# 0| The Startup hub: Exploring natural materials and techniques to alleviate stress

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# ABSTRACT

The report is the documentation of Master's thesis at Aalborg University conducted by Anubhavi Tiwari and Marta Grasso.

The focus of the thesis is to analyse stress alleviation as much as natural materials used in architecture under numerous factors; primarily the psychological and sustainable impact. The solution from the analysis is implemented in the evidence based research of a stress alleviating workplace.

The report provides a design solution in the form of a workplace at Nørresundby, Denmark; as a culmination to the research findings on natural materials. The design also addresses the well being of its users in providing a conducive stress alleviating workplace design. A recreational space acts as an adhesive for the cohesion of workplace and the urban fabric. With functions such as workshop, showrooms, meeting rooms, common area, the design of the workspace is based on research on stress alleviation.

The report sequentially discloses the design process and its iterative progress on the research and scientific evidence.

# 1| PROLOGUE

# 1.1 MOTIVATION AND SCOPE OF WORK

The Thesis takes its roots from the curiosity toward the role of architecture and natural materials in the psychological impact on the users' wellbeing.

The theoretical part of the research will be applied to the design of a workplace, in order to assess some criterias and strategies that can help the architecture evolve into a sensorial design.

The function of the building has been chosen due to the considerable time the urban population spends in these facilities. In fact, the state of the art knowledge will be implemented and adapted to the architectural design, aiming to stress alleviation and promoting mental health.

The Thesis will focus on the building and landscape design, with special care for the internal organization, use of materials and hierarchy of interior walls. Since the interiors are relevant for the project, the furniture layout will be suggested in the presentation but not detailed.

| | | Why: | |
|---|---|---|---|
| Who: | STARTUP COMPANY | Higly stressful job due to unpredictability (Virk, 2018) | + |
| What: | Design of workplace | Flexible space, where the startup can grow | + |
| Where: | Denmark | The country is promoting the development of start up companies | + |
| | Nordre Havnegade 4-10 | The specific site provides opportunity for promotion of start ups due to visibility | = |
| How: | Natural materials | For a stress alleviating workplace | |

*ill. 1 - Project's foundations -*

# 1.2 METHODOLOGY

The integrated design method by Mary-Ann Knudstrup, will be applied throughout the duration of the process.

It seems a linear method, on the contrary, it is a flexible system, which allows a holistic approach to the design. In fact, it is possible to come back to the previous steps if needed, implementing the knowledge already gained. It is divided into five parts, problem, analysis, sketching, synthesis, presentation.

The first one consist on the formulation of the main problem that is intended to be faced with the project. It is expressed at the beginning of the process and in the last phase will be presented. In this case the question is to which extent it is possible to design a stress alleviating workplace, especially thanks to the use of natural materials and architectural design. It will be evaluated following a scheme developed by the group and presented later in the report.

The analysis consists on the study from a theoretical point of view and application in real life project, phenomenological experience, evidence based research and state of art research. It helps to set the foundation of the thesis, especially in the conclusion, where the design criteria will be derived from the research.
The sustainability addressed for the study are social and ecological; with economy being addressed based on general knowledge, in order of relevance for the Thesis's aim.

The third step is the sketching phase, where digital and hand tools, will be used to start designing; where the considerations from the analysis will converge into the design. In particular, sketching, modeling and calculations will direct the project toward a quantified design. The sustainability explored in the sketching are social and ecological.
The synthesis part consist on showing the cumulation of the collaborated architectural and engineering aspects since the analysis phase, through presentation of technical studies and calculations.

The presentation of the final design will be presented with drawings, design narrative and the process that led toward a conclusive outcome; in both the report and in the posters.

INTEGRATED DESIGN PROCESS

PROBLEM → ANALYSIS → SKETCHING → SYNTHESIS → PRESENTATION

Program
-3D modelling (hand and digital)
-2D sketches (hand and digital)
-Volume studies
-Diagramming

Sketching phase
-3D modelling (hand and digital)
-2D sketches (hand and digital)
-Volume studies
-Diagramming
-LCA
-Daylight iterations
-Be18
-BSim
-Render

Thesis
-Evidence based research

Theory
-State of art research
-Evidence based research

Application
-Case studies

Material analysis
-LCA
-Evidence based research

Site
-Kevin Lynch
-Tomographies by M. Krieger
-Photographing
-Phenomenological experience
-Local plan
-Sketchup for Sun analysis

User
-Empiric data
-Research of literature and articles

-Drawings evolution
-Revit 3D/2D
-AutoCAD
-Evaluation material
-Diagramming
-Sketchup
-LCA
-Velux daylight
-Be18
-BSim
-Renderings

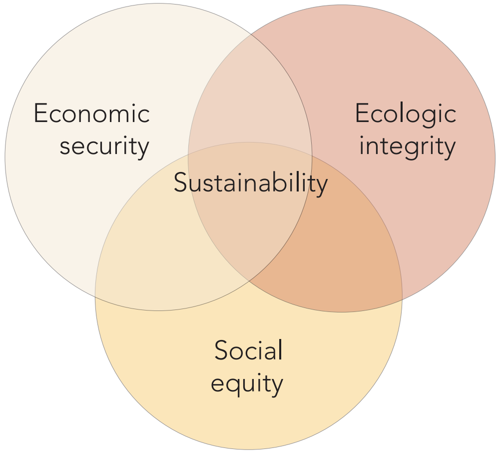
Final design
-Report
-Oral presentation with Powerpoint
-3D models
-Posters

*ill. 2 - Methodology -*

# 1.3 SUSTAINABILITY

Sustainability is an important topic in Architecture as well as in other fields.Especially, the will to evaluate whether a design solution is sustainable and to what extent. Since it is difficult to define the sustainability of a building, some certification systems have been developed which follow parameters of various nature. These parameters belong to three main fields -economic, social and environmental- and sustainability, which is a complex term, is placed in the middle, because it is the optimal balance of the three components. However, it is possible to address sustainability in all the diagram's sections (Warren,2013).

Moreover, the topic is so urgent that 17 Global Goals, for a sustainable development, have been set for the Agenda 2030 by the United Nations General Assembly in 2015.



*ill. 3 - Components of sustainability -*

## 1.3.1 BR18

In Denmark, it is compulsory to conform to the laws, while the regulations can be followed depending on the stakeholders. After the oil crisis, the awareness of finding new ways of construction has became popular; thus architecture has started a new chapter where the integration of energy savings is vital. In this context, Denmark set the goal of becoming free of fossil fuel by 2050, where the laws that need to be fulfilled are essential.

Nowadays, the Danish Building Regulations 2020 has set a strict energy standard to be achieved, where the standards will be applied to the project. Especially, measures concerning the risk class for fire safety and U-values to lower energy consumption will be followed in the process.

Passive strategies will guide the design from the beginning, where the architecture provides a good indoor environment and help to reduce the energy demand, thanks to the careful planning. The passive features taken into account are the climate and orientation of the design on the site, the U-values of the envelopes and the quantity of glazed areas, the consequent need of shadings, the possibility of natural ventilation, acoustics, achieving a good daylight factor in the building.

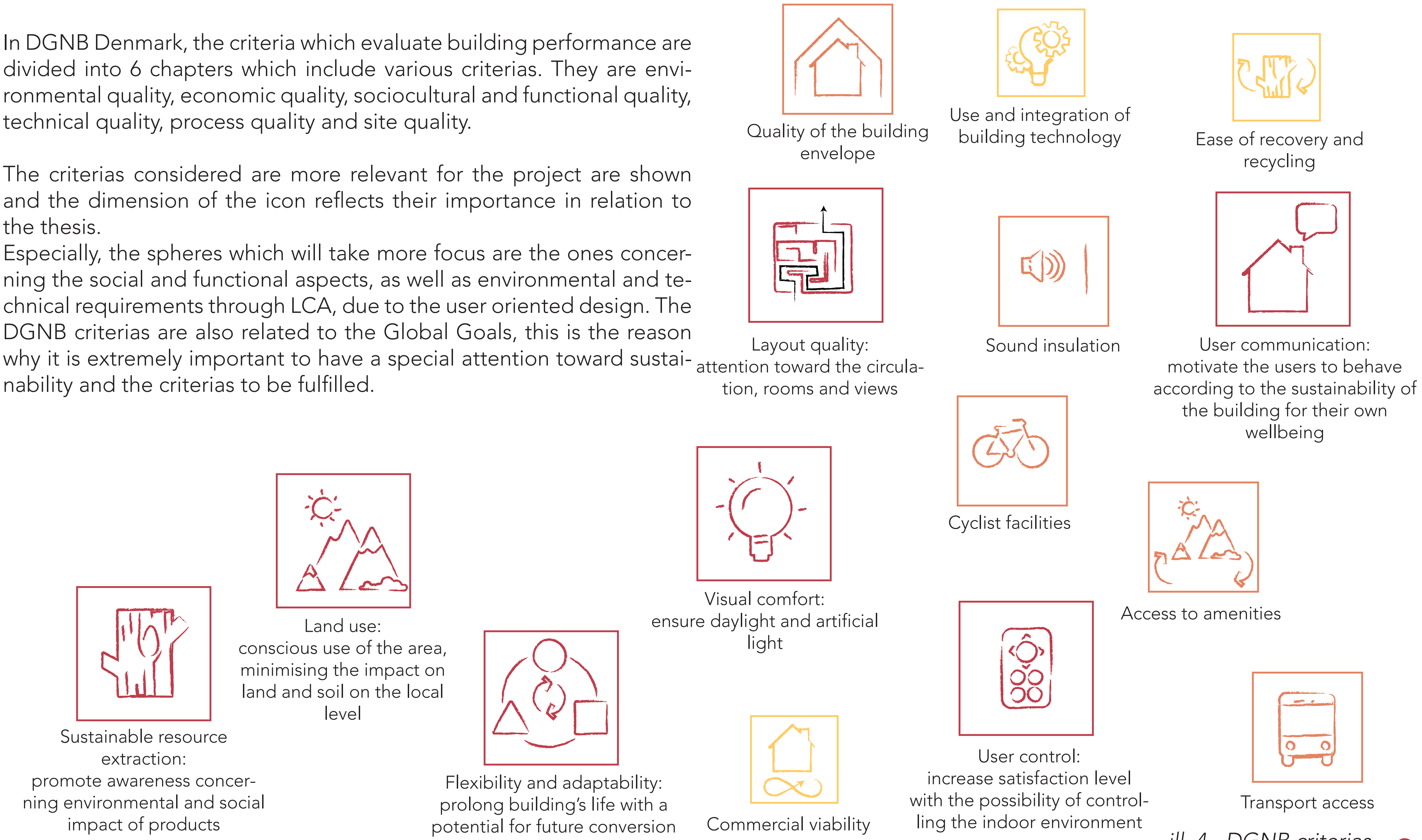
On the other hand, the active strategies will be included in the design, however this is not a secondary step, but it will be planned along with the passive strategies. In fact, from the early stage design, engineering and architectural considerations will guide the process, thanks to the theoretical knowledge gained, with an holistic method.

= *Design parameter: passive and active strategies*

## 1.3.2 DGNB criterias

In DGNB Denmark, the criteria which evaluate building performance are divided into 6 chapters which include various criterias. They are environmental quality, economic quality, sociocultural and functional quality, technical quality, process quality and site quality.

The criterias considered are more relevant for the project are shown and the dimension of the icon reflects their importance in relation to the thesis.
Especially, the spheres which will take more focus are the ones concerning the social and functional aspects, as well as environmental and technical requirements through LCA, due to the user oriented design. The DGNB criterias are also related to the Global Goals, this is the reason why it is extremely important to have a special attention toward sustainability and the criterias to be fulfilled.



*ill. 4 - DGNB criterias -*

### 1.3.3 ZEB

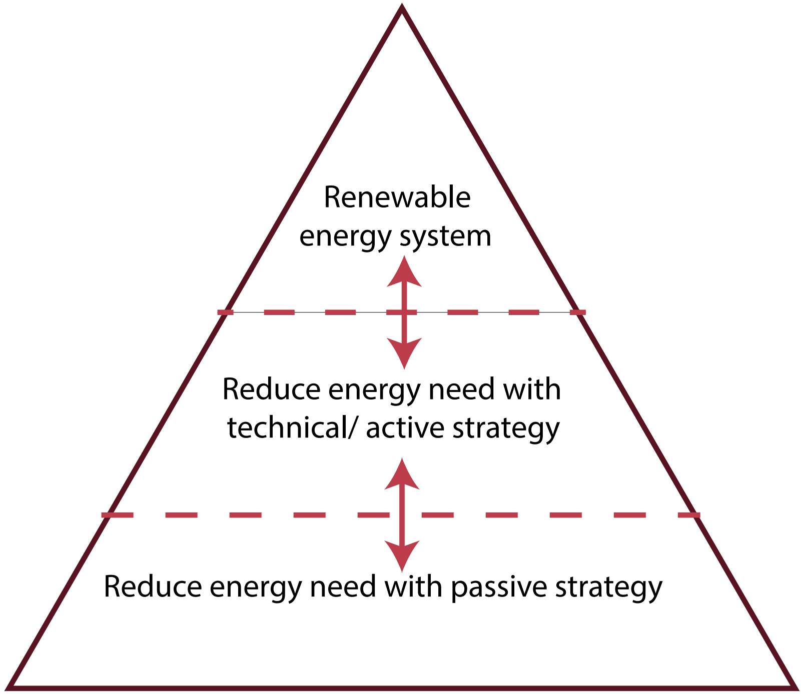
Zero energy in buildings (ZEB) can be achieved through four different approaches. When the site ZEB generates energy equal to its consumption quantity, when accounted for at site; it is defined as Net zero site energy. Net Zero energy cost balances the energy consumption and production costs annually; while net zero energy emissions produces emission free renewable energy equivalent to emission generating energy consumption.

The project aims to attain Net Zero Source Energy- where ZEB produces energy equivalent to its annual consumption, when accounted for at source. Source energy is the primary energy delivered to the site. Energy consumed and produced are multiplied by conversion factors to determine the building's total source energy. Net zero source energy is chosen due to its better impact on Danish energy system, and easier attainability for ZEB (Marszal, 2009).

ZEB will be attained in the project using energy conserving strategies learnt in Zero energy building course from the previous semester, and calculated by the software Be18. Since the ZEB definitions specify renewable energy sources to produce energy, the project will inculcate photovoltaic panels in the design; as part of its active strategy. Energy produced by winds will also be considered (Torcellini, 2006). The primary design strategy to attain ZEB is to reduce energy consumption of the building through design.

Through integrated design method, the technical and architectural considerations will be in sync; addressing the functions and the engineered aspects such as daylight, ventilation and the indoor environment. The temperature, acoustics and atmosphere indoors should be comfortable according to standards (Bejder, 2014).

The building envelope, which comprises of windows, roof, exterior walls and lowest floor slab; have to attain U-values according to Building regulations 2020. The exterior membrane or building envelope will have materials that help maintain the indoor environment (Bejder, 2014).
In addressing all the mentioned passive and active strategies, the project aims to be a zero energy building.



*ill. 5 - ZEB design approach -*

# 1.4 THESIS STATEMENT

The Thesis aims at designing a workplace free of stress accoding to the scheme developed, using natural materials and other criterias concerning the practical design, which will be explained further on. Shared belief is that the design can benefit from the implementation of natural components, because of their positive sensorial properties on humans.

Especially, an holistic method will be adopted during all the process, since the topic is still subject to studies and researches.

The Integrated Design method will guide the structure of the project, where the initial part of analysis and study will be as much important as the final output. In fact, learning from the examples and the path of the workplaces design throughout the history, will strongly help to reinforce the knowledge first and the project then.

# 2| THEORY

WORKFLOW:

| | |
|---|---|
| Gain knowledge about materials | 2.1 Materials |
| Investigate the theory, practice and stress | 2.2 Workplace |
| Combination of the two topics in the applied studies | 2.3 Evidence Based Research |
| Summarise the knowledge toward architecture strategy | 2.4 Conclusion |

# 2.1 MATERIALS

## 2.1.1 Materials in Architecture

The use of materials is integral in creating an idea into architecture. Architectural expression is also feasible by the use of specific materials in compliance with the idea (Schröpfer, 2011).

