 447.71 | $kgCO_2eq/m^3$ | (IBU, 2017) | 0.03 | 24,069 |
| | Chamber (insulation) | - | - | C-01 | 1.33 | $kgCO_2eq/kg$ | (IBU, 2015) | 0.03 | 20,556 |
| | Chamber (coating) | 0.61 | g | B-03 | 3.28 | $kgCO_2eq/kg$ | (IBU, 2015) | 0.00 | 1,469 |
| | Compressor (steel) | 2.892 | g | C-03 | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.01 | 7,500 |
| | Compressor (el. comp.) | 0.262 | g | C-03 | 10.26 | $kgCO_2eq/kg$ | (IBU, 2016) | 0.00 | 1,962 |
| | Compressor (piping) | 0.285 | $cm^3$ | C-03 | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.01 | 5,796 |
| | Ventilator (steel) | 1.903 | g | C-04 | 3,550 | $kgCO_2eq/t$ | (IBU, 2014 | 0.0 | 4,935 |
| | Ventilator (aluminium) | 0.091 | g | C-04 | 8.60 | $kgCO_2eq/kg$ | (Ecoinvent, 2014) | 0.00 | 569 |
| | Ventilator (polymeric) | 0.023 | g | C-04 | 1.97 | $kgCO_2eq/kg$ | (Ecoinvent, 2014) | 0.00 | 33 |
| | Ventilator (insulation) | 0.136 | g | C-04 | 1.39 | $kgCO_2eq/kg$ | (Ecoinvent, 2014) | 0.00 | 138 |
| | Ventilator (el. comp.) | 0.091 | g | C-04 | 10.26 | $kgCO_2eq/kg$ | (IBU, 2016) | 0.00 | 679 |
| | Extractor (steel) | 0.701 | g | C-05 | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.00 | 1,817 |
| | Extractor (el. comp.) | 0..063 | g | C-05 | 10.26 | $kgCO_2eq/kg$ | (IBU, 2016) | 0.00 | 4,76 |
| | Shaft lift (steel) | 5.000 | g | (Keijzer, 2016) | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.02 | 12,966 |
| | Shaft hatch (steel) | 1.205 | g | C-06 | 3,550 | $kgCO_2eq/t$ | (IBU, 2014) | 0.00 | 3,124 |
| | | | | | | | **Total $kgCO_2eq$:** | **80.34** | **58,687,303** |

## CONCLUSION

In the end, it is clear to see that the decomposition process is the better option with 67 less kgCO2eq per interment. It is, however, interesting to notice that the energy production from waste heat is significantly greater from the crematorium than that of the decomposition process and the energy production from the methane combined. But, in the end, this aspect is still undermined by the equally large amount of greenhouse gases released directly by the burning process. Production emissions of the two systems also vary greatly from 2.35 kgCO2eq/interment of the cremation oven to 0.13 kgCO2eq/interment. Of course, this is due to the short lifespan of a cremation oven (approx. 25000 cremation according to Keijzer = 13.7 years). Had the lifespan of the decomposition chamber been assumed to less than 100 years, the results would not be as significant. Lastly, the energy consumption - when not counting energy recovery - is far greater from the cremation process than the decomposition process; 56 kWh and 5 kWh respectively. This is of course due to the fact that the decomposition relies heavily on passive processes although the downside is the far longer process duration.

As a note: In both scenarios, filters would be installed to prevent these emissions but as we ignore it in both cases, we can still compare them. This also means, that these LCAs are not to be used as valid sources for anything else than their intended purpose as stated in the beginning of the document.