For an architect, an actual exploration of material nature will provide a perception of conceptual and potential for expression. It further enhances the understanding of the constructability of the material and its prospective application in a building. Remarkable architects such as Frank Lloyd Wright, Alvar Aalto and Louis Kahn used materials creatively, where the building material informed their design (Schröpfer, 2011).

Revelation of material properties such as the surface texture, elasticity and fragility can be understood with a hands on material experience (Schröpfer, 2011). The study can further lead to material solution for the architect with combination and balance as the answer.

## 2.1.2 Materials and environment

The technical performance and properties of natural materials vary according to their occurrence and physical composition. Thus, the materials can be compared on the basis of similar physical properties with respect to their technical attributes and building application. Thatch has high insulation properties, while earth can provide thermal mass (Theconstructor.org, 2018). Natural building materials present a lower threat to the environment, as compared to manufactured materials; due to availability and less energy intensive processing (Ricci, 2011).

However, the major challenge in the use of natural materials is the economy. Due to industrial production synthetic materials are cheaper, easy to use and can be customized according to need. Moreover, in the use of natural materials, compliance with building regulation and acquiring the building permit can be challenging and costly (Ricci, 2011).

For instance, timber and bamboo are mostly global building materials that are renewable and do not need to be manufactured. While the availability of stone and clay may be subjective and limited. However, architecture with the use of natural materials has the prospective to enhance the wellbeing and health of the inhabitants (Bakker, 2017). The widespread choice of exposed wooden floorboards and wooden interiors can also be interpreted as a positive response to natural materials (Bakker, 2017).

### 2.1.3 Culture and tradition in materials

Materials such as clay, stone and timber have been used all over the world traditionally. Thus, many of the materials used over the years are associated with traditional and cultural meaning; in accord to the craftsmanship. The inherent meaning associated with materials used traditionally may also be due to their initial role in nature. For instance, the role of timber in construction as structural members can be traced to the character of wood as trunk (Schröpfer, 2011).

With the case of timber in architecture, examples that illustrate the use of wood through tradition can be made. The tradition of reconstructing the Ise Shrine in Japan every twenty years can be seen as an example of the association of material with culture and heritage. The specificity of using cypress trees treated for three years in ponds to (prevent over drying) before construction, since the seventh century also associates religious values in the tradition (Schröpfer, 2011). Thus, this example projects the retention of a tradition in construction, which is also costly in the life cycle aspect.

On the other hand, in America, the traditional heavy timber wood frame construction was replaced by light framed systems. Moreover, joints accomplished by craftsmanship were replaced by nails (Schröpfer, 2011).

Thus, the two examples illustrated the pragmatic utility of timber in tradition and the replacement of tradition with economy and time efficiency. However, the change in use of materials is mostly by the alteration of their process. As the appearance of the material changes with its function, so does the traditional meaning and significance (Schröpfer, 2011).

*ill. 6* - Stone masonry -

*ill. 7* - Ise Shrine in Japan -

## 2.1.4 Design philosophy of materials

The atmosphere created by a space is the interaction of material and the human perception (Pallasmaa, 2014). Material brings architecture into reality, and in revealing the essence and meaning of a material-specific to a building and is past cultural meaning; a poetic quality can be generated in architecture (Zumthor, 1988).
Moreover, architectural expression can be conveyed through only specific materials (Schröpfer, 2011). The materiality and fragility incur a perception of humility and duration in an architecture product. Humility of a material can be interpreted as the scale and earthen quality it projects, for instance by a brick. Architecture that evokes multiple senses projects time as a healing and pleasant experience (Pallasmaa, 2000).

Due to the vital role of materials in our architectural experience, it is essential to understand the importance of the interplay of materials with our senses. In experiencing architecture, we need to sense it through its material by vision, touch, smell and audition (Zumthor, 1988). Tactile architecture engages and unites, while on the contrary, without tactility and details that address a hand, structure can be flat and immaterial. The importance of touch in architecture has been emphasised by veterans of various fields. The tactile experience comes unconsciously while assisting the vision in perceiving edge and surface, which can be shaped for 'touch of the eye' to create fine architecture (Pallasmaa, 2005).

Further, vision and tactility can also stimulate oral senses, due to transference between human senses (Pallasmaa, 2005). For instance, viewing certain colors can evoke gustatory senses, something experienced seeing edibles.

Materials invoke different senses with their own language in expressing time (Pallasmaa, 2000). For instance, glass is a highly sensorial material as it stimulates emotion by its tactile and visual quality. In its recyclability, glass attempts to compensate for its high production energy (Pallasmaa, 2005). Stone demonstrates durability while brick of ageless custom of construction. Wood shows growth and journey to become a human artefact, (Mahindru, 2016) it is perceived more as 'natural'. (Masuda, 2004). Even metal such as bronze evokes a sense of heat from its production process (Pallasmaa, 2000).

*ill. 8 - Multisensory environment -*

## 2.1.5 Natural materials and perception

The materials that can be used in construction after minimal or no processing, for instance- timber, straw and earth; are defined as natural materials (Theconstructor.org, 2018). The natural materials used traditionally can also be classified by their sources: earthen and plant materials.

While some materials such as timber and straw are renewable; stone and earth cannot be replenished. As building components, most natural materials also demonstrate the ability to hold and release moisture (Theconstructor.org, 2018). Due to the air pockets in timber, outdoor pollutants, humidity and temperature are regulated. Natural materials can thus mitigate indoor moisture and pollution (Day, 1993). Moreover, natural materials such as stone, wood and brick, express their journey as well as their application traditionally (Pallasmaa, 2005).

Human perception related to natural materials in construction are mostly positive, probably also due to traditional association; in addition to the emotion they evoke due to their qualities. Evidence has concluded that plant or wood based environmental materials with apt surface roughness has a positive impact on physiological functioning (Li, 2010).

For instance, wood is perceived as warm and reminiscent of life, while brick projects the warmth from its conceivement (Day, 1993). On the other hand, industry processed materials such as steel grants the idea of cold and hardness; while plastic gives the impression of its molecular technology (Day, 1993). Moreover, brick can be seen as being characteristic for its 'humility', in comparison to the 'elitist' status of stone (Schröpfer, 2011). Thus, it is challenging to create a space against the material perception; for instance a soft concrete space or a cold environment with exposed wood (Day, 1993).

Moreover, it is natural to feel more at home in a built environment that comprises of 'modified' natural materials; giving a space 'roots' (Day, 1993).

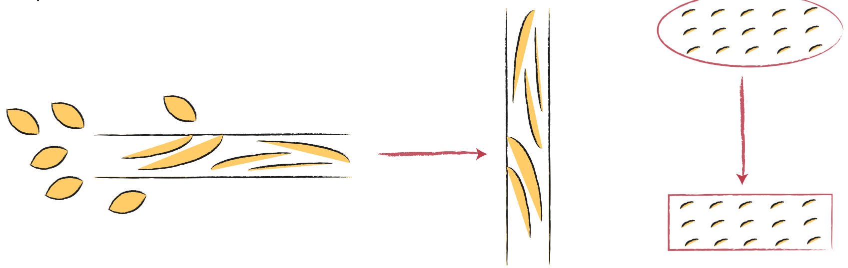
### The definition

At this point, it is necessary to formulate the definition of natural materials that will be carried out during the thesis.

Based on the theory, natural materials can be interpreted as materials that have negligible carbon dioxide impact in the production process, since the raw material is generated naturally. Natural materials retain their physical, mechanical and aesthetic quality and thus the extent of processing is lower compared to the manufactured material. For example, concrete is produced after extensive treatment and production using a natural element such as lime. While wood is treated with preservatives, yet still retains its physical and aesthetic qualities.

Thus, the main purpose of treatment is to improve the performance of natural materials in the building for structural strength, maintaining indoor environment and protection from outdoor. Natural materials when are decomposable when disposed after removing the treatment, else do not harm the environment.

Moreover, manufactured materials have multiple components, while natural mainly come from one source. Lastly, the aesthetics and human perception of natural materials are generally positive, compared to industrial products.



*ill. 9 - Natural materials retain original properties -*

### 2.1.6 Material sustainability

The definition of sustainable development is 'the development that meets the needs of present without compromising the needs of future generations to meet their own needs' (United Nations, 1987). The aspect can be viewed with respect to the environmental impact of production, installation, renewability and disposal stages of building materials. However, the current scenario in terms of construction globally seems costly to the environment.

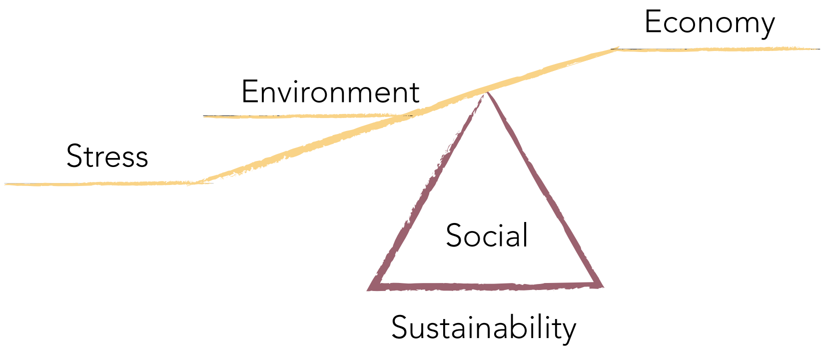
Globally, building structures through their lifespan cause 40% solid waste generation, 33% and 12% of resource and water use respectively (Toyne, 2007). The contribution of building materials in these numbers is in the production, procedure and demolition phases of construction (Day, 1993).

Certain ecological damage occurs in order to accomplish the performance criteria for efficient buildings. (16) For instance, timber can be viewed as a sustainable material due to its renewability and positive impact to the environment in its production phase. Yet, the material cannot be used without treatment before construction; which is expensive with respect to the environment (Day, 1993).

Moreover, half of the chlorofluorocarbons and carbon dioxide emissions is produced due to building operations and the building materials (Day,1993).Thus, in addition to the direct environmental impact of materials, embodied energy is also an important factor to evaluate their sustainability. Embodied energy is discussed in elaboration at the Life Cycle Assessment segment.

Aspects of sustainability of materials can also be viewed broadly as the material's economic, social and environmental impact. The environmental aspect will be further examined by Life Cycle Assessment while social sustainability will be addressed by design based on research related to the user and perception.

To sum up, the design will address material considerations such as life cycle analysis and social sustainability will be probed.
Moreover, the material analysis will determine the application of materials in design. The analysis will give more weightage to environmental impact of materials over the economy, thus implementing certified materials which are expensive, but environmentally sustainable.



*ill. 10 - Thesis priorities of the sustainable features -*

## 2.1.7 Innovation in natural materials

Several innovations have been made with natural as well as industrial materials, with respect to application in building construction. Further, non conventional elements such as water and vegetation have also become a part of improving building performance. For building insulation, natural material such as expanded cork and hemp fibres are highly effective. Moreover, both hemp fibre and cork are renewable and recyclable; being organic they do not require disposal or production energy.

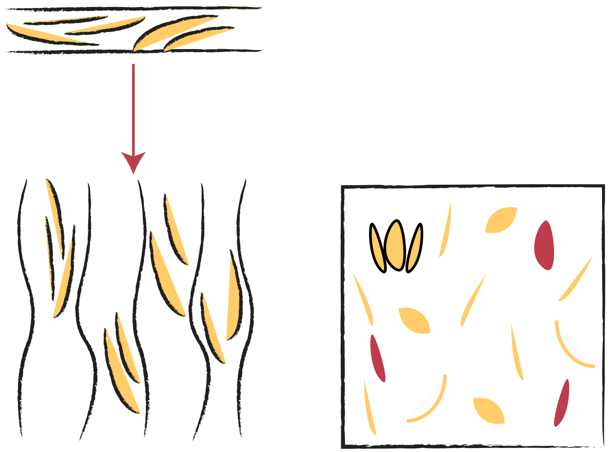
Depending on the temperature, phase change materials (PCMs) change their state between solid and liquid while absorbing or releasing heat. There application in buildings is to reduce indoor heating and can be organic paraffin base (Tdorgal, 2013). Water, being a recyclable material, can be used as an affective thermal mass, since it readily absorbs and releases heat to the environment. Water can be placed in tubes for regulating the indoor temperature (COM 571, 2011). Even the inclusion of green roof is relatively low on maintenance and practical for climate in Europe. Green roof and facades can considerably lower the cooling load of a building in summer (Castelton, 2010).

There are natural material products marketed globally for various building applications. Organoid is a company which uses natural plant materials, majorly hay; to create furniture, acoustics panels and interior surfaces, while retaining the raw natural materials and their textures. Using pine cones and flowers as raw material, the products address the olfactory senses (Archdaily).

Bole, a flooring company; scans harvested timber, later to be used to be simulated and used for flooring which does not cut but retains the source timber's original non linear form in flooring (Bole.eu.). It demonstrates the energy saved in the processing stage.

By 2020, waste will be 'managed as a resource' in Europe; according to Roadmap to a resource Efficient Europe (COM 571, 2011). Waste generated from mining activities are unprocessed natural materials, which can be reused in construction. The material will not be toxic to the environment, and will also save on production energy (Tdorgal, 2013). Thus, industrial waste materials can be seen as a resource to be utilised in buildings, and similar to natural materials- do not require production energy.

Summing up, hemp and cork can be analysed in consideration of insulation material in the design project. Further, green facade can be considered with perennial plantation for design since in summer the building will be unshaded from the south.



*ill. 11 - Commercial application of natural materials -*

# 2.2 WORKPLACE

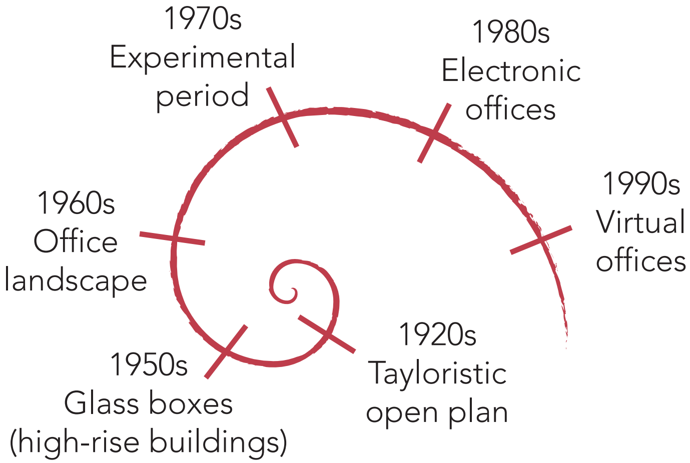
## 2.2.1 History of offices

The design of offices characterised the 20th century as much the industrial design did for the 19th century. At first the role of this new new kind of design, related to economy and money, was not matching with the artistic and the sublime role that Architecture has always tended to cover. However, nowadays it is possible to spot many buildings which represent power with the great amount of glass and their outstanding height (Meel, 2001).

The design of workplace layouts is taking more relevance in the last years, because of the increasing number of people working in the office rather than in other realities, as agriculture, sales and industrial production or transport. For instance, in the last century the percentage of population working in offices rose from 17% to 50% in the United States (Czaja, 1987). Further nowadays, half of the world's population is approximately calculated to work in offices (Brounen, 2008).

The historical development of the office plans, focusing on the 20th century, are driven by new concepts, which are the result of the current trends. From the beginning it is possible to recognise some types: Tayloristic open plan (desk orientated in the same direction and orthogonal), landscape plan, small parenthesis of cellular offices, the combi-office (combination of open plan and cellular office) and the virtual office (due to the introduction of computers and laptops) (Meel, 2001). What it is interesting to notice, is that the new concept ideas born and spread very fast worldwide, thus it becomes more an international movement, difficult to strongly differentiate from country to country.

Especially, the landscape plan attracts the curiosity of the past and contemporary studies because it is the place where the majority of people work and consequently have solid opinions about it (Camerota, 2018).
The landscape plan was born in opposition to the traditional and hierarchical plan layout, where the partition walls and doors worked as boundaries between the workers, also to remark their hierarchical and departmental differences (Camerota, 2018)(Wallace, 2004). After the World War II, a democratic sentiment become popular, where eliminating the boundaries seemed to be the best approach in promoting communication and collaboration between the employees (Meel, 2001).
In fact, the definition of "office landscape" was invented by the brothers Wolfgang and Eberhard Schnelle in the '50s. This layout option attracted many attentions because of the human-centered concept and the economic advantage. It meant having less walls, maintenance and the possibility of flexible workplace configurations (Meel, 2001).
In the end, each period brings new ideas and concept that seems to be the most efficient and convenient, however the progress is always moving toward new descoveries and experiments.



*ill. 12 - Worldwide offices of the 20th century -*

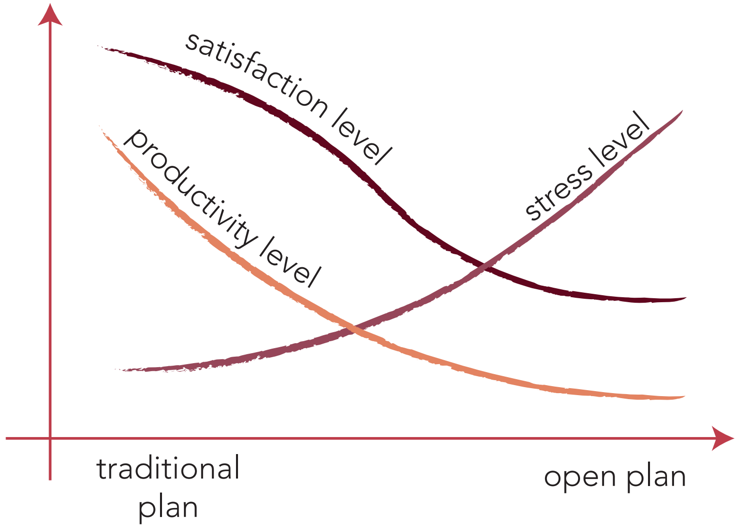
## 2.2.2 The existing studies

Nowadays, when talking about plan layouts, the difference is in between open plan and traditional plan layouts. The open plan stands for a space with limited quantity of division and common space of work, and traditional plan for a more wall oriented design in hierarchical clusters.

Since the invention of the open plan, the percentage of open offices increased up to 70% (Konnikova, 2014), consequently the interest concerning the real effect of the popular layout on the workers started to be attractive for the researchers. For instance, what many investigators seem to agree, is that when people pass from a traditional plan layout to a open plan layout, their satisfaction level decrease, followed by higher stress and less productivity. In fact, the negative effects involve all the workers, both young and senior, whether they are multitasking or not. The reaction to the many stimulations given by the context, is translated into more effort in achieving the aim.

When talking about open plan offices, the main physical issue seems to be the the noise level, which cannot be avoided. Thus, the employees try to find their own balance, trying to isolate themselves with headphones, rather then collaborate and communicate more, as the German brothers thought. Further, the human interactions are not under control anymore, lowering the concentration and motivation levels, as well as the possibility of control the surrounding environment, as lighting, temperature and ergonomic adjustments (Konnikova, 2014). The last feature needs to be taken seriously because, as it will be shown afterwards, the physical adaptation of people to their environment is a constant element that needs to be considered, studied and not underestimated.

Another study reveals the negative impact of open plan layout on the employees health, the analysis shows that the number of people getting the sick leave is proportional to the increased number of people working in the same room. The survey is based on 2403 employees aged between 18 and 59 years in Danish environment. In particular, the result shows that the workers in open plan offices take on average more than 62% of sick days than the people working in cellular offices (Pejtersen, 2011).  The professor Ethan Bernstein carried on a study to quantify on empirical basis the correlation between the layout of the open office

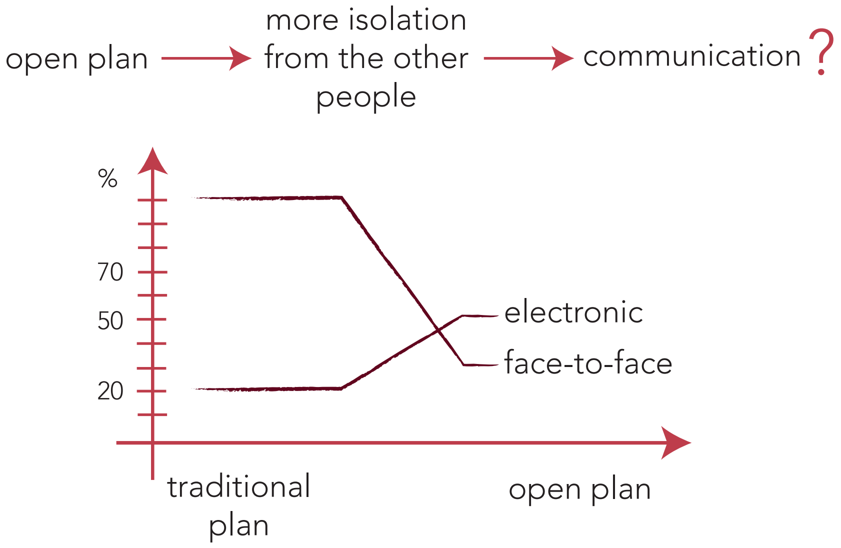


*ill. 13 - Plan layout effects -*

and the interaction of the people, in order to compare if the aim, in which the open plan was born, reflects the actual situation. The survey, as other experiments, gathered information before and after the moving from a traditional office to an open plan one.

When thinking about removing the physical walls which separate the people, the consequent thought is that the interaction between people should increase. The result show that the initial premises of the open plan do not work in real life.
In fact, the study calculates that, on one hand, the face-to-face communication decrease of 70%, while, on the other one the electronic communication rise from 20% to 50% (Bernstein, 2018).

Furthermore, the adaptation of the employees to the environment is translated into isolation with headphones and similar, with the aim to defend the privacy that they need to work and that got lost with the removal of boundaries. According to the same study, the productivity decreased as well because of the many stimulations given by the environment, also the proximity to other people can somehow distract the workers because feel observed by the others and consequently they want to look as busy as possible (Bernstein, 2018).
All these studies reveal the problems that the open plan layout implies, however, the problem presented are related to the extreme use of this solution. In fact, often the enthusiasm of adopting new solutions, which seem to be the optimal, prevail on the wise use. For instance, not all the functions need the same level of private space or flexibility, thus using the same principle would not be effective.



*ill. 14 - The communication in offices -*

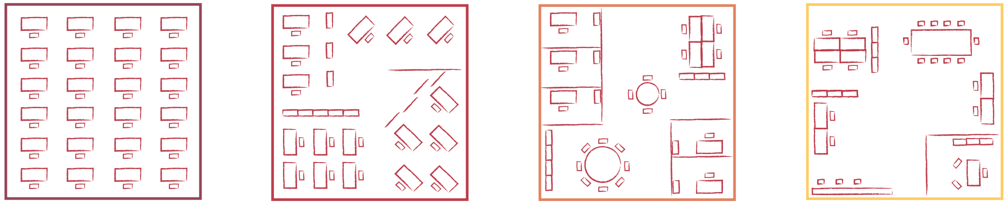
= *Design parameter: hybrid plan layout*

## 2.2.3 Current and future workplace design

All the eras, which are part of an iterative process, bring with them new concepts and ways of apply those ideas in the design. The new concepts always want to separate themselves from the past, showing how they are more efficient and smart than the old habits.
When designing offices, the common requirements are efficiency, flexibility and two related to the users concerning identity and security, which are connected to the context, in fact some solutions could work in a country, but not in another one because of the cultural diversity (Meel, 2001).

The current design varies depending on the country, however the hybrid solution of open plan and cellular unit is used in many offices. Sometimes a place for desk sharing is set as well, for the people to move around depending on the task and creating relaxing informal areas as well. Sizewise the American offices are still bigger than the European, except for cities as London, Frankfurt and Rotterdam.

Concerning the floor plan, it is not possible to have a clear division nowadays, in fact bigger and more narrow plans still exist. Also, they can still have different configurations, open, landscape, combi-offices and non-territorial plans. Anyway, the adoption of combi-offices is the leading trend in Europe, with tendency to non-territorial spaces and teleworking.



Open plan Landscape plan Combi-office Non-territorial plan

*ill. 15 - Plan configurations -*

Even if it is difficult to predict how the future office design will be, it is still possible to have a general idea about it, knowing how it developed in the past until the present. In fact, the design of offices usually follows the same trend, ideas emerge and develop fast and after a period of time disappear, substitute for new concepts. Usually, an euphoric feeling accompanies the newly ideas, guided by more aesthetic than realistic reasons, for instance if it could really work in reality (Meel, 2001).

However, there is something important and even predictable that need to be said, the design trend is not self standing, but it is part of a broader phenomenon and context, which take into account the economy, new technologies and cultures. Where the human centered perspective is considered especially lately in the history.

In Europe, the trend of the future design seems to take distance from the high rise buildings, due to the not considered effect on human being. Considering the political and economic features though, the building will try to increase their height, but not as much as in other parts of the world. When buildings are used by the owner, the presence of green is an upgrowing factor, rooftop, sky gardens and the recycled materials. Then double facade with layer of air for energy savings.

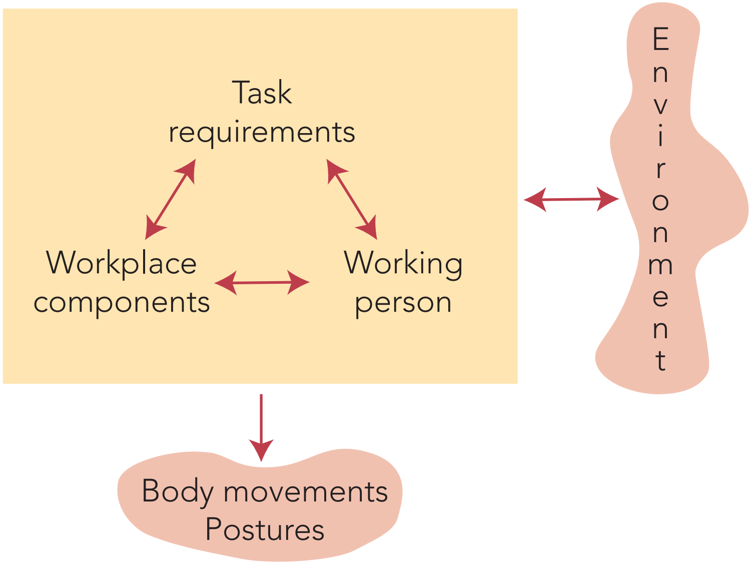
= *Design parameter: transparent solutions*

Concerning the plan layout, big plans, of medium-depth building of 14-15 m, will be preferred to the narrow ones, where it is possible to host more easily the functions needed and the natural light and natural air are better provided.
In the smaller scale of workplace design, the transparent solution seems to be the preferred of the future, combination of traditional and open plans with glazed partition walls. Especially, the non-territorial office is increasing, where people share their desks because of the new way of working, due to the digitalization and new technologies, where it is possible to work in different part of the office.

This sharing concept need to be contextualised, firstly how much time people spend at work and secondly it is applicable when the the financial advantage is convenient.
Virtual work is also becoming in the present a new way of working -known as teleworking, thus smaller offices are more probable to be the concept of the future, where people meet for sharing their work.
In the end, following the market and the current trend is a necessary step to design competitive solutions, nevertheless, exploring and experimenting new possibilities.

### 2.2.4 The design of workplace

The design of the workplace encompasses features from a microscale to a macroscale, firstly the workplace components, the tasks demands and the working person, then the environmental conditions, which for instance are given by the orientation, natural or artificial light, noise, temperature. The majority of the elements mentioned are subject to variability, depending on the period or from the time of the day.
Furthermore, these factors are related to the design only, but if we consider the building process as a whole, adding the interests of the stakeholders, economic boundary and aesthetic characteristics, the situation becomes highly complicated. Thus, from the beginning it is necessary to control some features, hopefully definite and not changeable, the user, the kind of demanding tasks and the environment



*ill. 16 - The interrelation between the features of the working process -*

(Salvendy, 2012).
It is generally asserted that the building sector run when there is a positive income for the stakeholders, it means that the design needs to satisfy some requests. First of all, the awareness of the kind of users will be hosted because the design addresses the specific needs, then the competition with other options on the market and the affordability for the future sale or rent (Brorson, 2015).
As said, in this scenario usually buildings are designed for specific users and needs, but the nowadays market is evolving towards more flexible solutions.

*Design parameter:*
= *flexibility within a specific kind of user*

### 2.2.5 The layout of the workstations

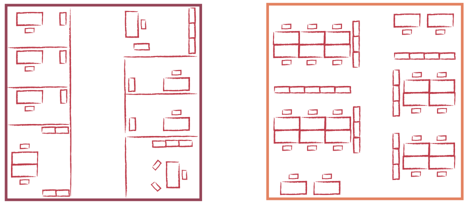
The layout of the workstations is firstly related with the position of the singular workstations as well as the orientation within the building, secondly, it needs to fulfill some requirements that determine better the overall layout. In fact, it needs to promote the workflow and the cooperation, fit into the organizational structure of the company, establish privacy and proper uniform light to avoid glare and reflections, the temperature should be appropriate without draughts, finally the safety should be considered for the easy access to the stations (Salvendy, 2012).

Some plan layouts of workplaces exist, nowadays, the new trend is the flexible office, where the elements can be moved to form new configurations and adapt to other necessities. However, it is interesting to deepen the two major and opposite configurations: the private office and the open plan, which is characterised by the lack of walls up to the ceiling.

It would be restrictive and incautious to prefer one to the other without considerations, because they both have positive and negative aspects in terms of privacy, control of the user on the environment, noise level, disposal and maintenance cost, cooperation, possibility of supervision, adaptability to the organizational structure.

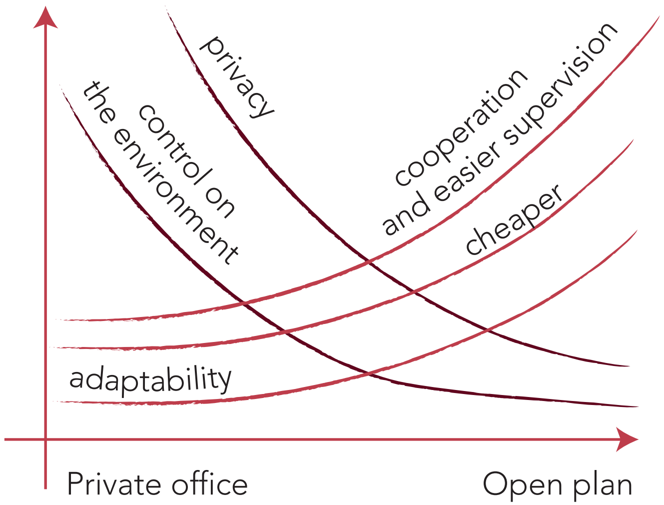
Studies concerning the effect of the open plan on the workers have been carried out by Mary D Zalesny (Zalesny, 1987), where three points of view have been chosen- the social relations, sociotechnical systems and symbolic meaning. The result of the study shows how much it is relevant to carefully choose the plan layout, keeping in consideration that a plan can have, intrinsically, a meaning of working hierarchy.
On one hand, it is easy to understand how the social relations and communication change depending on a private or open plan. While, on the other one, the plan layout has an implicit psychological influence. In

fact, it reflects on how the employees sense their job in relation to the same or different opportunities that their physical position implies. For instance, if workers on two different hierarchy are sitting together having the same utilities, the one with the higher position would feel dissatisfied; while the other one would be more motivated.