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# APPENDIX 03

## ACOUSTICS

| Iterations | Receiver | Reverberation Time_T-30 (s) | | | | | | | | Definition (%) | | | | | | | | Overall | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Target: | | | | 1 | - | 1,6 | | | | | Target: | 60 | | | | | | | |
| | | 62,5 hz | 125 hz | 250 hz | 500 hz | 1000 hz | 2000 hz | 4000 hz | 8000 hz | 62,5 hz | 125 hz | 250 hz | 500 hz | 1000 hz | 2000 hz | 4000 hz | 8000 hz | Reverberation | Definition | Total | |
| Control_01: 3b | 0 | 1,04 | 1,07 | 1,36 | 1,89 | 3,66 | 3,24 | 3,00 | 2,54 | 60 | 63 | 65 | 65 | 69 | 68 | 66 | 62 | -35 | 3 | -16 | Although the reverberation time vary too much, the values for reverberation and definition are both within an average of 4% different between the controls. |
| | 1 | 1,08 | 1,15 | 1,48 | 2,01 | 3,76 | 3,30 | 3,07 | 2,59 | 60 | 64 | 66 | 68 | 69 | 69 | 68 | 66 | | | | |
| | 2 | 1,07 | 1,13 | 1,43 | 1,99 | 3,63 | 3,28 | 2,99 | 2,58 | 58 | 61 | 61 | 61 | 58 | 59 | 58 | 57 | | | | |
| | 3 | 1,07 | 1,14 | 1,50 | 2,03 | 3,94 | 3,51 | 3,22 | 2,70 | 57 | 60 | 60 | 59 | 57 | 57 | 57 | 56 | | | | |
| Control_02: 3b | 0 | 1,04 | 1,07 | 1,36 | 1,85 | 3,57 | 3,23 | 2,92 | 2,43 | 60 | 63 | 64 | 64 | 69 | 69 | 66 | 62 | -34 | 3 | -15 | |
| | 1 | 1,08 | 1,11 | 1,39 | 1,91 | 3,84 | 3,49 | 3,11 | 2,61 | 60 | 64 | 67 | 68 | 70 | 70 | 68 | 66 | | | | |
| | 2 | 1,08 | 1,12 | 1,42 | 1,90 | 3,68 | 3,29 | 2,98 | 2,53 | 58 | 61 | 61 | 61 | 59 | 59 | 58 | 57 | | | | |
| | 3 | 1,07 | 1,13 | 1,46 | 1,95 | 3,86 | 3,45 | 3,15 | 2,58 | 57 | 60 | 60 | 59 | 57 | 57 | 57 | 56 | | | | |
| Control_03: 3b | 0 | 1,04 | 1,07 | 1,36 | 1,87 | 3,66 | 3,36 | 2,93 | 2,46 | 60 | 63 | 65 | 65 | 69 | 69 | 66 | 62 | -39 | 3 | -18 | |
| | 1 | 1,07 | 1,12 | 1,42 | 1,93 | 4,01 | 3,63 | 3,19 | 2,68 | 60 | 64 | 66 | 68 | 69 | 69 | 68 | 66 | | | | |
| | 2 | 1,08 | 1,14 | 1,46 | 1,99 | 3,85 | 3,44 | 3,16 | 2,72 | 58 | 61 | 61 | 61 | 58 | 59 | 58 | 57 | | | | |
| | 3 | 1,07 | 1,13 | 1,51 | 2,10 | 4,17 | 3,78 | 3,39 | 2,80 | 58 | 60 | 60 | 59 | 56 | 57 | 57 | 56 | | | | |
| 3b_NewMat. | 0 | 2,87 | 1,67 | 0,84 | 0,65 | 0,41 | 0,27 | 0,34 | 0,46 | 42 | 56 | 72 | 79 | 92 | 97 | 92 | 85 | -23 | -4 | -13 | With more high frequency absorption on the walls, the reverberation time is now too low on the higher frequencies and too high on the lower. I will ajust materials further. |
| | 1 | 3,05 | 1,79 | 0,91 | 0,72 | 0,43 | 0,26 | 0,36 | 0,50 | 40 | 56 | 74 | 82 | 93 | 98 | 94 | 87 | | | | |
| | 2 | 3,03 | 1,79 | 0,90 | 0,71 | 0,43 | 0,27 | 0,36 | 0,48 | 37 | 52 | 70 | 78 | 90 | 97 | 92 | 85 | | | | |
| | 3 | 3,03 | 1,78 | 0,91 | 0,72 | 0,47 | 0,28 | 0,39 | 0,49 | 37 | 51 | 69 | 77 | 89 | 97 | 92 | 84 | | | | |
| 3b_NewNewMat. | 0 | 2,02 | 1,16 | 0,72 | 0,66 | 0,49 | 0,41 | 0,45 | 0,63 | 46 | 62 | 75 | 79 | 90 | 92 | 88 | 80 | -12 | -3 | -7 | The reverberation time is now more balanced, though still not enough. Definition likewise. I will try with another material on the lower part of the walls. |
| | 1 | 2,14 | 1,22 | 0,79 | 0,75 | 0,52 | 0,41 | 0,47 | 0,73 | 46 | 63 | 77 | 82 | 92 | 93 | 90 | 83 | | | | |
| | 2 | 2,14 | 1,23 | 0,75 | 0,70 | 0,51 | 0,43 | 0,47 | 0,68 | 42 | 59 | 74 | 78 | 88 | 90 | 87 | 79 | | | | |
| | 3 | 2,12 | 1,23 | 0,75 | 0,71 | 0,53 | 0,45 | 0,49 | 0,69 | 41 | 58 | 73 | 77 | 86 | 89 | 86 | 78 | | | | |
| 3b_NewNewNew-Mat. | 0 | 1,69 | 1,22 | 1,29 | 1,74 | 2,60 | 2,46 | 2,39 | 2,12 | 55 | 67 | 74 | 75 | 77 | 78 | 77 | 74 | -11 | 0 | -5 | This combination of materials show very nice results in reverberationm although still a bit low definition. I will use these materials for the geometry iterations. |
| | 1 | 1,74 | 1,27 | 1,30 | 1,70 | 2,65 | 2,45 | 2,42 | 2,05 | 53 | 66 | 75 | 77 | 78 | 79 | 78 | 76 | | | | |
| | 2 | 1,73 | 1,27 | 1,29 | 1,67 | 2,40 | 2,26 | 2,21 | 2,02 | 55 | 67 | 74 | 75 | 74 | 75 | 75 | 74 | | | | |
| | 3 | 1,76 | 1,31 | 1,36 | 1,78 | 2,57 | 2,46 | 2,37 | 2,15 | 50 | 60 | 66 | 66 | 62 | 63 | 64 | 65 | | | | |
| 2a | 0 | 1,61 | 1,16 | 1,29 | 1,73 | 2,64 | 2,53 | 2,39 | 2,13 | 56 | 68 | 76 | 77 | 77 | 78 | 78 | 76 | -14 | 0 | -7 | The results are only slightly worse than the flat celing - 3b. |
| | 1 | 1,61 | 1,21 | 1,36 | 1,80 | 2,59 | 2,56 | 2,41 | 2,15 | 53 | 66 | 75 | 77 | 77 | 78 | 78 | 76 | | | | |
| | 2 | 1,52 | 1,20 | 1,37 | 1,79 | 2,70 | 2,76 | 2,59 | 2,25 | 57 | 70 | 77 | 78 | 75 | 76 | 76 | 76 | | | | |
| | 3 | 1,69 | 1,26 | 1,36 | 1,83 | 2,63 | 2,58 | 2,37 | 2,18 | 49 | 60 | 66 | 66 | 62 | 63 | 64 | 64 | | | | |
| 4c | 0 | 1,56 | 1,15 | 1,16 | 1,55 | 2,48 | 2,35 | 2,21 | 1,91 | 46 | 58 | 67 | 70 | 76 | 76 | 74 | 69 | -12 | -3 | -7 | |
| | 1 | 1,57 | 1,20 | 1,34 | 1,74 | 2,46 | 2,39 | 2,27 | 2,04 | 45 | 57 | 68 | 72 | 76 | 77 | 75 | 71 | | | | |
| | 2 | 1,59 | 1,19 | 1,28 | 1,68 | 2,71 | 2,51 | 2,36 | 2,01 | 49 | 61 | 70 | 72 | 73 | 74 | 74 | 71 | | | | |
| | 3 | 1,62 | 1,21 | 1,30 | 1,70 | 2,73 | 2,62 | 2,43 | 2,17 | 37 | 48 | 57 | 59 | 60 | 61 | 60 | 57 | | | | |
| 1a | 0 | 1,44 | 1,12 | 1,25 | 1,70 | 2,65 | 2,52 | 2,37 | 2,07 | 53 | 65 | 73 | 75 | 77 | 78 | 77 | 73 | -14 | -2 | -8 | |
| | 1 | 1,43 | 1,17 | 1,40 | 1,81 | 2,79 | 2,61 | 2,51 | 2,14 | 52 | 64 | 73 | 76 | 77 | 78 | 78 | 75 | | | | |
| | 2 | 1,41 | 1,14 | 1,34 | 1,74 | 2,54 | 2,57 | 2,33 | 2,04 | 57 | 68 | 75 | 76 | 74 | 75 | 76 | 75 | | | | |
| | 3 | 1,46 | 1,18 | 1,36 | 1,81 | 2,65 | 2,53 | 2,39 | 2,18 | 41 | 52 | 60 | 61 | 61 | 62 | 62 | 60 | | | | |
| 4a | 0 | 1,60 | 1,18 | 1,22 | 1,60 | 2,59 | 2,45 | 2,31 | 2,00 | 53 | 64 | 72 | 74 | 77 | 77 | 76 | 73 | -12 | -1 | -7 | |
| | 1 | 1,63 | 1,25 | 1,36 | 1,81 | 2,69 | 2,60 | 2,45 | 2,18 | 51 | 63 | 73 | 75 | 76 | 77 | 76 | 74 | | | | |
| | 2 | 1,61 | 1,22 | 1,31 | 1,73 | 2,72 | 2,63 | 2,47 | 2,12 | 57 | 68 | 75 | 76 | 74 | 75 | 76 | 75 | | | | |
| | 3 | 1,61 | 1,21 | 1,24 | 1,64 | 2,65 | 2,48 | 2,37 | 2,06 | 43 | 54 | 61 | 61 | 60 | 61 | 61 | 60 | | | | |
| 3a_10m | 0 | 1,94 | 1,29 | 1,22 | 1,59 | 2,51 | 2,30 | 2,15 | 1,94 | 52 | 65 | 74 | 75 | 77 | 78 | 77 | 74 | -12 | -1 | -7 | |
| | 1 | 2,03 | 1,39 | 1,37 | 1,73 | 2,72 | 2,50 | 2,33 | 2,01 | 47 | 61 | 72 | 75 | 77 | 78 | 77 | 74 | | | | |
| | 2 | 2,02 | 1,36 | 1,23 | 1,60 | 2,75 | 2,46 | 2,31 | 1,97 | 49 | 62 | 71 | 73 | 74 | 74 | 74 | 72 | | | | |
| | 3 | 2,03 | 1,36 | 1,33 | 1,71 | 2,36 | 2,24 | 2,12 | 2,01 | 42 | 54 | 62 | 63 | 61 | 62 | 62 | 61 | | | | |
| 3c_5m | 0 | 1,44 | 1,14 | 1,19 | 1,54 | 2,61 | 2,39 | 2,26 | 1,94 | 61 | 71 | 77 | 78 | 78 | 79 | 79 | 77 | -15 | 2 | -6 | This iterations has the best score on definition so far in both spread and closeness to target. Reverberation is still too low but can be fixed with materials. |
| | 1 | 1,49 | 1,21 | 1,35 | 1,74 | 2,64 | 2,51 | 2,35 | 2,03 | 61 | 71 | 78 | 79 | 77 | 79 | 79 | 78 | | | | |
| | 2 | 1,47 | 1,20 | 1,28 | 1,68 | 2,81 | 2,62 | 2,45 | 2,00 | 64 | 73 | 78 | 79 | 76 | 77 | 78 | 78 | | | | |
| | 3 | 1,52 | 1,24 | 1,30 | 1,67 | 2,94 | 2,74 | 2,45 | 2,02 | 58 | 66 | 70 | 70 | 63 | 65 | 67 | 68 | | | | |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7c | 0 | 1,22 | 0,90 | 0,69 | 0,60 | 0,58 | 0,54 | 0,56 | 0,61 | 40 | 52 | 64 | 70 | 81 | 83 | 79 | 71 | -2 | -3 | -2 | |
| | 1 | 1,24 | 0,89 | 0,67 | 0,56 | 0,50 | 0,50 | 0,50 | 0,55 | 51 | 63 | 73 | 79 | 87 | 87 | 85 | 80 | | | | |
| | 2 | 1,23 | 0,89 | 0,66 | 0,56 | 0,49 | 0,49 | 0,50 | 0,54 | 53 | 65 | 74 | 79 | 85 | 86 | 84 | 80 | | | | |