Private office Open plan

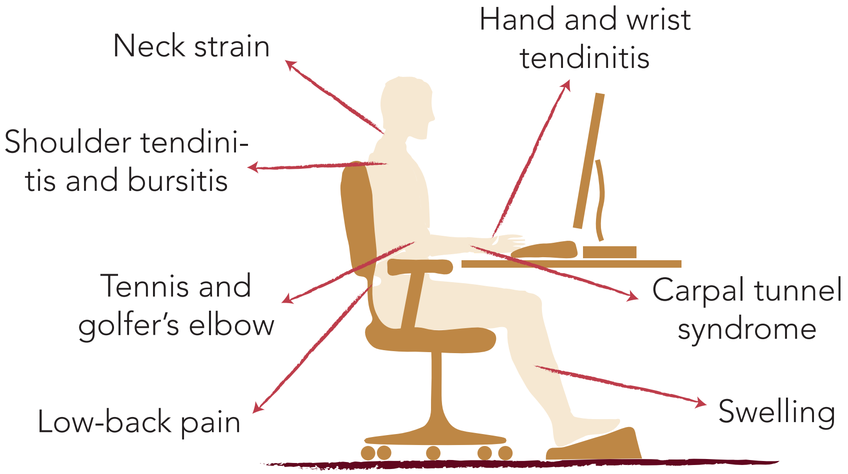
*ill. 17 - Private office and open plan, the rental cost of the former can be estimated between three and five times more than the latter (Geoffrey, 2016)  -*



*ill. 18 - The characteristics of private office and open plan office -*

What needs to be acknowledged is the importance of the worker's posture and the layout configuration (Marmaras, 2002).

In fact, the design of the workstations affect greatly the future posture and movements that the worker will assume. Sitting and standing are usually the possible postures in work environment. None of the two is the optimal position for long term, in fact, for long period of time they both become uncomfortable and tiring. For this reason a solution could be the possibility of change the body position during the working day, avoiding the usual physical consequences as musculoskeletal disorders (Salvendy, 2012).



*ill. 19 - Muscoloskeletal disorders -*

When digging into the design of workstations, there are 3 steps to follow in order to reach the optimal result.

The first two concerns are in identifying the constraints and requirements through the analysis and data collection: kind of desks and furniture, as well as equipment and tools, the work organization of the company, the environmental conditions of the office as well of the location of the site, the scenarios in which the workers can be, regular or irregular situations caused by external or internal sources, which could or not interfere, the collection of legislation data is also important in this phase.

The last one is related to the user needs and characteristics: the elements present in the station, the possible movements and actions of the user, the information exchange, privacy, the closeness to other workers or elements.
As it is easy to imagine, all the above information are subject to dynamism and in real life it is not possible to limit them in categories, for instance, some tasks can change from a period of time to another one, there can be exceptional working situations, personal characteristics of the users, which can be gender, age, culture and so on.

To summarize, the features to consider are many and interrelated, where the study of existing solutions is the starting point for designing consciously and take into account the possible different scenarios (Salvendy, 2012).

= *Design parameter: dynamic stimulating environment*

## 2.2.6 Stress aspect

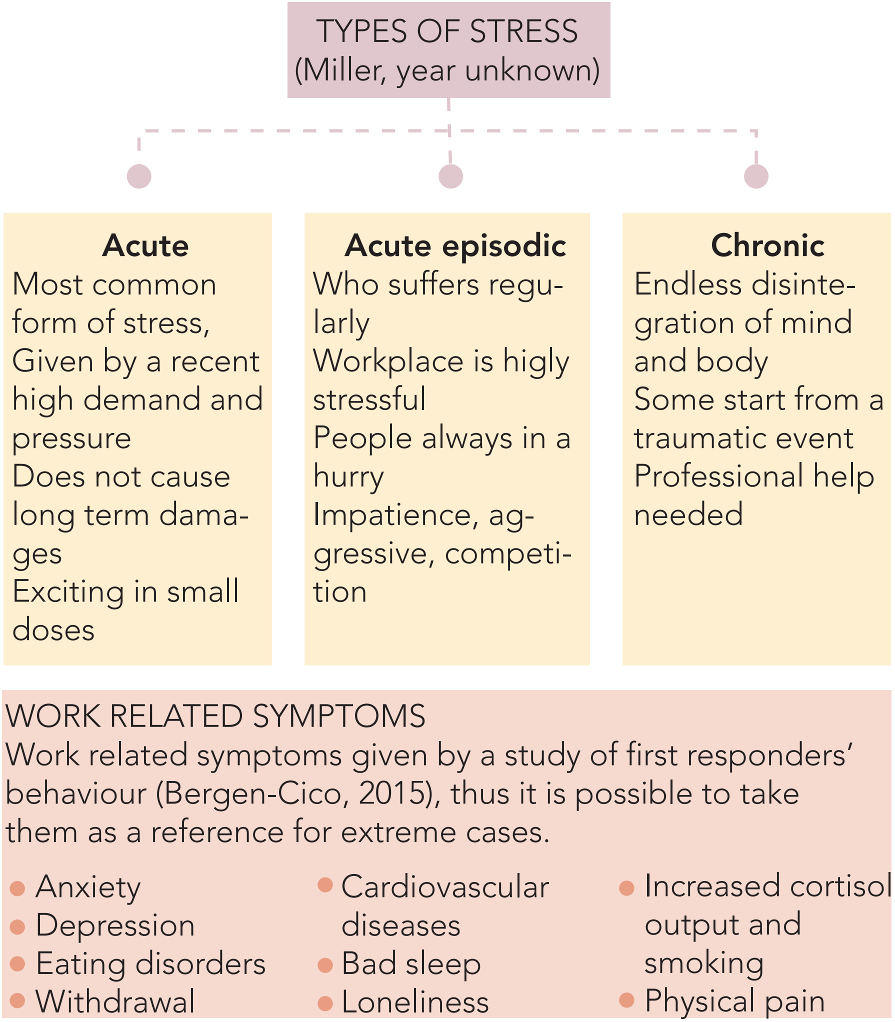
The thesis borns from the awareness that stress related to work is an health problems that affects one in four workers and represents an ongoing and increasing issue in Europe (European agency for safety and health at work, 2011).

### Types of stress

In order to have a better understanding of the matter, it is necessary to point out the three different kinds of stress that an individual can suffer from. The disease is given by personality or traumatic events, which lead to various symptoms of physical or mental fatigue. They are in an increasing order of importance.

### Architecture

In architecture, the users experience stress when there is not balance between the environmental stimulations and the human resources. Thus, the careful control of some architectural elements helps to control the stress caused by the design features. Particurarly, it is possible to list 5 dimensions (Evans, 1998).
Stimulation is the amount of information that the user must cope with, the problem is given by a extreme complexity of spaces, however the lack of informations leads to boredom, thus it is necessary to find a balance between the 2 opposites.
Coherence is about the comprensibility of the building, a place that should be easy to navigate and find your direction. For instance, view toward the outside, use of symbols and landmarks.
Affordances concerns the ambiguity and misunderstanding that some elements can provoke, especially whith conflicting information, as pulling or pushing a door.
Control is given by the possibility of altering the environment, in order not to reduce choices and options, for instance light and temperature
Restorative consist on the design of elements which can alleviate the mental fatigue, as seats focusing on the outside nature (Evans, 1998).



TYPES OF STRESS
(Miller, year unknown)

**Acute**
Most common form of stress,
Given by a recent high demand and pressure
Does not cause long term damages
Exciting in small doses

**Acute episodic**
Who suffers regularly
Workplace is higly stressful
People always in a hurry
Impatience, aggressive, competition

**Chronic**
Endless disintegration of mind and body
Some start from a traumatic event
Professional help needed

WORK RELATED SYMPTOMS
Work related symptoms given by a study of first responders' behaviour (Bergen-Cico, 2015), thus it is possible to take them as a reference for extreme cases.

- Anxiety
- Depression
- Eating disorders
- Withdrawal
- Cardiovascular diseases
- Bad sleep
- Loneliness
- Increased cortisol output and smoking
- Physical pain

*ill. 20 - Types of stress and work related symptoms -*

Further, it is known that a view toward the outside helps in stress alleviation, because of the implicit possibility of escape, the scientific reason is the difference of cortisol produced by the body.

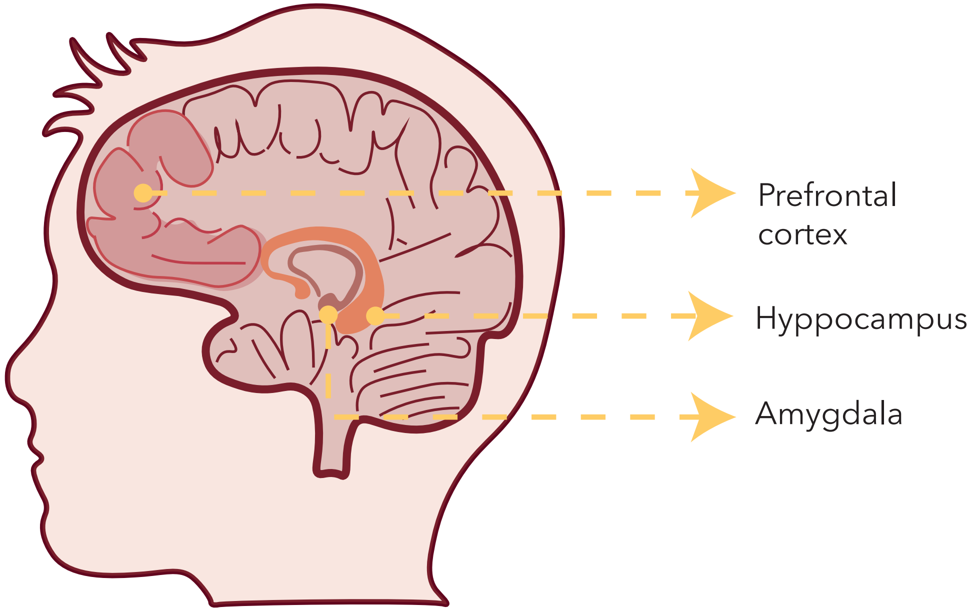
An experiement showed how the saliva cortisol and the heart rate in partecipants exposed to a room with or without virtual window. When a participant experienced the induced stress, responded with higher level of cortisol, as well as in the recovery phase compared to the participants of the room with window. While, the heart rate increased during the test and decreased in the recovery (Fich, 2014).

Living beings as mammals have developed an internal day-night cycle - circadian clock-, it helped in the evolution of the species to predict the time of the day, extremely important factor for survival, preventing pain and discomfort.
It modifies the behavior and psychology following the external natural conditions.
When this clock does not follow the natural process, a stress condition is induced. It can happens when the light exposure is alterated because of shift-work, alterated sleeping and eating behaviour). The hypotalamus-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS) are the part of the body that regulate the stress responses and they are strongly related to the circadian input.

More in detail, the stress signals from the hyppocampus, prefrontal cortex or amygdala, pass to the paraventricular nucleus (PVN) of the hypothalamus, inducing the production of corticotrophin releasing hormone (CRH) to initiate HPA axis activation.

Even when the exposure to circadian light is short in time, humans can respond with higher levels of insuline, blood glucose and pressure.

A solution for the design would be the limited use of blue ligth, known as dark therapy, and daily morning exposure to natural daylight or daylight lamps (light therapy), it helps in reducing depression and to maintain the circadian rhytm (Koch, 2016).



*ill. 21 - Parts of the brain involved in stress response -*

### Workplace and previous studies

It is generally asserted that the design of workplaces can have a negative effect on the users, in fact the studies presented in the previous chapters are the proof of this theory.
As mentioned, the stress related to the offices is embracing two spheres - the psychological and the physical. However, these aspects are interrelated, the dissatisfaction given by a noisy environment can translate into physical sickness, as the negative physical condition becomes dissatisfaction.

At this point, it is necessary to recapitulate all the aspects directly or indirectly related to stress, which have been discussed previously.
According to the majority of the studies so far presented, noise is the most relevant problem causing psychological stress, when regaining the necessary concentration to work seems implausible. Then, the decreasing motivation level given by the adoption of open plan and the dissatisfaction for the impossibility of directly change working environment.
While, on the physical level, the need of taking sick leave increases when working in open plan.

General physical issues -musculoskeletal disorders- are also strongly connected to the posture and movements that the workers assume during the day.
Further, stress produces not only different mental conditions like anxiety and depression, but it is connected to some physical sickness as heart attack, ulcers and stroke. Even incidents are increasing at work, caused by some chronic conditions and stress related issues.
According to the World Health Organization, heart disease will be the first cause of disability followed by the mental illness by 2020 (Clarkin, 2003).
Architecture then, can have a major influence in this field, where the design is based on the human needs and it adapts to the specific purpose.
The thesis then will embrace both the spheres, on one hand, a positive psychological effect will be addressed by the use of natural materials, while, on the other one, reducing physical problems related to work will be chase with a user friendly layout design.

### 2.2.7 Indoor environment

The indoor environment of a building is the governing factor in user-comfort. In a workspace, due to a weekly occupancy of users averages 40 hours, comfort becomes instrumental in the wellbeing and productivityof users. Basic features to fulfill workplace needs architecturally are air quality, control of temperature and lighting, daylight, view, privacy and ergonomic furniture (Loftness, 1997). Moreover, good acoustics ensure harmonious and productive functioning in the workspace. Built environment regulates the indoor climate, thus determining the wellbeing, productivity and health of the inhabitants. Moreover, elements such as aesthetics, color, view and nature can induce motivation and create a positive mood (Croome, 2006).

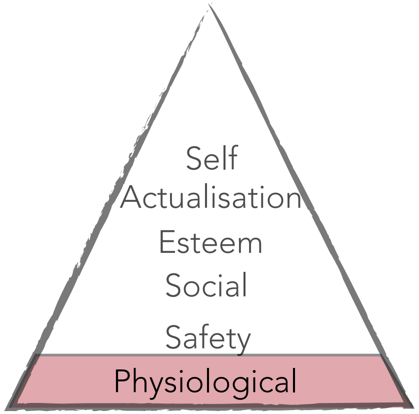
Studies have been conducted to assess the role of indoor environment
at workplaces, along with elements which can improve productivity. Evidence has been found suggesting that low and high temperatures cause aggression in people (Cao, 2005).
Thus, temperature is instrumental for the behaviour of inhabitants. In workplaces, illness in the people working increased when the temperature rose from 20.5- 24.5 degree celsius (Wyon, 1993). However, it has been proven that 23.5 degree celsius is the temperature favored at offices (De Dear, 1993). For lighting, optimum light between 300-500 lux levels for horizontal and 200 lux for vertical surfaces have been proven by research (Boyce, 2000).

Further, a survey based study revealed 73% of employees prioritising 'comfortable work conditions', closely following 'money' and 'opportunities' (Brown, 2000). Studies conducted in offices concluded that discomfort from the ambient environment affect the performance of workers on cognitive tasks.(Baron, 1994).

However, there are several elements designed that can improve the indoor environment. Green surroundings and better indoor climate comprise of measures that can lead to productivity improvement (Kaczmarczyk, 2002).

In the end, research emphasises on the control of environmental conditions to create a comfortable indoor environment. Temperature of 23.5 degree celsius is optimal for workplaces. Moreover, green surroundings and view are essential for user productivity, along with use of optimum light levels: 300-500 lux.

The indoor environment is associated also to the space's height in terms of user's perception. In fact, rooms with high ceilings and open plan are considered as more beautiful than the enclosed ones, which educes the exit decision (Vartanian, 2014). On the other hand, if blue and curvy shapes are added to an high ceiling space, a creative and friendly atmosphere is created, while red rectilinear low ceiling spaces induces more focus and concentration (Steemers, 2015).



*ill. 22 - Aspect addressed by design from Maslow's human workplace needs -*

# 2.3 EVIDENCE BASED RESEARCH

## 2.3.1 Senses, wellbeing and productivity in a workspace

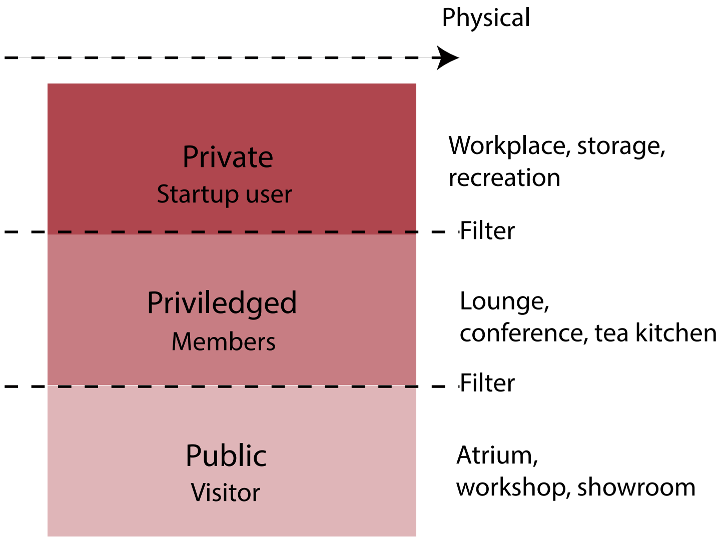
Well being, safety and security are essential components of any workspace. In fact, physiological needs and safety are the primary aspects to attain Maslow's hierarchy of needs in a workspace. (CIBSE, 1999),(Huczynski, 1991). In the aspect of architecture, work safety and physiological needs also comprise of comfortable and safe work conditions. Well being can be defined as a reflection of a person's feelings of self with respect to the world (Croome, 2006).

Moreover, the physical ambience of a built environment can affect an individual's motivation (Croome, 2006). Factors vital to human well being in relation to architecture can be identified as choice of solitary or group work, opportunity to develop self expression, visual scene, optimal acoustics, contrast and changes to stimulate senses and option to switch from work to other activities (Heerwagen, 2001). Well being of a building's inhabitants can also be enhanced by designing a multi sensory experience. The architecture will impact the user by alleviating their mood. The polyphony of senses engages all human senses while walking in woods, which results in invigoration and healing (Croome, 2006). Thus, senses are an important factor for the well being of humans.

A built environment has its own scent, which may be due to the usage and inhabitants. But more importantly, construction materials also have their own smell, which can persist in the environment but also be pleasant if considered in design. Scents can affect cognition, which in turn influences creative task performances (Warren, 1993). Senses such as vision and touch can also affect the perception of other senses. For instance, human skin perceives temperature, texture, weight and density of the environment. Further, vision can evoke gustatory stimuli and thermoception (Croome, 2006). Thus, senses can be redirected and stimulated from one to multiple.

The qualitative aspects of architecture are only designed superficially (Croome, 2006). For instance, the difference between a designed level of illumination and the existing quality of shadow, light and hues. The same can also be considered for the quality of views and spaces.

In conclusion, it can be established that the wellbeing of a user in a built environment can be alleviated by architecture. There are several aspects that should be taken into design consideration to ensure user wellbeing in a workspace. Simultaneous stimulation of multiple senses, acoustics, variety of space usage in user numbers and activities can aid in the workplace wellbeing. Thus, space for recreational or restorative activity is essential. Also, the quality of ambience created by design should be considered.



*ill. 23 - Workplace model of a hybrid Workspace -*

### 2.3.2 Natural materials in offices

Numerous factors determine an occupant's comfort in a built environment. More specifically, factors that influence the occupant's productivity in a workplace environment are personal, social, organisational and environmental. Architectural research and design can ensure that the physical environment addresses the user's comfort with planned spaces and indoor quality. The indoor environmental quality can be enhanced by introducing a natural environment or greenery into the workspace. The workplace should also include recreational spaces, parks and sports facilities for the employees; wellbeing and option to take work breaks (Horr, 2016).

Design interventions that offer a prospect for view to the outside, sanctuary, water, biodiversity, a variation for senses, biomimicry, playful design and allure are features of biophilic design (Heerwagen, 2001). Due to increasing urbanization and densification globally, in future it is already becoming challenging to provide view to nature to all the users throughout a workspace. Thus, exploring the potential of using natural materials can be beneficial to the users of the space.

Among multiple theories, the concept of biophilia has been prominent in the study of effects of nature on human beings. Biophilia can be defined as the 'innate human attraction to nature' . The concept of biophilic design is based on three components- nature in space, nature analogues and nature of space.

Nature in space is the inclusion of natural elements- such as vegetation, water and earth; into the built environment. The characteristics and atmosphere generated can be seen as the nature of space. Natural analogues are the 'material and patterns that evoke nature' and can be classified under ornamentation, artwork, biometric and using natural materials (Green, 2012). However, natural analogues do not have an effect equivalent to nature. Biophilic design has proven to help retain employees and affect productivity at a workplace. Since the focus is the study of natural materials, the effect of analogues in a workplace is examined; with the knowledge that nature in space and nature of space are factors included in the study. Nature analogues include the use of natural materials and patterns, other than artwork in a workspace environment; since the prospect of view to nature may not be viable in an urban set up and a multi level building (Green, 2012).

For instance, Daewha Kang studio has created a user wellness workspace biophilic using patterns in natural materials such as variable shades and textures of bamboo incorporating plants (Angelopoulou, 2018). Similarly, architect Oliver Heath designs workspaces with texture and pattern in natural materials to create biophilic designs, as an indirect representation of nature. The design of Bank of America Tower was designed by using wood and stone as natural analogues, to retain employees (Green, 2012).

Since the architectural design of a workcenter should also be a financially sustainable endeavour, biophilic design should benefit the owner economically.

# 2.4 CONCLUSION

Research related to materials in architecture emphasised the importance of the built environment to be a multi sensory experience; with materials being instrumental to create the atmosphere, in addition to the design. The perception of natural materials in buildings is positive and warm, due to being analogous to nature.
The natural materials also have less environmental impact especially due to negligible production and disposal energy and no toxic emissions to the environment. Most natural materials are either decomposable else can be recycled and used in some other building function. For instance, stone can be recycled as it is, while structural timber can be used in minor building components such as windows or panels. Based on the theory, the definition of natural materials was established.

The aim is to use materials that are either recyclable such as glass; or else decomposable after use such as wood and hay. With the aid of tools such as LCA, material analysis will assess and determine the materials to be used in design. Research on the innovations related to natural materials suggest minimal processing and the potential of natural materials in replacing industrial products. Thus, the design project will be based on biodegradable and recyclable materials, with minimal industrial treatment.

Further research explored the history of offices, and concluded on a hybrid flexible plan with possibility of working from home or change desk as an effective spatial strategy. The traditional and open plan studies should be analysed critically; implementing them where necessary, without generalizing the needs. Glass can be used as partition walls for transparency between internal functions. It will also make the user aware of the tasks, functions and body movement that the workplace will host, in order to predict the needed distances.

Inclusion of nature in offices has proven to be beneficial, as a part of biophilia, as it ensures economic benefits to user companies; thus addressing economic sustainability.

Architectural design can alleviate stress with a user friendly layout, while use of natural materials can aid in the concept due to the psychological impact caused by the users. The research also identifies elements to create a conducive indoor environment to ensure user wellbeing. Summing up, the theory has formed a basis for the progress, design approach  and the design criteria for the project.

# 3| APPLICATION

WORKFLOW:

| | |
|---|---|
| Examples of natural material centered projects | 3.1.1 Natural material usage |
| Explore the office function | 3.1.2 Office |
| Combination of the two topics in existing projects | 3.1.3 Natural materials in offices |
| Application to the project | 3.2 Conclusion |

# 3.1 CASE STUDIES

## 3.1.1 Natural material usage

### Hayball Sydney Studio, Sydney, Australia

2017
Hayball
450 m²
Study Focus- welcoming place to encourage collaboration

A five storey factory building has been restored to accomodate a collaboration oriented way of work.
In fact, rooms are customised for individual or group study, using a room covered by whiteboard panels and meeting rooms, with flexibility in customising privacy.

Some key points that summarize the idea of the project are- a mock workspace, designing an embracing a healthy place for working, encouraging creativity, collaboration, and creating a safe place for the staff. An associative feeling is central for the study; a sense of community and engagement with the people helps to create a welcoming environment. The floors are made of concrete, in order to recall the industrial personality of the place, while the walls are clad with plywood. Thus, the overall perception is of being surrounded by warmth and soft wood material that alludes to the "home" feeling.

The combination of the materials help to create a warm, comfortable and informal atmosphere. Plastic walls are provided for brainstorming, while the concrete structure is clad by white plaster.

The palette's furniture comprises of soft and calm colours such as grey, skin colour, light brown, green plants and more active colours as blue for specific areas. Thus, the colors and materials can be considered in the project to create the desired user perception.

*ill. 24*

*ill. 25*

*ill. 26*

### Farmhouse, Aarhus, Denmark

2006
Niels Meyer
200 m²
Study Focus- Application of hay in building

The material in focus of the case study is the usage and aspects of straw in construction. Straw or hay is used in the farmhouse on sloping facades and the gable roof. The use of straw as a facade material is to visually integrate the structure with the conserved grass landscape. To create an architectural expression respectful to the surrounding context, straw was also used for its has insulating properties. The sloping roof continues in form with wall facade and rids the building of rainwater. The roof also is layered with protruding curves roof feature along the windows. In conclusion, the protruding layered curves demonstrate a flexibility inconfiguration in straw construction, instead of restriction to right angles. In combined application with fire retarding and fireproofing treatment, straw facade or roof is a safe material which can be used to integrate the built with the site in the project.Further, the insulating properties of straw can be utilised in construction;especially with respect to the availability of straw and low environmental
impact.


ill. 27


ill. 28

## 3.1.2 Office

### Bloxhub, Copenhagen, Denmark

2017
OMA
Area- 28000 m²
Study Focus- professional networking, mix use building

This architecture represents a landmark for the city of Copenhagen, located in between the canal and a busy road. Different functions are gathered in the building as co-working and exhibition spaces, residences, fitness center, car park and commercial functions. The use of glass and complete see-through effect reflect the vision of the project, as a showcase work. In fact, what was important for the architect, was to show the backstage work to the people, because usually is what attracts more the curiosity.

The spaces are organised around the central exhibitional core, allowing views from the workstations and towards the context, framing the outside. The staircases are placed all around the perimeter of the inner core, the functions are divided into the floors,expanding the spaces where needed, doing so the facades create a play of shadows and lights. The sharp and clean lines characterize all the construction, the outside expression is also used in the inner spaces, same materials with exception of more textiles and colours. For instance, the big spaces are visually divided using different furnitures to create several atmospheres, from more to less informal.

The internal organization of some areas responds to the need of fast flexibility of the spaces, indeed furniture that can be piled up in one line and paper walls that can be stretch and modeled when necessary.
What it is noticeable is the lack of response to the context, especially

the strong industrial character expressed by the materials -glass and metal- and the linear geometric shape, the only feature is the volumetric footprint of a neighbour building.

The project is born from the will of solving urban challenges concerning climate adaptation, energy consumption, infrastructure, resilience.


ill. 29

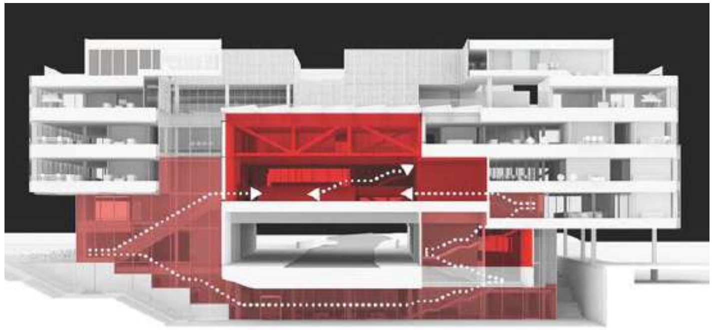

ill. 30


ill. 31


ill. 32

The common belief is that a new way of working and cooperation is needed to solve the nowadays issues. The fields involved are architecture, engineering, tech, management, construction and design, all of them together help the individual to create a professional networking in a stimulating environment. Startups, researchers and corporates are encouraged as well, with the focus of sharing ideas to create better cities and lives. Further, facilities as labs, workshops, virtual reality studios, various technologies are available for the members to improve sustainability, which is focal part of the adaptation/ development process.
In BLOXHUB companies can grow, interact with others and share, in fact the term collaboration is the foundation of the vision.

Particularly, a 3 steps program is provided for startups - screening the kind of business, mapping the challenges and matching suitable members. Accelerating programs, access to the facilities, labs and workshops are part of the initiative that help the Startup to grow and evolve. A price of participation includes the desk, access to conference room, cleaning and wifi.


ill. 33

## 3.1.3 Natural material in offices

### Believe in Better Building, London, United Kingdom

2014
Arup Associates
Area- 3850 m²
Study Focus- flexibility, natural materials, function, sustainability

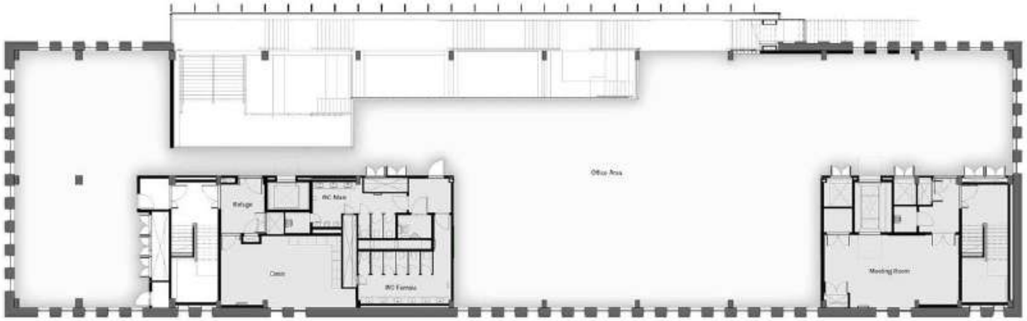
The four storey building caters to multiple functions shared between school children, training program apprentices and office. Ground floor accommodates visiting children while restaurant, training and commercial functions in the upper storeys. The design concept is in flexible creative spaces, with open layout offices with column free open spaces. The spaces are divided by movable and foldable partitions acoustically designed to generate workspaces or to be removed for larger events. Raised floor creates a gap between floor and slab, which ensures no additional requirement for acoustical treatment between floors.

The rainwater is harvested for use in toilets. A central staircase is an instrumental design feature, which includes breakout spaces within to enhance social interaction; and also aids in built orientation and wayfinding. Natural materials are used in the construction along with glass. The construction mostly constitutes of different applications of wood, including engineered cross laminated timber for exposed structural members. The building has provision for mechanical ventilation, but natural ventilation is majorly functions. The untreated structural members and wooden surfaces create an attractive and warm ambience. The use of wood enhanced the client organisation's cultural and sustainable philosophy.

Thus, learning from the study, cross laminated timber can be used as structural elements in the design. Moreover, the untreated natural materials enhance the workplace ambience, along with acoustic strategy of creating a gap between floor and slab. Sustainable strategies such as rainwater harvesting and natural ventilation can be considered. The staircase has become a central ornamented design feature, with services and core function on the building corners; and free flexible space in the centre.

ill. 34

ill. 35



ill. 36

# 3.2 CONCLUSION

Due to urbanisation and the resulting lack of urban space, it is challenging to include greenery and natural spaces in building designs. However, natural materials can act as natural analogues, in addition to natural features in the stress alleviating role of architecture.

The importance of stimulation of multiple senses in a workplace has been established for user wellbeing and productivity.

Research has also investigated the role of nature and natural materials in offices, known as biophilia. Further, material case studies focus on the application of the natural materials such as hay and engineered timber; and the perception of materials and their role in architecture is investigated.

The architectural study shows methods and approach in the design concept, along with sustainable strategies, the use of industry processed timber engineered into cross laminated timber.

The design strategy is observed constituting of a flexible plan with multiple functions, while ensuring acoustical intervention for seamless work operation. Recreational activities are also important in offices, which will be included in design. Thus, the natural materials from the research will be analysed while the design features identified in the study will be incorporated in the design project.