| | 3 | 1,23 | 0,90 | 0,70 | 0,63 | 0,83 | 0,78 | 0,72 | 0,70 | 45 | 58 | 70 | 75 | 82 | 83 | 81 | 76 | | | | |
| 7b | 0 | 1,41 | 1,00 | 0,76 | 0,67 | 0,67 | 0,64 | 0,64 | 0,67 | 43 | 54 | 65 | 68 | 75 | 77 | 75 | 68 | -3 | -2 | -2 | |
| | 1 | 1,44 | 1,05 | 0,79 | 0,65 | 0,50 | 0,47 | 0,52 | 0,63 | 51 | 61 | 69 | 74 | 77 | 79 | 78 | 74 | | | | |
| | 2 | 1,40 | 1,02 | 0,78 | 0,66 | 0,53 | 0,50 | 0,54 | 0,64 | 55 | 64 | 72 | 77 | 83 | 85 | 83 | 78 | | | | |
| | 3 | 1,41 | 1,01 | 0,77 | 0,71 | 0,92 | 0,82 | 0,78 | 0,75 | 44 | 56 | 65 | 67 | 68 | 70 | 69 | 66 | | | | |
| 7b_mirrored | 0 | 1,39 | 0,99 | 0,75 | 0,65 | 0,59 | 0,56 | 0,57 | 0,65 | 48 | 59 | 68 | 72 | 77 | 78 | 77 | 72 | -3 | -1 | -2 | |
| | 1 | 1,40 | 1,01 | 0,76 | 0,63 | 0,53 | 0,50 | 0,53 | 0,62 | 54 | 65 | 74 | 77 | 80 | 81 | 81 | 77 | | | | |
| | 2 | 1,40 | 1,00 | 0,75 | 0,64 | 0,51 | 0,47 | 0,52 | 0,62 | 57 | 68 | 76 | 81 | 86 | 87 | 86 | 82 | | | | |
| | 3 | 1,37 | 0,98 | 0,78 | 0,72 | 0,74 | 0,68 | 0,68 | 0,73 | 46 | 58 | 67 | 70 | 72 | 73 | 72 | 69 | | | | |
| Saddle | 0 | 1,45 | 1,09 | 1,24 | 1,81 | 3,58 | 3,34 | 3,00 | 2,47 | 54 | 64 | 70 | 72 | 72 | 72 | 72 | 70 | -34 | 0 | -17 | No. It's shit. |
| | 1 | 1,50 | 1,12 | 1,27 | 1,87 | 3,77 | 3,47 | 3,18 | 2,54 | 51 | 63 | 71 | 73 | 72 | 73 | 73 | 71 | | | | |
| | 2 | 1,50 | 1,15 | 1,37 | 2,03 | 3,82 | 3,52 | 3,18 | 2,66 | 48 | 58 | 65 | 66 | 62 | 63 | 64 | 64 | | | | |
| | 3 | 1,45 | 1,10 | 1,33 | 1,90 | 3,77 | 3,40 | 3,18 | 2,58 | 47 | 56 | 63 | 64 | 59 | 60 | 61 | 62 | | | | |
| Saddle_reversed | 0 | 1,38 | 1,03 | 1,20 | 1,68 | 3,45 | 3,15 | 2,84 | 2,31 | 53 | 64 | 71 | 72 | 72 | 72 | 72 | 70 | -35 | 2 | -16 | Still shit. |
| | 1 | 1,42 | 1,10 | 1,39 | 1,94 | 3,89 | 3,49 | 3,20 | 2,46 | 54 | 65 | 73 | 74 | 72 | 73 | 74 | 72 | | | | |
| | 2 | 1,44 | 1,11 | 1,38 | 1,95 | 3,79 | 3,50 | 3,17 | 2,63 | 61 | 70 | 73 | 72 | 63 | 64 | 67 | 69 | | | | |
| | 3 | 1,39 | 1,07 | 1,37 | 2,01 | 3,71 | 3,48 | 3,15 | 2,59 | 54 | 63 | 67 | 66 | 59 | 60 | 62 | 63 | | | | |
| 3a_NewMat. | 0 | 1,72 | 1,03 | 0,56 | 0,51 | 0,50 | 0,67 | 0,94 | 2,03 | 50 | 66 | 83 | 86 | 89 | 86 | 80 | 69 | -10 | -3 | -6 | Decent definition values but too spread. Reverberation is WAY to spread. |
| | 1 | 1,80 | 1,07 | 0,58 | 0,53 | 0,58 | 0,75 | 1,06 | 2,28 | 45 | 62 | 81 | 84 | 90 | 87 | 82 | 70 | | | | |
| | 2 | 1,82 | 1,07 | 0,60 | 0,54 | 0,55 | 0,72 | 1,05 | 2,37 | 44 | 62 | 84 | 86 | 87 | 82 | 76 | 63 | | | | |
| | 3 | 1,77 | 1,04 | 0,59 | 0,54 | 0,56 | 0,73 | 1,07 | 2,26 | 41 | 59 | 84 | 86 | 84 | 80 | 73 | 60 | | | | |
| 2a_final-ish | 0 | 1,65 | 1,07 | 0,66 | 0,63 | 0,55 | 0,71 | 0,96 | 2,01 | 57 | 72 | 86 | 89 | 94 | 91 | 88 | 79 | -8 | -5 | -6 | Reverberation is a bit high in the lower and high frequencies. Definition has high values, but is very low in the lower frequencies. |
| | 1 | 1,70 | 1,13 | 0,71 | 0,69 | 0,56 | 0,70 | 1,02 | 2,23 | 50 | 65 | 80 | 85 | 90 | 87 | 82 | 72 | | | | |
| | 2 | 1,70 | 1,11 | 0,71 | 0,70 | 0,58 | 0,75 | 1,09 | 2,21 | 54 | 68 | 81 | 84 | 91 | 88 | 83 | 73 | | | | |
| | 3 | 1,63 | 1,07 | 0,62 | 0,59 | 0,53 | 0,72 | 1,09 | 2,26 | 35 | 50 | 71 | 74 | 81 | 77 | 70 | 57 | | | | |
| 2a_final-ish_ tweaked materials | 0 | 2,36 | 1,44 | 0,87 | 0,75 | 0,48 | 0,42 | 0,48 | 0,66 | 57 | 70 | 81 | 85 | 95 | 97 | 94 | 88 | -15 | -5 | -10 | Worse.... |
| | 1 | 2,44 | 1,48 | 0,91 | 0,78 | 0,44 | 0,38 | 0,46 | 0,69 | 46 | 59 | 71 | 77 | 91 | 94 | 89 | 80 | | | | |
| | 2 | 2,37 | 1,49 | 0,89 | 0,77 | 0,48 | 0,40 | 0,48 | 0,70 | 50 | 63 | 75 | 80 | 92 | 94 | 90 | 83 | | | | |
| | 3 | 2,48 | 1,55 | 0,86 | 0,73 | 0,46 | 0,37 | 0,45 | 0,63 | 32 | 43 | 57 | 64 | 84 | 90 | 82 | 69 | | | | |
| 2a_final-ish_wood floor | 0 | 1,29 | 1,11 | 1,29 | 1,77 | 3,45 | 3,18 | 2,82 | 2,35 | 65 | 72 | 78 | 79 | 79 | 79 | 79 | 78 | -35 | -3 | -19 | Definition generally lower.. |
| | 1 | 1,33 | 1,15 | 1,38 | 1,94 | 3,65 | 3,43 | 3,09 | 2,61 | 54 | 62 | 69 | 70 | 71 | 72 | 72 | 70 | | | | |
| | 2 | 1,34 | 1,14 | 1,32 | 1,95 | 3,92 | 3,63 | 3,23 | 2,76 | 59 | 66 | 72 | 73 | 72 | 73 | 73 | 71 | | | | |
| | 3 | 1,28 | 1,10 | 1,37 | 1,96 | 3,87 | 3,56 | 3,19 | 2,62 | 38 | 45 | 53 | 55 | 57 | 58 | 57 | 54 | | | | |
| 2a_final-ish_ tweaked materi-als_again | 0 | 1,48 | 1,23 | 1,22 | 1,72 | 3,29 | 3,00 | 2,69 | 2,30 | 58 | 67 | 75 | 78 | 79 | 80 | 80 | 78 | -29 | -3 | -16 | |
| | 1 | 1,55 | 1,29 | 1,38 | 1,92 | 3,67 | 3,41 | 2,88 | 2,56 | 51 | 59 | 67 | 71 | 71 | 73 | 72 | 71 | | | | |
| | 2 | 1,53 | 1,27 | 1,33 | 1,94 | 3,52 | 3,40 | 3,02 | 2,70 | 51 | 59 | 68 | 72 | 73 | 74 | 73 | 72 | | | | |
| | 3 | 1,47 | 1,23 | 1,35 | 1,95 | 3,61 | 3,38 | 3,01 | 2,65 | 38 | 46 | 54 | 57 | 57 | 59 | 59 | 58 | | | | |
| 2a_final-ish_ tweaked materi-als_again_again | 0 | 1,88 | 1,26 | 0,84 | 0,74 | 0,51 | 0,42 | 0,48 | 0,65 | 54 | 66 | 78 | 84 | 94 | 95 | 93 | 87 | -10 | -5 | -7 | |
| | 1 | 1,97 | 1,31 | 0,88 | 0,76 | 0,48 | 0,39 | 0,44 | 0,65 | 47 | 59 | 72 | 78 | 90 | 92 | 89 | 82 | | | | |
| | 2 | 1,98 | 1,32 | 0,88 | 0,76 | 0,49 | 0,41 | 0,45 | 0,67 | 47 | 59 | 72 | 78 | 91 | 92 | 88 | 82 | | | | |
| | 3 | 1,91 | 1,24 | 0,83 | 0,73 | 0,49 | 0,42 | 0,47 | 0,64 | 34 | 45 | 61 | 68 | 84 | 88 | 84 | 73 | | | | |
| 2a_final-ish_least aborbant ma-terials | 0 | 1,07 | 1,19 | 1,43 | 1,68 | 2,73 | 2,50 | 2,32 | 2,03 | 68 | 65 | 59 | 56 | 48 | 50 | 51 | 53 | -16 | -2 | -9 | Surprisingly low reverberation time, but very low definition values. |
| | 1 | 1,11 | 1,24 | 1,51 | 1,76 | 2,67 | 2,48 | 2,30 | 2,07 | 59 | 56 | 51 | 51 | 45 | 46 | 46 | 49 | | | | |
| | 2 | 1,12 | 1,25 | 1,50 | 1,72 | 2,64 | 2,45 | 2,30 | 2,05 | 60 | 57 | 52 | 50 | 43 | 44 | 45 | 48 | | | | |
| | 3 | 1,07 | 1,19 | 1,45 | 1,70 | 2,95 | 2,67 | 2,42 | 2,07 | 49 | 45 | 39 | 37 | 31 | 32 | 32 | 35 | | | | |
| 2a_final-ish_cur-tain | 0 | 1,89 | 1,35 | 1,14 | 1,56 | 3,12 | 2,88 | 2,64 | 2,20 | 50 | 61 | 72 | 77 | 79 | 83 | 82 | 79 | -27 | -5 | -16 | |
| | 1 | 2,03 | 1,40 | 1,16 | 1,60 | 3,45 | 3,33 | 2,90 | 2,35 | 41 | 52 | 64 | 70 | 73 | 77 | 76 | 73 | | | | |
| | 2 | 2,02 | 1,41 | 1,21 | 1,72 | 3,20 | 3,17 | 2,91 | 2,26 | 41 | 52 | 64 | 70 | 73 | 78 | 77 | 73 | | | | |
| | 3 | 1,88 | 1,32 | 1,21 | 1,77 | 3,40 | 3,16 | 2,86 | 2,32 | 30 | 40 | 52 | 57 | 58 | 61 | 61 | 59 | | | | |
| 2a_final-ish_ tweaked materi-als_again_again | 0 | 1,30 | 0,93 | 0,63 | 0,63 | 0,55 | 0,69 | 0,95 | 1,97 | 64 | 75 | 85 | 87 | 93 | 91 | 86 | 77 | -8 | -2 | -5 | If we ignore the initial geometry iteration (which were the wrong geometry), this iteration is the best so far. Reverberation is a little low and definition is good is most frequencies. |
| | 1 | 1,36 | 0,97 | 0,65 | 0,67 | 0,58 | 0,76 | 1,04 | 2,15 | 57 | 67 | 80 | 82 | 89 | 86 | 81 | 69 | | | | |
| | 2 | 1,38 | 0,97 | 0,66 | 0,66 | 0,57 | 0,71 | 0,98 | 2,10 | 57 | 67 | 76 | 79 | 90 | 87 | 81 | 70 | | | | |
| | 3 | 1,29 | 0,91 | 0,61 | 0,64 | 0,55 | 0,74 | 1,01 | 2,11 | 44 | 56 | 75 | 77 | 82 | 77 | 70 | 57 | | | | |
| 2a_final-ish_hard ceiling | 0 | 1,33 | 1,04 | 0,77 | 0,82 | 0,90 | 0,85 | 1,00 | 1,75 | 63 | 69 | 75 | 75 | 77 | 79 | 75 | 66 | 0 | -1 | 0 | Definition is a little worse, but reverberation is much better! |
| | 1 | 1,38 | 1,09 | 0,79 | 0,84 | 0,93 | 0,87 | 1,05 | 1,74 | 56 | 61 | 68 | 68 | 68 | 71 | 66 | 58 | | | | |
| | 2 | 1,38 | 1,10 | 0,80 | 0,86 | 0,95 | 0,88 | 1,03 | 1,78 | 56 | 61 | 64 | 64 | 66 | 69 | 65 | 57 | | | | |
| | 3 | 1,33 | 1,03 | 0,75 | 0,80 | 0,87 | 0,82 | 0,98 | 1,88 | 42 | 49 | 62 | 61 | 61 | 64 | 57 | 46 | | | | |