# 4| MATERIAL ANALYSIS

WORKFLOW:

| | |
|---|---|
| Objective level:<br>Environmental impact | 4.1 LCA |
| Sensorial level:<br>Uditive implication | 4.2 Acoustics |
| The materials considered to be visually accessible | 4.3 Material table |
| Implication for the design | 4.4 Conclusion |

# 4.1 LCA

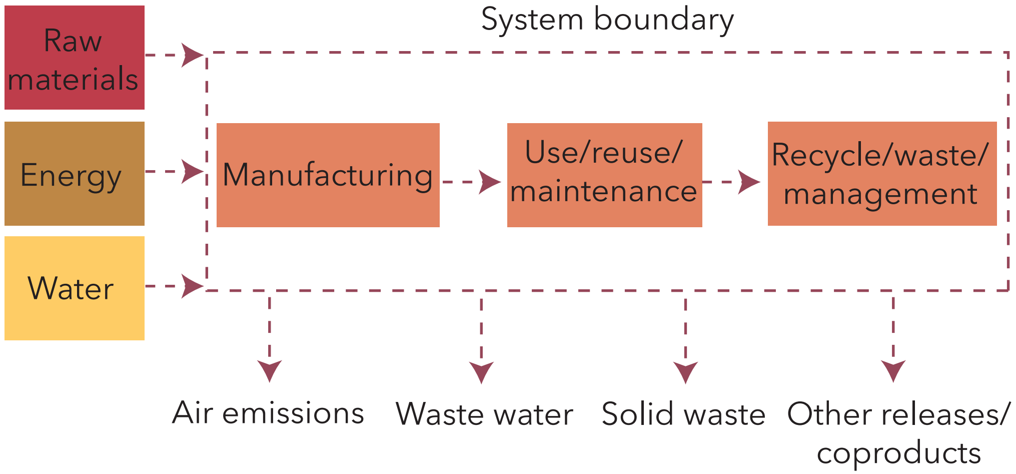
Life cycle assessment can be defined as the estimation of potential effects of extraction of resources, transportation, production, operation, recycling and discarding of a product on the environment (United Nations Environmental Program, 2011). The definition can also be modified as the "compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle." (International Standards Organisation, 2006). In addition to the environmental impact, when social and economic factors are also considered, the analysis is called 'Life Cycle sustainability Assessment'(United Nations Environmental Program, 2011).

Two aspects that that are accounted for in LCA are embodied energy and embodied carbon. Embodied energy is defined as the quantity of energy needed to unearth, collect, refine, extract and process a material into usable form (Domone, (2010). Embodied energy also accounts for the energy required to transport the material from the source to the constructionsite. Embodied Carbon, on the other hand, is the quantity of carbon dioxide emission during extraction and processing, in addition to source of energy and impact of the environment (Domone, (2010).

The production, construction, operation and destruction stages of the resources are accounted for, along with the environmental, health and resource affects. The intention of conducting a LCA is to choose the materials for project design and estimate the impact of construction on the environment (Life Cycle analysis and assessment). The materials compared are of similar physical properties and building application.

There are four steps in LCA- defining the scope, life cycle inventory analysis, life cycle impact assessment and interpretation of results. The scope defines the boundary for the mass balance, assumptions, limitations and functional unit of analysis (Sellers, 2015). The measure of function that unifies data to analyse between products or processes to choose alternatives is the functional unit of analysis. In life cycle inventory analysis, diagram quantifying the steps in the product cycle marking the input and output is created. The third step of life cycle impact assessment is the evaluation of environmental impact of the product

or process. The last step is the interpretation of the results of the study with conclusions and recommendation (Sellers, 2015).



*ill. 37 - LCA and the environment -*

# 4.2 ACOUSTICS

When designing, different requirements need to be accomplished depending on the function of the building. Thus, the sound insulation is one of the main parameters to take care of in a workplace.
In fact, the building needs to be protected by the sound pollution from two perspective.
Firstly, the building should shield itself from the external noise produced by non controllable sources, secondly, it should manage the sound produced inside, in order to guarantee a good indoor environment to its users.
As the existing studies have shown in the previous chapter, noise also is one of the main causes of stress and concentration loss. Thus, the rooms or zones of the workplace have different requirements or aims for sound insulation, depending on the function. For instance, quiet areas as telephone or restorative rooms need a stricter requisite, where special panels can be integrated in the design.

In a workplace, the noise sources are composed by voices, calls, computers, printers, technical devices and all those elements that are needed for a place to be professionally efficient. Thus, the ventilation system plays a role in this overall, due it is essential for a healthy indoor environment, particularly, in order to assure a good system functioning, the ventilation starts before the operation hours in non residential buildings.

DS/EN 15251 is followed to assess the sound pressure level suggested, depending on the type of building and the kind of space.
In the design process, the reverberation time will be calculated, especially for the most critical zones. In fact, materials reflect the sound differently depending on their surface, absorbtion differes because of the posority, inclination, tortuosity and all the superficial characteristics.

The reverberation time will be calculated, considering the material and its area, room’s volume, absorption coefficients, number of people, furniture and so on. It will be calculated using the formula of Wallace C. Sabine, as follows:

$$T= \frac{0,16 * V}{\sum S * a}$$

Where,
V is the volume of the room,
$\sum$ is the sum of all the specific material multiplied by their coefficient,
S is the area of a specific material,
a is the absorption coefficient of the specific material.

# 4.3 MATERIAL TABLE

The direct experience of the users in the building are essential for the Thesis approach; the materials considered to be visually accessible are listed in the chart.

On one hand, the design would benefit from the use of innovative materials such as algae for energy production; while characteristics such as strong colour presence, smell and visual expression need to be examined.

Nowadays, brick is largely used because of its expression and the long tradition. However, it would not represent a long-established connection to the context for the project, since the urban fabric is industrial and made of concrete constructions. Thus, concrete and metal would resemble the historical connection to the area.

Plants are considered as a material itself, the dense application on the internal walls would facilitate wellbeing of the users, for visual and smell properties.

| Material | Conventional building application | Perception associated | Possible project application |
|---|---|---|---|
| Wood | Wall member, window frame, roof member | Warmth, journey of before and after process | Cladding, flooring, window frame |
| Stone | Wall, foundation | Durability, elitist | Cladding, flooring |
| Hemp | Insulation, facade | Tradition | Cladding, insulation |
| Glass | Window | Higly sensorial, tactile and aestethic | Internal partitions, window |
| Brick | Wall | Tradition of construction, humility | - |
| Algae | Curtain wall, window | Scepticism (innovation) | Landscape elements |
| Cotton | Insulation, textile for furniture | Home feeling | Insulation, textile for furniture |
| Cork | Insulation | - | Interior panels, insulation |
| Cork board | Insulation, acoustics | - | Interior panels, insulation |
| Concrete | Structure, foundation | Durability and cold | Wall, foundations |
| Galvanized steel | External cladding | Durability and cold | Cladding |
| Cross laminated timber | Structure, floor | Innovation | Structure, flooring, interior panels |
| Plants | Landscape | Nature and tranquility | Cladding interior walls, landscape |

# 4.4 CONCLUSION

The materials will be calculated or simulated on the basis for the analysis criteria. Assessment of different life cycle stages of materials, acoustical, and visual qualities such as tactile and glare will be calculated and compared.

For example, a material such as wood has no production energy or processing, but has to be replaced every 10-20 years in outdoor application; while more years in interior usage. Thus, it might be economically viable and have low embodied energy; but require chemical treatment that is environmentally harmful. On the basis of theoretical research, the four criteria were chosen to analyse the natural materials in detail, and further implement the materials that satisfy the criteria in a sustainable frame.
The analysis will thus have an implication on the project design in the form of calculated choice of building materials.

# 5| SITE ANALYSIS

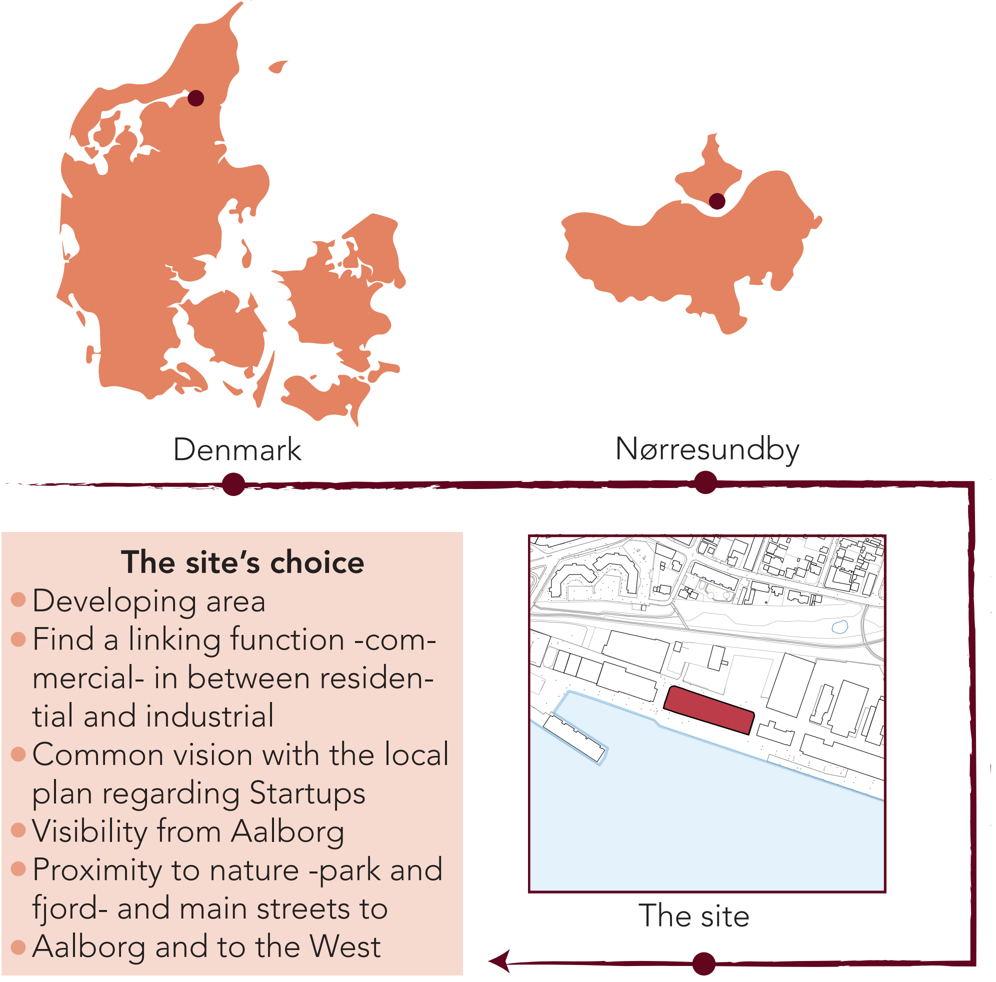
WORKFLOW:

| | |
|---|---|
| Natural level | 5.1 Environment |
| Architectural macroscale | 5.2 Urban |
| Architectural microscale | 5.3 Building character |
| Textures nano scale | 5.4 Tomographies |
| Objective perspective | 5.5 Conclusion |

# 5.1 ENVIRONMENT

## 5.1.1 Geography

The project takes place in Nørresundby, Denmark on an area of 3650 m². On West it has the main connection to Aalborg, while towards South it faces the fjord. Especially in this part of the city, the industrial constructions are prevalent.



**The site's choice**

- Developing area
- Find a linking function -commercial- in between residential and industrial
- Common vision with the local plan regarding Startups
- Visibility from Aalborg
- Proximity to nature -park and fjord- and main streets to
- Aalborg and to the West

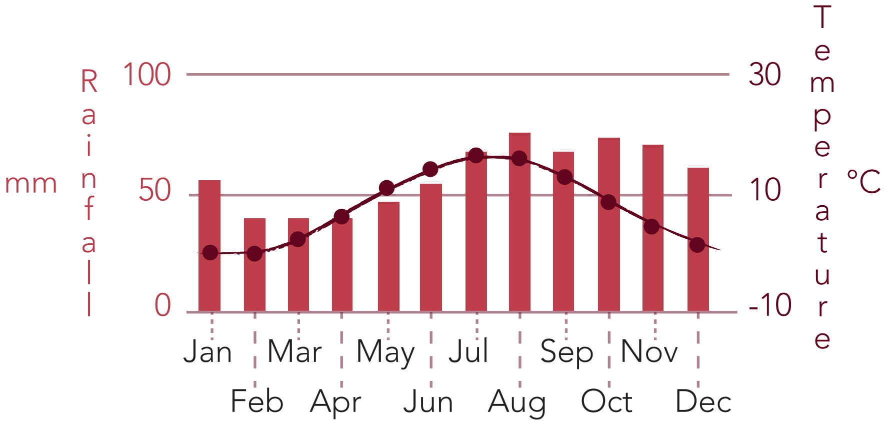
*ill. 38 - The location of the site -*

## 5.1.2 Climate

The mean temperature and precipitation in Aalborg is 8 degree celsius and 21.4 mm annually. The rain is almost evenly distributed throughout the year. The annual average winds are 17 km/h, with the predominant wind direction being from south west (Timeanddate.com, (2019) (Windfinder.com). The high rise residential buildings to the west and northwest of the site do not hinder the wind speed due to the direct winds from the fjord. The wind force experienced next to the fjord is much stronger than along the building sheltered regions of Nordre Havnegade.

Conclusion

Due to frequent precipitation in Aalborg, the roof requires to be designed to redirect water from the building to the drainage. Especially a sloped roof with gutter will also prevent water seepage in the building. Further, the pedestrian and bicycle approach from Aalborg to the site should be considered along Nordre Havnegade, due to the road being relatively more wind sheltered compared to fjordside. In considering the building facade material, the wind pressure especially on the southern and western facade should be considered, along with window openings and terraces.