# APPENDIX 04

INDOOR CLIMATE

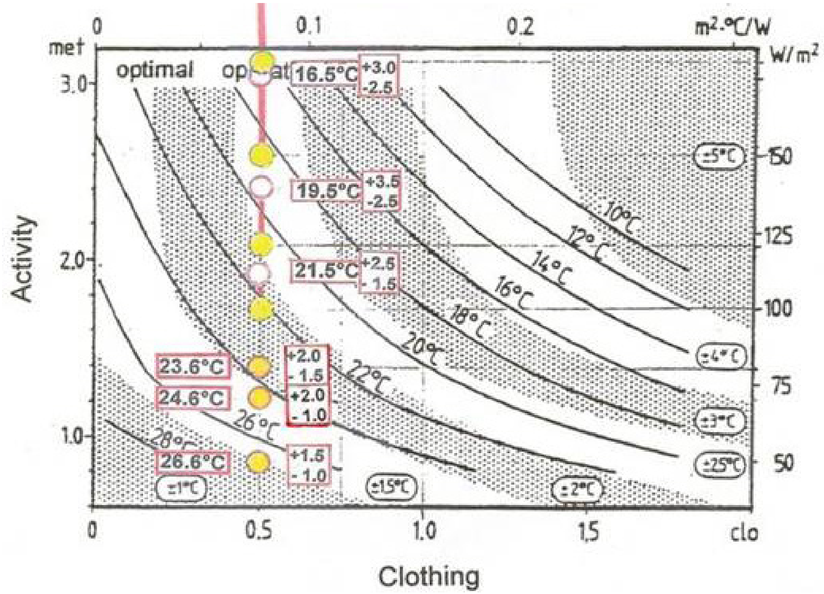
| Rooms | | | Atmospheric indoor climate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dimensions | | | | | Smell | | | | | | | |
| Room | Areal [m^2] netto | Volume [m^3] | Internal loads People | Activity [met] | Clothing [clo] | Smell [Olf] People | Building | experienced air quality, c (DS 447:2013 Kategori B: dp <) | Loads, q People: Building: quantity * olf sqm * olf | | Air flow [L/s] (VL = 10 * q / c) | Air flow [m3/h] | Air change (n = VL / VR) |
| Hallway | 500 | 2769 | 160 | 2 | 1,5 | 1 | 0,2 | 1,4 | 160 | 100 | 1857,14 | 6685,71 | 0,67 |
| Large Chapel | 340 | 2720 | 150 | 1,2 | 1,5 | 1 | 0,2 | 1,4 | 150 | 68,00 | 1557,14 | 5605,71 | 0,57 |
| Medium Chapel | 210 | 1764 | 80 | 1,2 | 1,5 | 1 | 0,2 | 1,4 | 80 | 42 | 871,43 | 3137,14 | 0,49 |
| Small Chapel | 141 | 1184 | 40 | 1,2 | 1,5 | 1 | 0,2 | 1,4 | 40 | 28,2 | 487,14 | 1753,71 | 0,41 |
| Staff | 51 | 316 | 8 | 1,2 | 0,9 | 1 | 0,2 | 1,4 | 8 | 10,2 | 130,00 | 468,00 | 0,41 |
| Mourning hall | 441 | 1632 | 10 | 2 | 1,5 | 1 | 0,2 | 1,4 | 10 | 88,2 | 701,43 | 2525,14 | 0,43 |
| Transfer hall | 324 | 875 | 3 | 2 | 1 | 1 | 0,2 | 1,4 | 3 | 64,8 | 484,29 | 1743,43 | 0,55 |
| Life room | 64 | 429 | 30 | 1,2 | 1 | 1 | 0,2 | 1,4 | 30 | 12,8 | 305,71 | 1100,57 | 0,71 |
| Counceling | 15 | 87 | 4 | 1,2 | 1,5 | 1 | 0,2 | 1,4 | 4 | 3 | 50,00 | 180,00 | 0,57 |
| Prep. Room | 45 | 207 | 2 | 2 | 1 | 1 | 0,2 | 1,4 | 2 | 9 | 78,57 | 282,86 | 0,38 |
| Staff hallway | 163 | 750 | 4 | 2 | 0,9 | 1 | 0,2 | 1,4 | 4 | 32,6 | 261,43 | 941,14 | 0,35 |

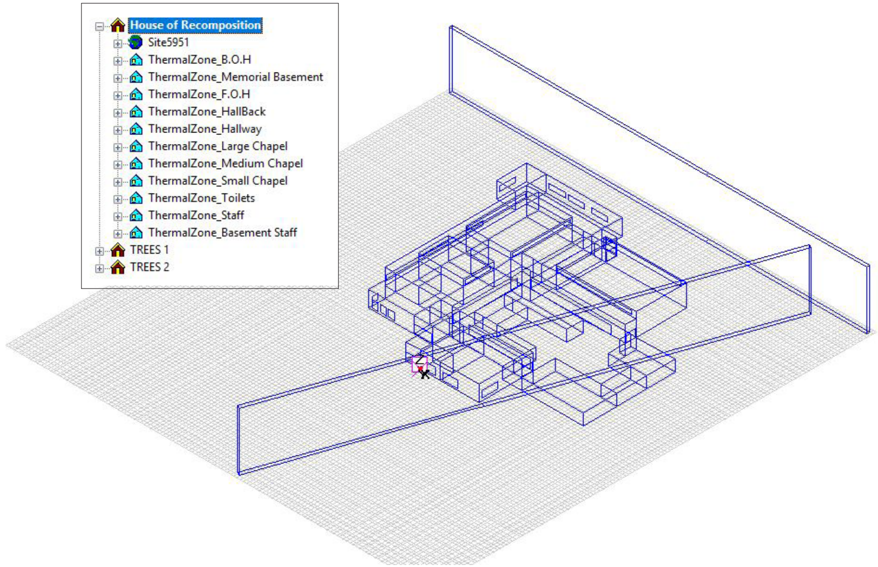
CO2-concentration

| Inside, C [ppm] | Inside, C [m3/m3] | Outside, Ci [ppm] | Outside, Ci [m3/m3] | Source of loads $q_{v,co2}$ (pr. person: 17 * M) L/h | Source of loads m3/h | Air flow [m3/h] ($V_L$ = q / (c - ci)) | Air flow [L/s] | BR18-demands 0,3 l/s pr. m2 | BR18-demands m3/h | Air change ($n = V_L / V_R$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | 0,001 | 350 | 0,00035 | 5440 | 5,44 | 8369,23 | 2324,79 | 150,00 | 540,00 | 3,02 |
| 1000 | 0,001 | 350 | 0,00035 | 3060 | 3,06 | 4707,69 | 1307,69 | 20,00 | 72,00 | 1,73 |
| 1000 | 0,001 | 350 | 0,00035 | 1632 | 1,632 | 2510,77 | 697,44 | 15,00 | 54,00 | 1,42 |
| 1000 | 0,001 | 350 | 0,00035 | 816 | 0,816 | 1255,38 | 348,72 | 42,30 | 152,28 | 1,06 |
| 1000 | 0,001 | 350 | 0,00035 | 163,2 | 0,1632 | 251,08 | 69,74 | 15,30 | 55,08 | 0,79 |
| 1000 | 0,001 | 350 | 0,00035 | 340 | 0,34 | 523,08 | 145,30 | 132,30 | 476,28 | 0,32 |
| 1000 | 0,001 | 350 | 0,00035 | 102 | 0,102 | 156,92 | 43,59 | 97,20 | 349,92 | 0,18 |
| 1000 | 0,001 | 350 | 0,00035 | 612 | 0,612 | 941,54 | 261,54 | 19,20 | 69,12 | 2,19 |
| 1000 | 0,001 | 350 | 0,00035 | 81,6 | 0,0816 | 125,54 | 34,87 | 4,50 | 16,20 | 1,44 |
| 1000 | 0,001 | 350 | 0,00035 | 68 | 0,068 | 104,62 | 29,06 | 13,50 | 48,60 | 0,51 |
| 1000 | 0,001 | 350 | 0,00035 | 136 | 0,136 | 209,23 | 58,12 | 48,90 | 176,04 | 0,28 |

CALCULATIONS MADE FOR THE VENTILATION NEEDS AFFILIATED WITH EITHER THE CO2-CONCENTRATION OR THE OLFACTORY CONDITIONS.
CALCULATIONS HAVE BEEN LIMITED TO SELECTED ROOMS, AS SEEN IN THE TABLE.

GRAPH // OPTIMAL OPERATIVE TEMPERATURE



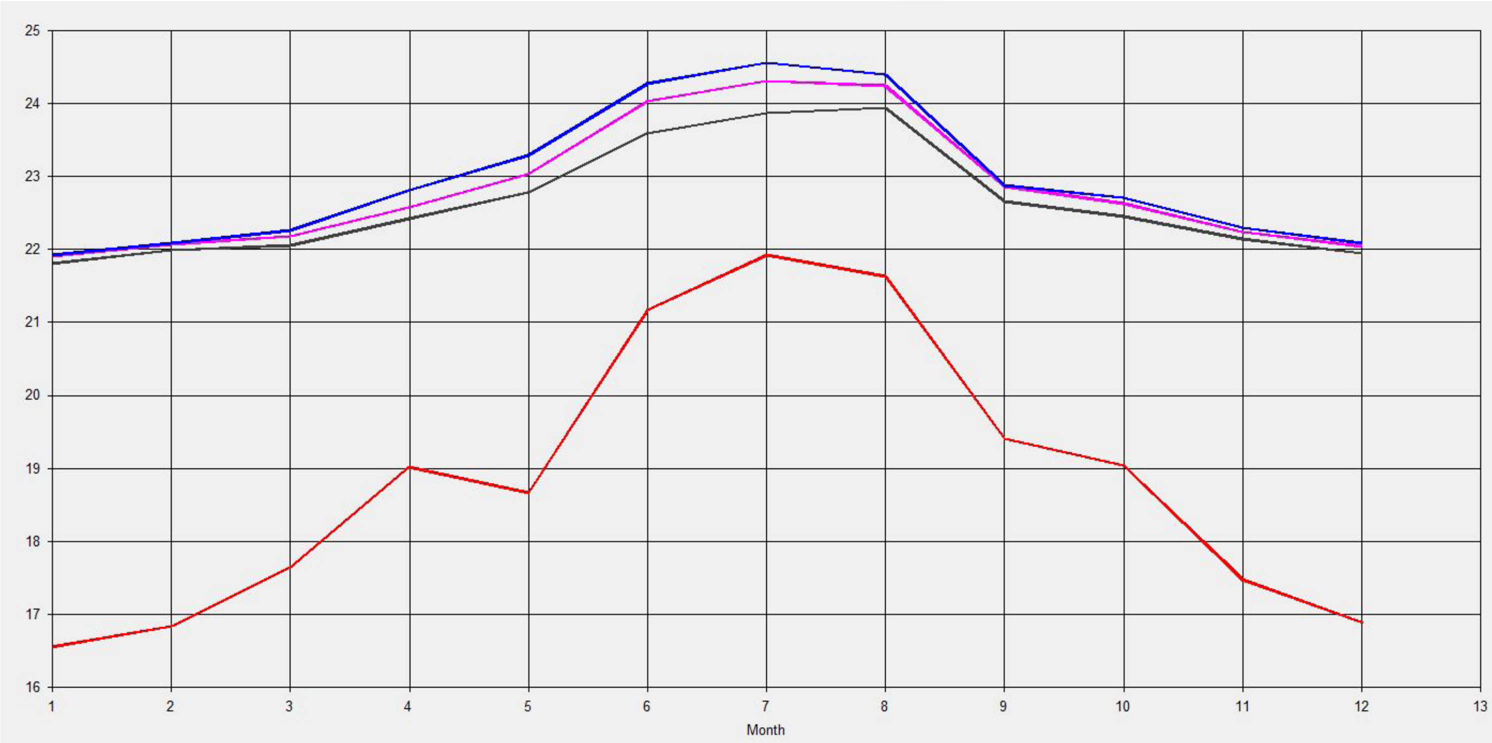

## BSIM

BSim has been used throughout the design process to achieve an acceptable indoor climate. From early in the design process, ventilation, heating, window design, and general building layout have implemented knowledge from BSim.

The focus in the use of BSim in the thesis has been on the thermal comfort of the three chapels and the hallway of the Woodland House of Recomposition. Iterations and results are shown in this appendix to give an insight in the use of BSim.

# APPENDIX 04

INDOOR CLIMATE




TOP MEAN TEMPERATURE
ANNUALLY OVERVIEW

- TopMean(ThermalZone_Hallway)°C
- TopMean(ThermalZone_Large Chapel)°C
- TopMean(ThermalZone_Medium Chapel)°C
- TopMean(ThermalZone_Small Chapel)°C

Difference in indoor climate and atmosphere between chapels and hallway:
Stable temperature in the chapels, while the temperature of the hallway follows the outside climate.

| ıorial Basement | | Mean | Max | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TopMean(Tl | 11,93 | 18,87 | 30,21 | 16,56 | 16,84 | 17,65 | 19,02 | 18,67 | 21,17 | 21,92 | 21,63 | 19,41 | 19,04 | 17,48 | 16,89 |
| TopMean(Tl | 19,02 | 22,97 | 30,17 | 21,93 | 22,09 | 22,26 | 22,81 | 23,29 | 24,27 | 24,56 | 24,40 | 22,88 | 22,71 | 22,30 | 22,09 |
| TopMean(Tl | 19,16 | 22,85 | 29,63 | 21,91 | 22,07 | 22,18 | 22,58 | 23,03 | 24,03 | 24,31 | 24,24 | 22,86 | 22,63 | 22,24 | 22,04 |
| TopMean(Tl | 18,87 | 22,65 | 29,17 | 21,81 | 21,99 | 22,06 | 22,42 | 22,78 | 23,59 | 23,87 | 23,94 | 22,66 | 22,45 | 22,14 | 21,95 |