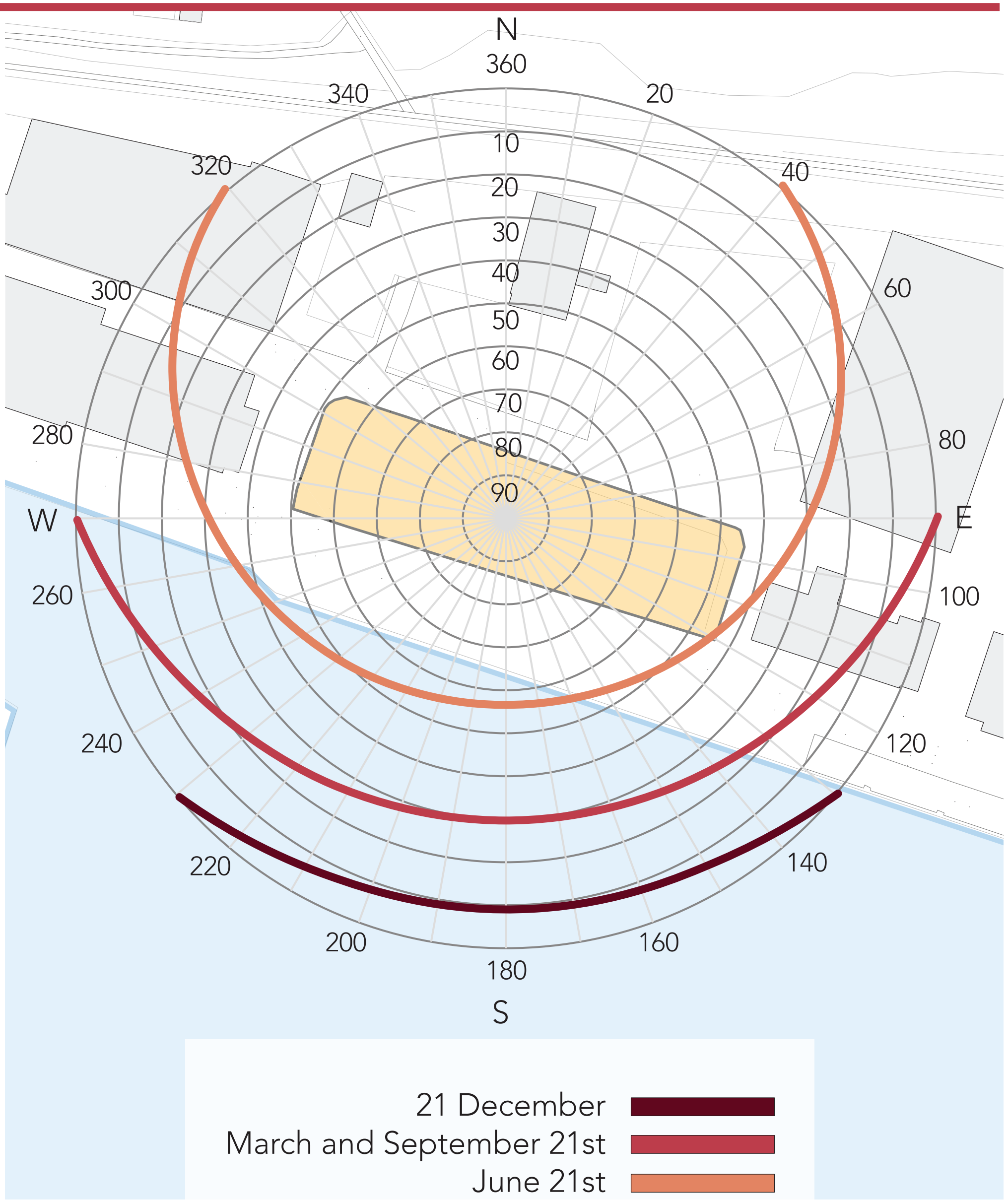


*ill. 39 - Rainfall and temperature diagram -*

## 5.1.3 Sun and shadows

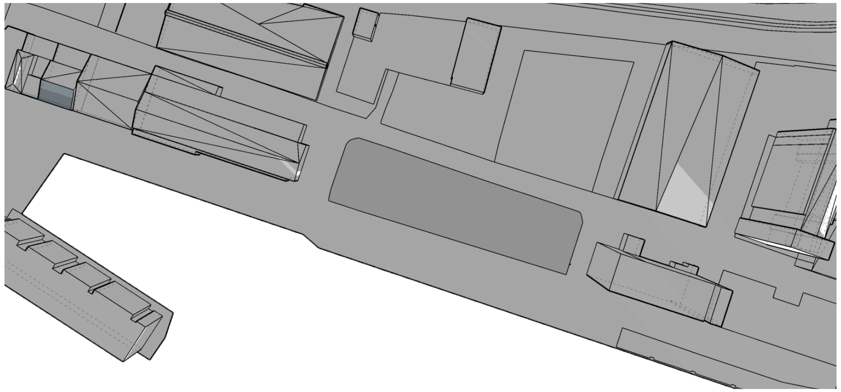
The seasonal shadow study is part of the climate analysis, showing the shadows created on June 21 and December 21 at different times of the day. The analysis reveals an unhindered south for potential sunlight on the site, which can also utilise the view to fjord. The shadows cast on the site are less by the high rise industrial building on the east in summer than in winter mornings. The daylight lux levels vary greatly between summer and winter. While due to the building height and site orientation, the two storey industrial structure on the west and residential building on the south west does not cast any shadows on the site. The built volume, however, casts shadow to the north of the site, which is used as outdoor industrial storage.

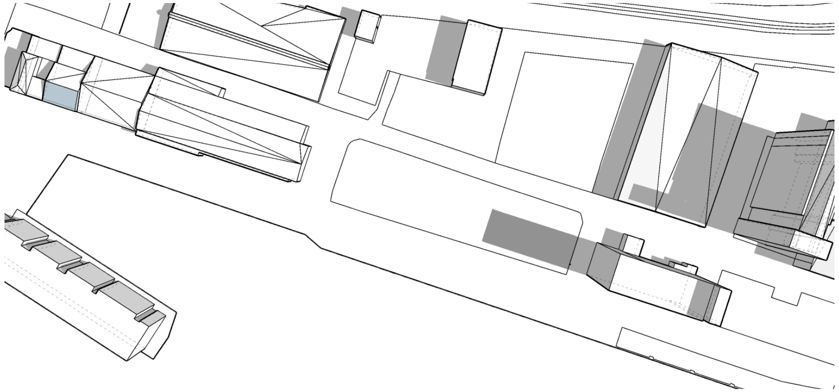
In conclusion the structure will utilise the sun from the unhindered south, with potential for energy produced by solar cells. The outdoor site functions will have to be prioritised according to usage. For example, outdoor spaces towards the north will not receive sun, while will be wind protected. While towards the south the outdoor spaces will receive more light, view to the fjord and unobstructed south west wind.

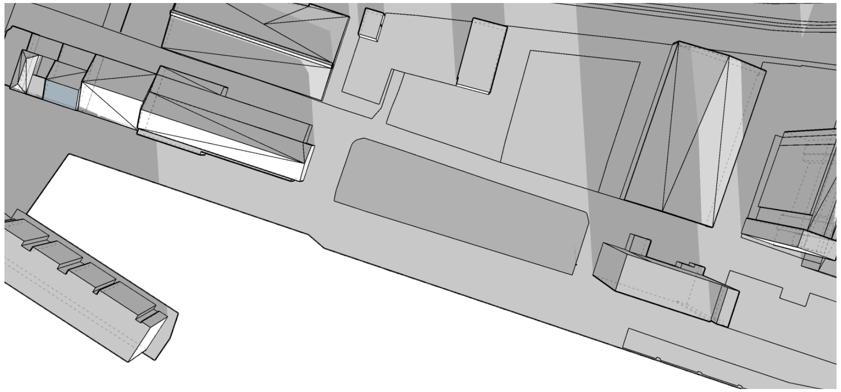


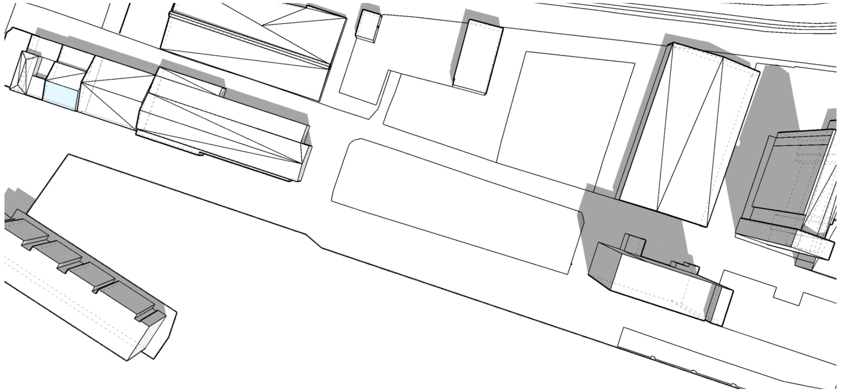
*ill. 40 - Sun diagram - scale 1:2000*

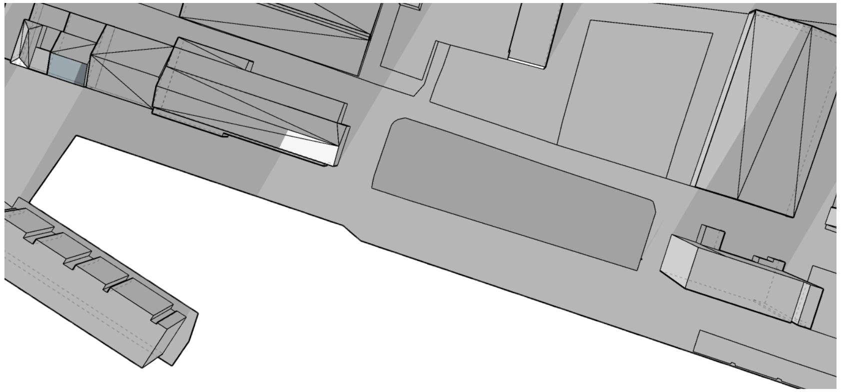
= *Design parameter: openness toward South and PV system*

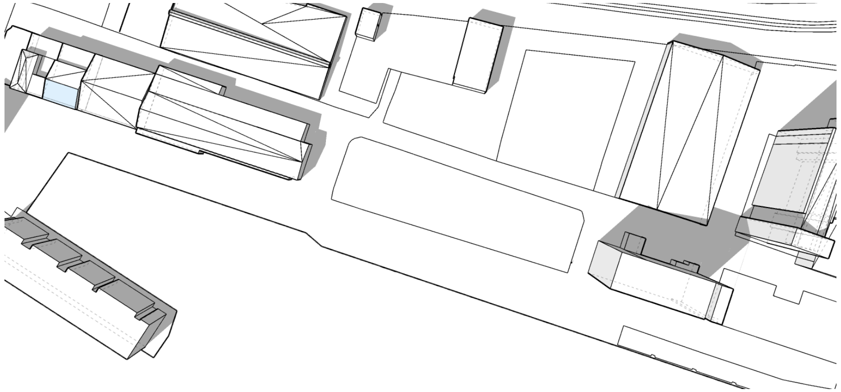

ill. 41 - 21 December at 9.00 -


ill. 44 - 21 June at 9.00 -


ill. 42 - 21 December at 12.00 -


ill. 45 - 21 June at 12.00 -


ill. 43 - 21 December at 15.00 -


ill. 46 - 21 June at 15.00 -

# 5.2 URBAN

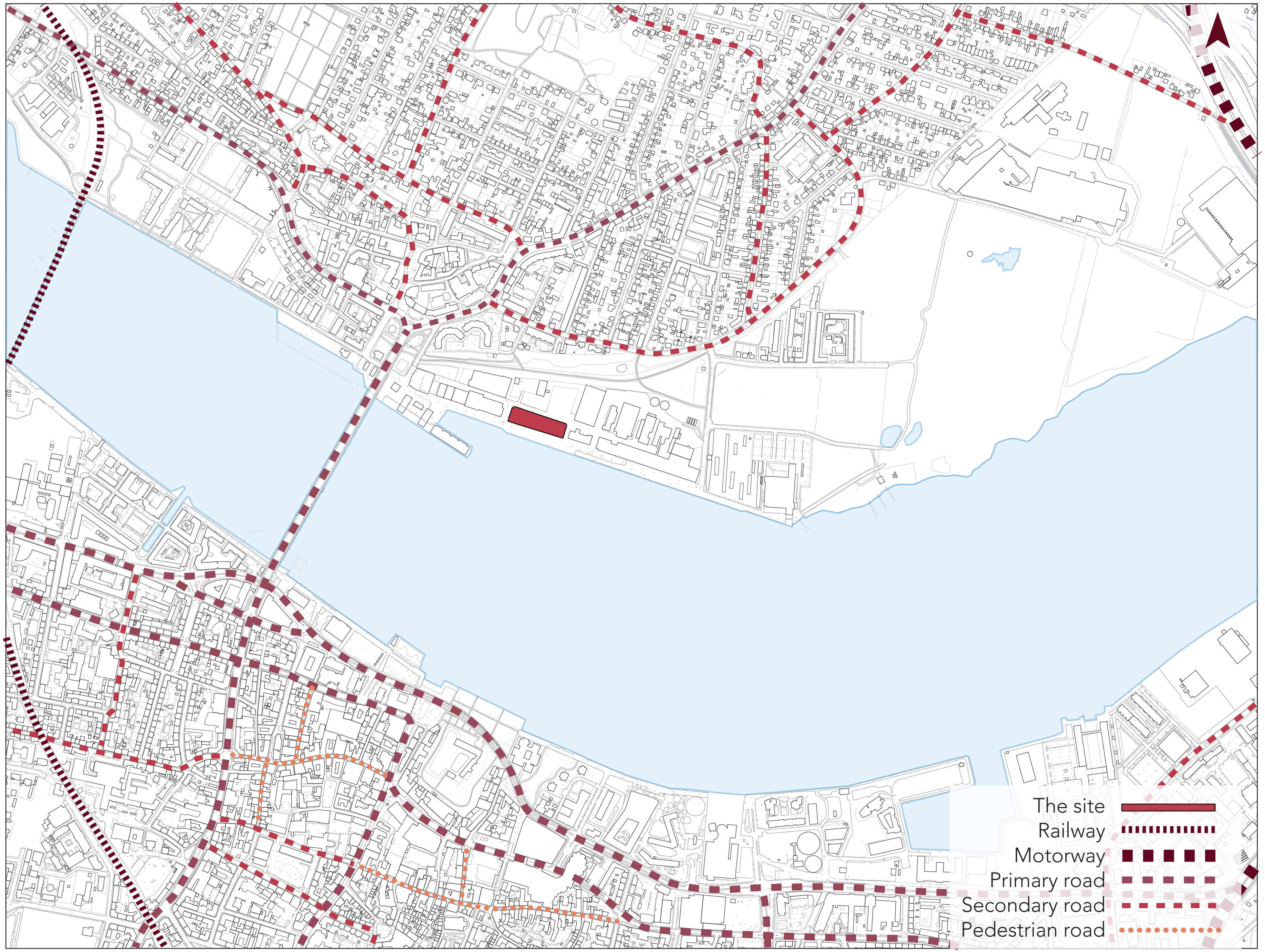
## 5.2.1 Infrastructure

Studying the hierarchy of the roads is one of the first step to take when analysing a site both if it is a known area or not, In fact, from this objective layering, it is possible to understand the flow of the area for cars, bicycles, public transport, as well as pedestrians.

The infrastructure analysis allows to understand the main connections in the area, which will be further analysed in detail with the transport and accessibility study. The primary road, which is crossing the bridge, represents the main arterial street, which connects the city to the rest of the country. After crossing the bridge, it divides into two streets, to the West and to the East of the country.
Furthermore, the plan shows a more activity in the South because of the presence of primary roards, while in the North, the percentage of primary roads is reduced by the presence of secondary roards that are connecting the residential suburbs.

The analysis shows the lack of connection with the city of Aalborg, which should be implemented, as well as the pedestrian roads, which in the Nørresundby part are not present, but they help for a more varied and active urban life.