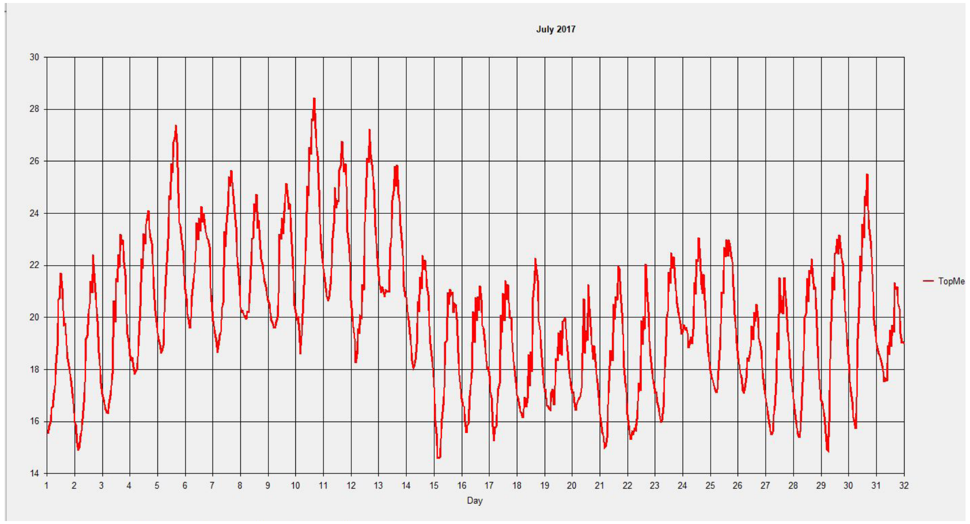
2011 | Month | Hours | ThermalZone_Hal

| ThermalZon | Sum/Mean | 1 (31 days) | 2 (28 days) | 3 (31 days) | 4 (30 days) | 5 (31 days) | 6 (30 days) | 7 (31 days) | 8 (31 days) | 9 (30 days) | 10 (31 days) | 11 (30 days) | 12 (30 days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours > 21 | 1922 | 0 | 3 | 16 | 131 | 155 | 375 | 509 | 476 | 145 | 108 | 4 | 0 |
| Hours > 27 | 39 | 0 | 0 | 0 | 0 | 0 | 13 | 12 | 14 | 0 | 0 | 0 | 0 |
| Hours > 28 | 12 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 5 | 0 | 0 | 0 | 0 |
| Hours < 20 | 6073 | 744 | 666 | 700 | 514 | 524 | 239 | 124 | 136 | 467 | 543 | 696 | 720 |

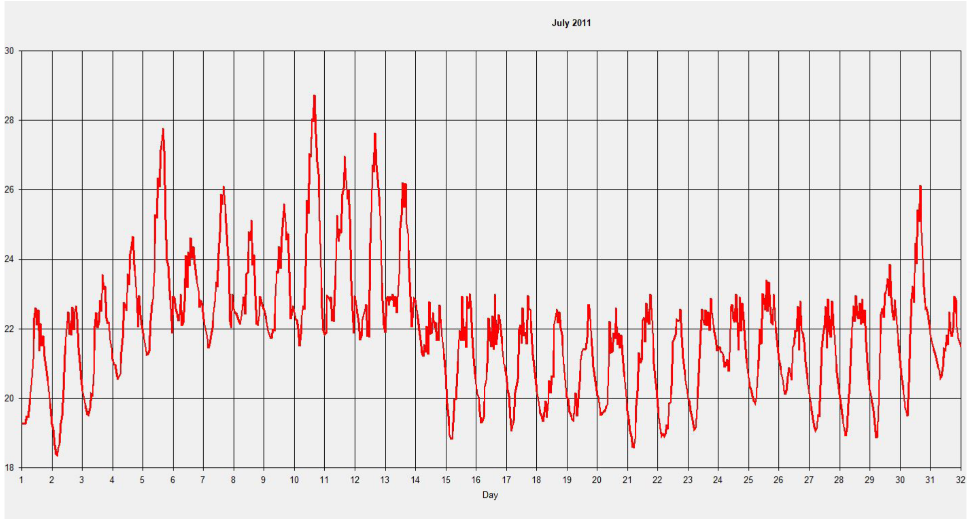
# APPENDIX 04

INDOOR CLIMATE

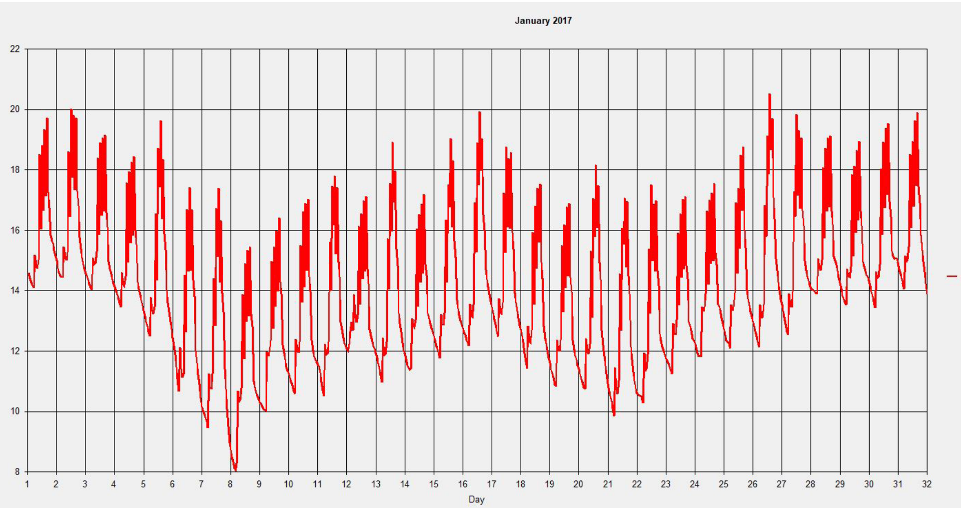
EARLY ITERATION // HALLWAY // TOPMEAN TEMPERATURE // JULY // TO LOW TEMPERATURES



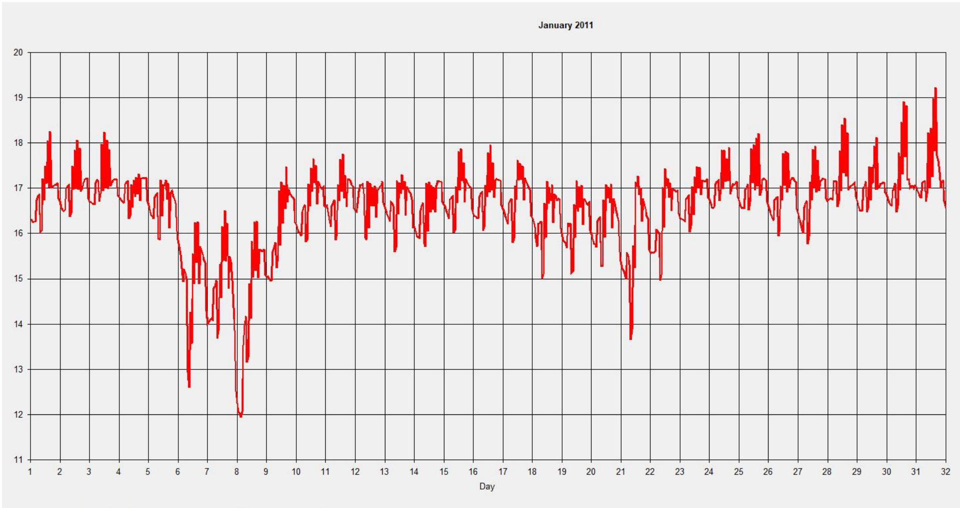

LATER ITERATION // HALLWAY // TOPMEAN TEMPERATURE // JULY // ACCEPTABLE TEMPERATURES




EARLY ITERATION // HALLWAY // TOPMEAN TEMPERATURE // JANUARY // TO MUCH VARIATION



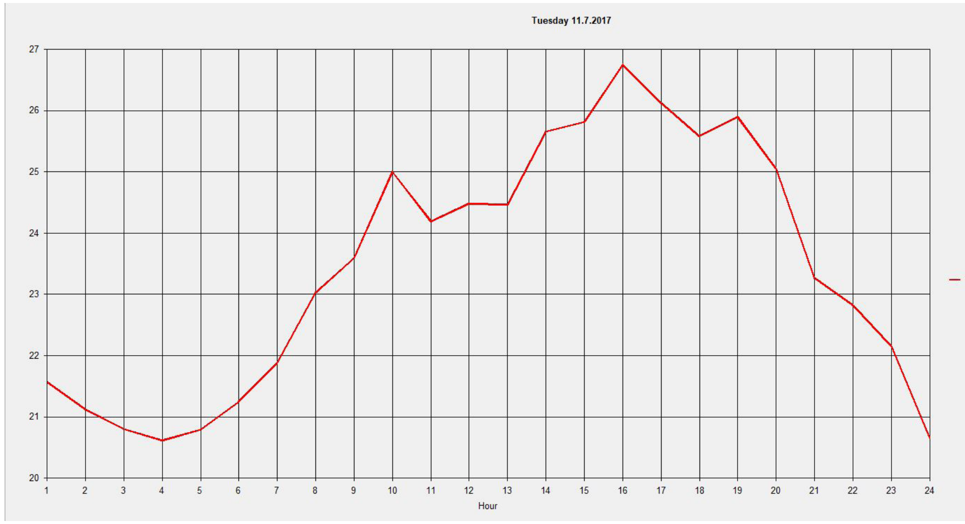

LATER ITERATION // HALLWAY // TOPMEAN TEMPERATURE // JANUARY// MUCH LESS VARIATION



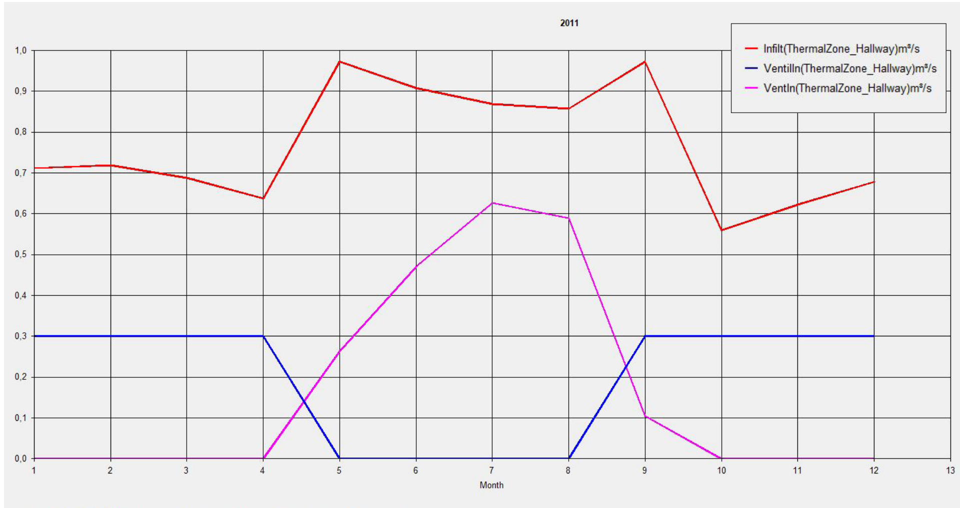
# APPENDIX 04

## INDOOR CLIMATE

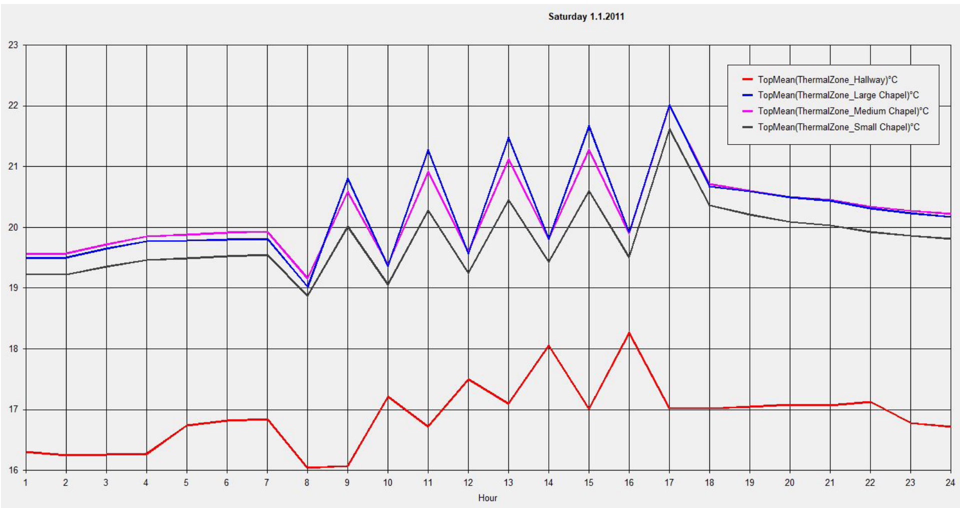
### HALLWAY // TOPMEAN TEMPERATURE // HOTTEST DAY



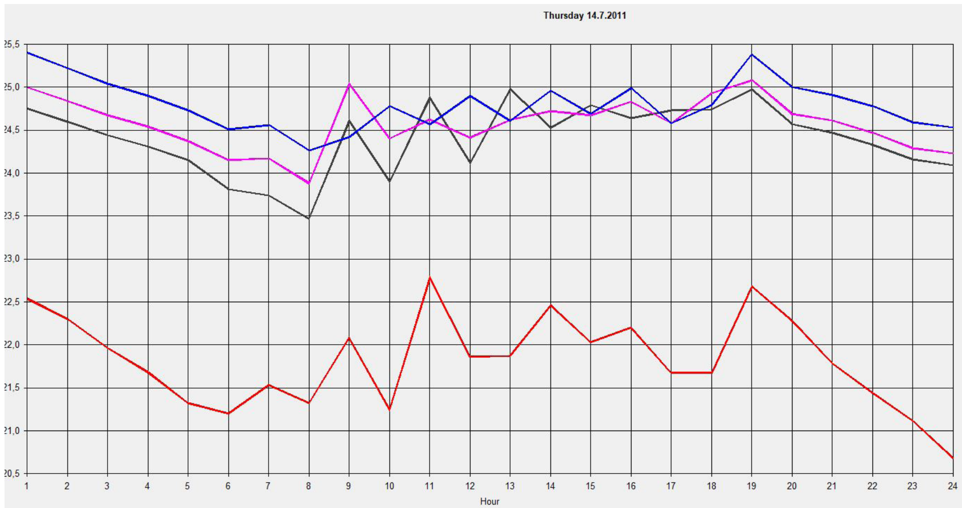

### HALL WAY // YEAR // NATURAL VENTILATION IN THE SUMMER MONTHS




### TOPMEAN TEMPERATURE // COLD DAY IN JANUARY // DIFFERENCE BETWEEN CHAPELS & HALLWAY




### TOPMEAN TEMPERATURE // WARM DAY IN JULY // DIFFERENCE BETWEEN CHAPELS & HALLWAY



01: EXTERIOR WALLS, ROOFS, FLOORS // 02: WINDOWS // 03: INTERNAL HEAT LOAD // 04: VENTILATION // 05: KEY NUMBERS

01

| | Ydervægge, tage og gulve | Areal (m²) | U (W/m²K) | b | Ht (W/K) | Dim.Inde (C) | Dim.Ude (C) | Tab (W) |
|---|---|---|---|---|---|---|---|---|
| | | 8993 | | CtrlClick | 737,037 | | | 18347,3 |
| 1 | BUILDING FACADES | 1998 | 0,09 | 1,00 | 179,82 | 21 | -12 | 5934,06 |
| 2 | ROOF CONSTRUCTION | 2105 | 0,09 | 1,00 | 189,45 | 21 | -12 | 6251,85 |
| 3 | BASEMENT WALLS | 669 | 0,09 | 0,70 | 42,147 | 21 | 7 | 842,94 |
| 4 | BASEMENT ROOF | 1005 | 0,09 | 0,70 | 63,315 | 21 | 7 | 1266,3 |
| 5 | BUILDING FLOOR | 2211 | 0,09 | 1,00 | 198,99 | 21 | 7 | 2785,86 |
| 6 | BASEMENT FLOOR | 1005 | 0,09 | 0,70 | 63,315 | 21 | 7 | 1266,3 |

02

| | Vinduer og yderdøre | Antal | Orient | Hældn. | Areal (m²) | U (W/m²K) | b | Ht (W/K) | Ff (-) | g (-) | Skygger | Fc (-) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 8 | | | 578,3 | | CtrlClick | 312,282 | | | CtrlClick | |
| +1 | NORTH windows | 1 | N | 90 | 61,5 | 0,54 | 1,00 | 33,21 | 0,6 | 0,5 | | 1 |
| 2 | NORTH EAST windows | 1 | NØ | 90 | 45 | 0,54 | 1,00 | 24,3 | 0,6 | 0,5 | | 1 |
| 3 | EAST windows | 1 | Ø | 90 | 80,5 | 0,54 | 1,00 | 43,47 | 0,6 | 0,5 | 1 _ Shading | 0,4 |
| 4 | SOUTH EAST windows | 1 | SØ | 90 | 47,6 | 0,54 | 1,00 | 25,704 | 0,6 | 0,5 | 1 _ Shading | 0,4 |
| 5 | SOUTH windows | 1 | S | 90 | 75 | 0,54 | 1,00 | 40,5 | 0,6 | 0,5 | 1 _ Shading | 0,4 |
| 6 | SOUTH WEST windows | 1 | SV | 90 | 73,5 | 0,54 | 1,00 | 39,69 | 0,6 | 0,5 | 1 _ Shading | 0,8 |
| 7 | WEST windows | 1 | V | 90 | 112,7 | 0,54 | 1,00 | 60,858 | 0,6 | 0,5 | 1 _ Shading | 0,8 |
| 8 | NORTH WEST windows | 1 | NV | 90 | 82,5 | 0,54 | 1,00 | 44,55 | 0,6 | 0,5 | 1 _ Shading | 0,8 |

03

| | Internt varmetilskud | Areal (m²) | Personer (W/m²) | App. (W/m²) | App.nat (W/r |
|---|---|---|---|---|---|
| | Zone | 3443,0 | 12932,0 W | 23598,0 W | 6000,0 W |
| +1 | S_ThermalZone_B.O.H | 331 | 4 | 6 | 4 |
| 2 | S_ThermalZone_Mourning Hall | 502 | 4 | 6 | 0 |
| 3 | S_ThermalZone_F.O.H (life room, counseling) | 224 | 4 | 6 | 0 |
| 4 | S_ThermalZone_Hallway Back (Staff) | 186 | 4 | 6 | 0 |
| 5 | S_ThermalZone_Hallway Front w/ niches | 469 | 4 | 6 | 0 |
| 6 | S_ThermalZone_Large Chapel | 362 | 4 | 6 | 0 |
| 7 | S_ThermalZone_Medium Chapel | 240 | 4 | 6 | 0 |
| 8 | S_ThermalZone_Small Chapel | 157 | 4 | 6 | 0 |
| 9 | S_ThermalZone_Toilets | 164 | 4 | 6 | 0 |
| 10 | S_ThermalZone_Staff | 119 | 4 | 6 | 4 |
| 11 | S_ThermalZone_Basement Transfer Hall | 479 | 4 | 6 | 0 |
| 12 | Chamber | 210 | 0 | 20 | 20 |

04

| | Ventilation | Areal (m²) | Fo, - | qm (l/s m²) | n vgv (-) | ti (°C) | El-VF | qn (l/s m²) | qi,n (l/s m²) | SEL (kJ/m³) | qm,s (l/s m²) | qn,s (l/s m²) | qm,n (l/s m²) | qn,n (l/s m²) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zone | 3233 | | Vinter | | | 0/1 | Vinter | Vinter | | Sommer | Sommer | Nat | Nat |
| 1 | V_ThermalZone_B.O.H | 331 | 1 | 0,51 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 0,51 | 0 | 0,4 |
| 2 | V_ThermalZone_Memorial Basement | 502 | 1 | 0,43 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 0,43 | 0 | 0,3 |
| 3 | V_ThermalZone_F.O.H | 224 | 1 | 1,9 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 2,4 | 0 | 1 |
| 4 | V_ThermalZone_HallBack | 186 | 1 | 0,35 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0 | 0,35 | 0 | 0,3 |
| 5 | V_ThermalZone_Hallway | 469 | 1 | 3,02 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0 | 3,02 | 0 | 2 |
| 6 | V_ThermalZone_Large Chapel | 362 | 1 | 1,73 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 1,73 | 0 | 0,5 |
| 7 | V_ThermalZone_Medium Chapel | 240 | 1 | 1,42 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 1,42 | 0 | 0,5 |
| 8 | V_ThermalZone_Small Chapel | 157 | 1 | 1,06 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 1,06 | 0 | 0,5 |
| 9 | V_ThermalZone_Toilets | 164 | 1 | 0,15 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,15 | 0 | 0 | 0 |
| 10 | V_ThermalZone_Staff | 119 | 1 | 0,79 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 0,79 | 0 | 0,3 |
| 11 | V_ThermalZone_Basement Staff | 479 | 1 | 0,55 | 0,85 | 18 | 1 | 0 | 0,09 | 0,85 | 0,3 | 0,55 | 0 | 0,3 |
| 12 | | | | | | | | | | | | | | |

05

Nøgletal, kWh/m² år

**Renoveringsklasse 2**

| Uden tillæg | Tillæg for særlige betingelser | Samlet energiramme |
|---|---|---|
| 136,0 | 0,0 | 136,0 |
| Samlet energibehov | | 44,9 |

**Renoveringsklasse 1**

| Uden tillæg | Tillæg for særlige betingelser | Samlet energiramme |
|---|---|---|
| 71,8 | 0,0 | 71,8 |
| Samlet energibehov | | 44,9 |

**Energiramme BR 2015 / 2018**

| Uden tillæg | Tillæg for særlige betingelser | Samlet energiramme |
|---|---|---|
| 41,3 | 0,0 | 41,3 |
| Samlet energibehov | | 40,9 |

**Energiramme Byggeri 2020**

| Uden tillæg | Tillæg for særlige betingelser | Samlet energiramme |
|---|---|---|
| 25,0 | 0,0 | 25,0 |
| Samlet energibehov | | 29,9 |

**Bidrag til energibehovet**

| | |
|---|---|
| Varme | 19,8 |
| El til bygningsdrift | 10,0 |
| Overtemp. i rum | 0,0 |

**Netto behov**

| | |
|---|---|
| Rumopvarmning | 14,7 |
| Varmt brugsvand | 5,3 |
| Køling | 0,0 |

**Udvalgte elbehov**

| | |
|---|---|
| Belysning | 4,9 |
| Opvarmning af rum | 1,9 |
| Opvarmning af vbv | 0,0 |
| Varmepumpe | 0,0 |
| Ventilatorer | 3,1 |
| Pumper | 0,1 |
| Køling | 0,0 |
| Totalt elforbrug | 35,3 |

**Varmetab fra installationer**

| | |
|---|---|
| Rumopvarmning | 7,0 |
| Varmt brugsvand | 0,0 |

**Ydelse fra særlige kilder**

| | |
|---|---|
| Solvarme | 0,0 |
| Varmepumpe | 0,0 |
| Solceller | 0,0 |
| Vindmøller | 0,0 |

ENERGY CONTRIBUTION FROM THE DECOMPOSITION CHAMBER (BIOGAS SENT TO THE GRID):

111 kWh/m² year

(appendix 02)

HEAT CONTRIBUTION FROM THE DECOMPOSITION CHAMBER:

298 kWh/m² year

(appendix 02)

## BE18 CALCULATION

As a result on the strategy and process of designing towards a Zero Energy Building, Be18 calculations have been made.

Here a focus have been on the energy consumption for the whole Woodland House of Recomposition as well as the heating of the house.

The defined strategy for ZEB, written in the report, have seeked to lower the energy consumption through passive design efforts and to optimize technical aspspects as ventilation. This has been important for the project to be as low as possible, and only in the end rely on the energy and heat produced by the Decomposition Chamber of the house.

With this large amount of internal energy production, as seen above, the Woodland House of Recomposition achives is goal of becomming a Zero Energy Building. Furthermore, the house have more than enough to contribute with energy to the grid.

MOURGE // REFRIGERATION CABINETS

The above refrigeration cabinets has been used to dimension the morgue.

| | | | |
|---|---|---|---|
| Depth of cabinet: | 2591 mm | Tray spacing: | >300 mm |
| Width of cabinet: | 660 mm | Capacity: | 5 bodies |
| Height of cabinet: | 30000 mm | Clear width: | 3000 mm |

AUTOPSY TABLE // PREPARATION OF DECEASED

The above autopsy table has been used to dimension the body preparation room.

| | | | |
|---|---|---|---|
| Length of table: | 2591 mm | Height of table: | 914 mm |
| Width of table: | 749 mm | Clear width: | 1100 mm |

## ROBOT // TRANSPORT OF COMPOST

For the collection and transportation of the many kilos of compost, these robots are to be placed in the compost storage going down with the elevator connected to the decomposition chamber.

| | | | |
|---|---|---|---|
| Length of chassis: | 1,700 mm | Height of chassis: | 340 mm |
| Length of load deck: | 1,325 mm | Wheel base: | 530 mm |
| Total width of chassis: | 620 mm | Ground clearance: | 30 mm |
| Width of chassis/load deck: | 600 mm | Stroke: | 40 mm |


## COMPOST EXTRACTOR

The above industrial kithen mincer has been used as data source for the compost extractor to be installed at the bottom of the decomposition chamber. The data has been used both as part of the LCA and the operational energy. See appendix 02 for source.

| | | | |
|---|---|---|---|
| Height of mincer: | 590 mm | Weight: | 65 kg |
| Width of mincer: | 759 mm | Capacity: | 7.3 kg/min |
| Depth of mincer: | 325 mm | Energy consumption: | 1.1 kW |


## DECOMPOSITION CHAMBER VENTILATION

The above air handling unit has been as data source for the chamber ventilation system. The data has been used both as part of the LCA and the operational energy. See app. 02 for source.

| | | | |
|---|---|---|---|
| Weight: | 331 kg | Minimum airflow: | 300 $m^3$/h |
| Energy consumption: | 0.5 kW | Maximum airflow: | 800 $m^3$/h |

## DECOMPOSITION CHAMBER COMPRESSOR

The above industrial screw compressor has been as data source for the chamber air compressor. The data has been used both as part of the LCA and the operational energy. See app. 02 for source.

| | | | |
|---|---|---|---|
| Height of compressor: | 1468 mm | Weight: | 392 kg |
| Lenght of compressor: | 1500 mm | Capacity: | 43 cfm |
| Width of compressor: | 623 mm | Energy consumption: | 7.5 kW |