*ill. 47 - Infrastructure - scale 1:10000*


The site
Railway
Motorway
Primary road
Secondary road
Pedestrian road

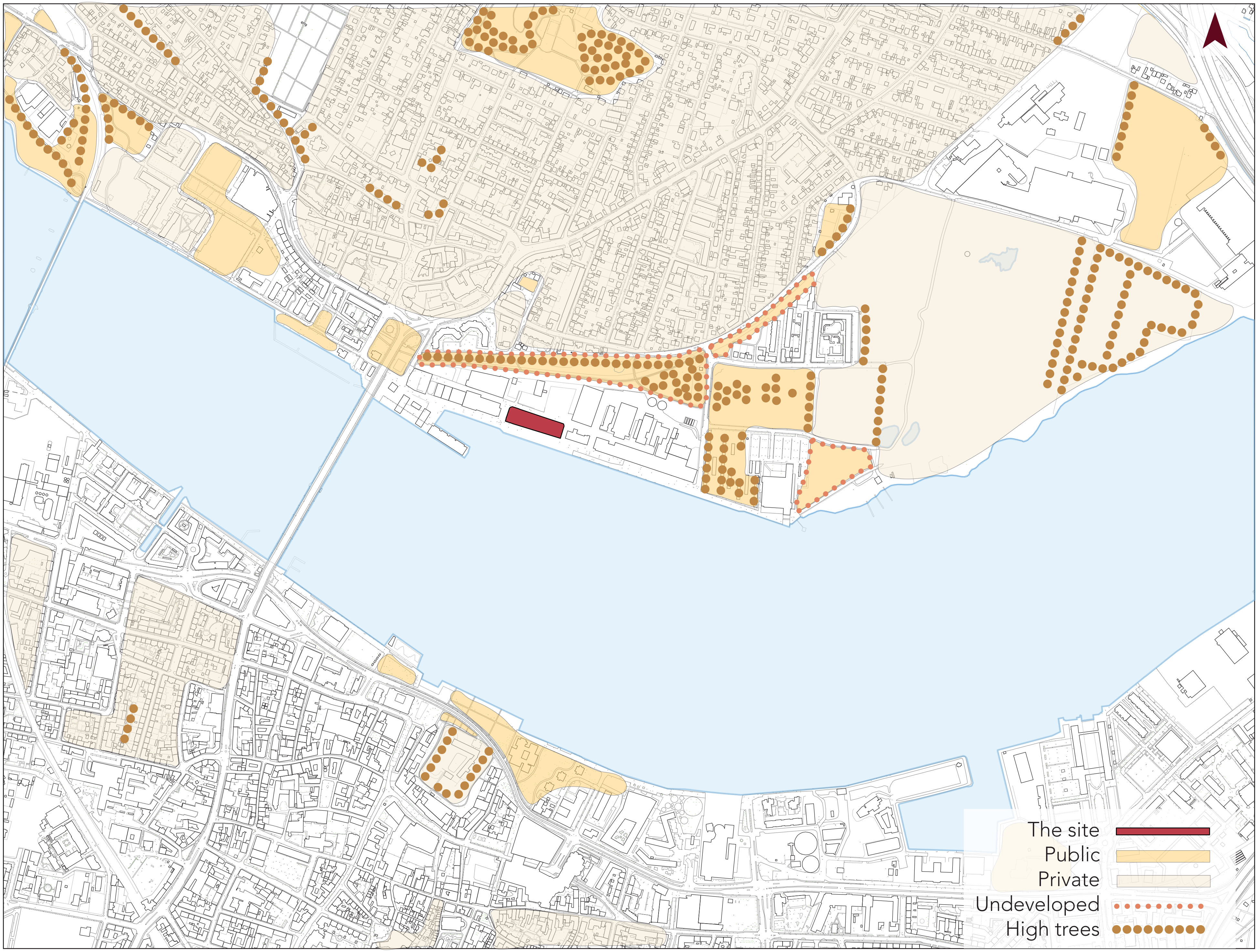
## 5.2.2 Green areas

The area is divided into the 2 macroscale categories, private and public green. Another feature is added to the public areas -undeveloped- which stands for all those zones where the nature grows without being trimmed and where the level of maintenance is low compared to the other areas, for instance the pavement is not appropriate for all the categories of people to walk on.
A tridimensional criteria is considered as well, the presence of high trees, in order to separate the flat green areas to the higher group of elements.
High trees determine less see through visibility, more dark spaces during winter times and deviation of the wind. However, it guarantees a nice variation and patter to the context, added to the presence of bushes, which are not shown on the plan.

In conclusion, the study gives information concerning in which direction it is possible to imagine a connection to the surrounding natural areas and the typology of green spaces. In fact in the next chapter, the vision of the local plan is shown, where green linking areas connect the urban framework to the Stigsparken.

= *Design parameter: implement neighbour nature toward North and East*

*ill. 48 - Green areas - scale 1:10000*


The site
Public
Private
Undeveloped
High trees

## 5.2.3 Services

The area close to the site is analysed to spot the context functions, divided into 3 ranges, 200m, 500m and 1km. It is possible to select different criterias to analyse the surrounding, the best approach is to chose services that are related to the function of the Thesis.

In fact, imagining a flexible workplace where people gather to work and cooperate, the features concerning food, as market and restaurant/cafè is focal. Thanks to the possibility of eating and cooking in the workplace or outside with colleagues to interact and share more informal moments.

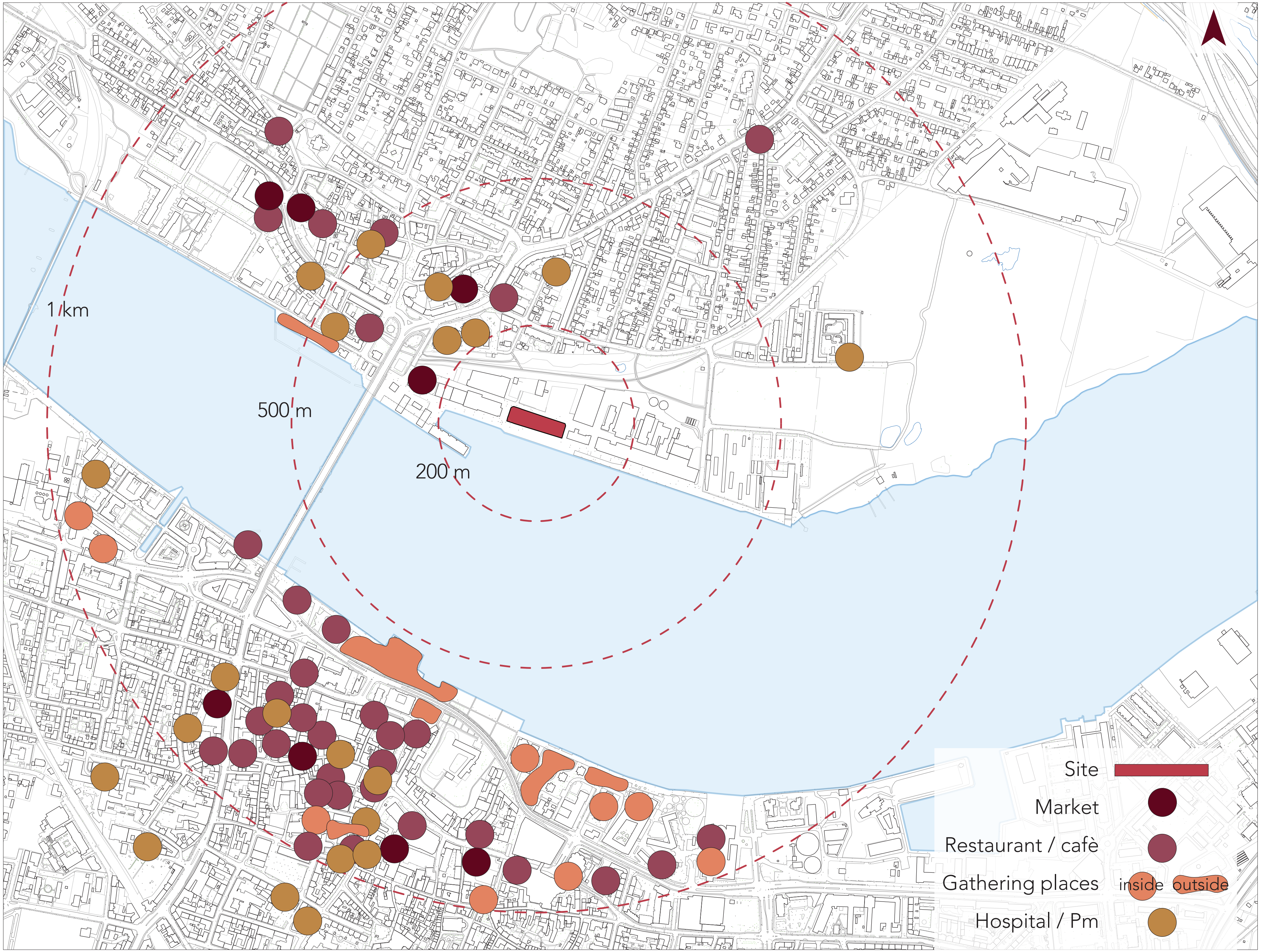
Gathering spaces are also in the plan, labelled with a circle if are inside areas and organic forms if they are outside. The gathering spaces spotted in the area covers functions where meetings and event are organised, essentially where people have the possibility to meet others of the same working/studying field. For instance, these social places are libraries, cafès, student house, Utzon center etc.

Beyond 1 km only the health facilities are present in the map because they represent an higher level of necessity, while the study on the plan of all the other criterias are within 1 km. It is also necessary to highlight that the distances are increasing when moving in the South-East side of the map, due to the presence of the fjord.

In sum, the plan shows a more active urban life in the city of Aalborg, while on the other side of the fjord the services are reduced.
Especially, from a quantitative point of view, the places where people can meet are highly reduced in comparison to the other side, decreasing the attraction of people toward the area.

= *Design parameter: implement gathering spaces*

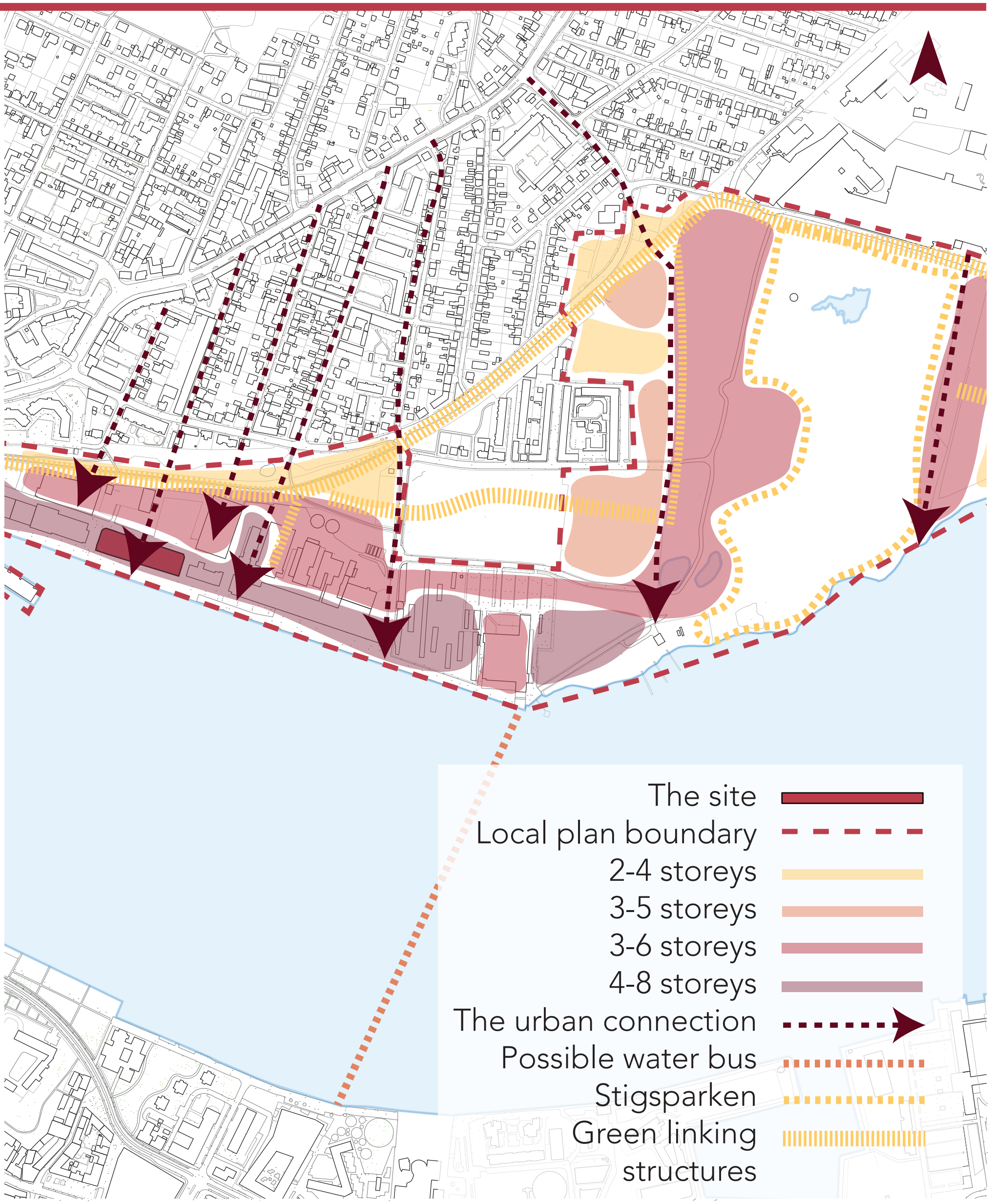
*ill. 49 - Services within 1 km distance - scale 1:10000*


1 km
500 m
200 m
Site
Market
Restaurant / cafè
Gathering places
inside
outside
Hospital / Pm

## 5.2.4 Local plan

The local plan by the Aalborg Kommune mentions that the connectivity of the Stigsborg Havnefront with Aalborg is important to create a variety of settlements. The region is planned to have mixed use areas of contemporary housing along with industries and offices. One of the strategies (Strategy 3) addresses the promotion of startups and small companies; while preserving silo and industrial buildings, in order to save the current character of the zone. The importance is to have a mix of business and innovation hub, along with the residential life.
The masterplan mentions the front as wholly residential function, with the structures along the fjord (including the site) to have four to eight storeys, with consequently lesser storeys towards north. The quality of the environment will be given by the connection between town, fjord and park, creating an interrelated network of attractions. For instance, the sport life on the fjord can be a visual interest for people on the coast, some wooden structure on the water are considered, where the citizens can play and learn. The masterplan states of creating edge zones such as front garden and semi public areas with interactive ground floor towards the fjord. The terrain of Stigsborg Havnefront will be even.
In the plan only the main aspect of the local plan are shown, due to the relation with the Thesis site.

To conclude, the local plan is forecasting a different use for the site, residential building with a minimum of 4 storeys. However, some functions are thought to be included in the building, as liberal business service, restaurant or gallery. Thus, could be plausible to imagine a different use for the site as in the vision of the Thesis, because of the combination between Strategy 3 and the mixed use proposed by the local plan.
Many aspects of the local plan are considered for the upcoming phase, for instance the relation to the natural elements, park and fjord, are very important to stimulate the users. Also, the height of the buildings that the kommune is predicting will be take into account as well.



*ill. 50 - Local plan - scale 1:10000*

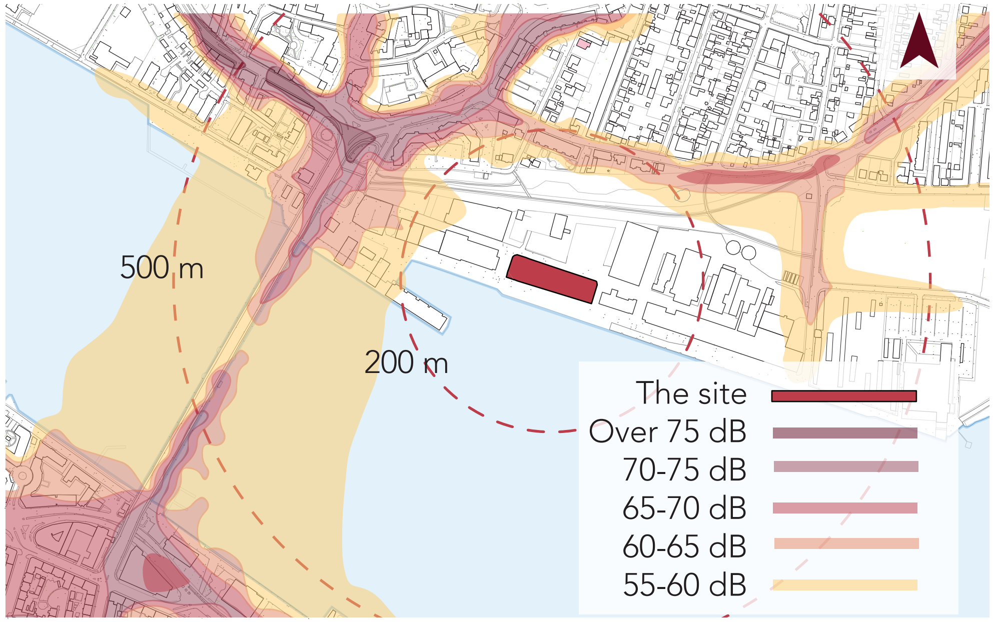
### 5.2.5 Noise

The authorities calculate and map the noise zone around the existing roads and other sources, setting noise limits depending on the functions to design. The data are also used to assess the negative acoustic impact in existing buildings. Strategies by the Government are intended to reduce the noise from roads, because of the annoyance and the health consequences that it generates.

Then, the recommended traffic noise limit for a commercial function such as offices is 63 dB, and for outdoor recreational activities is 58 dB.

The noise analysis confirms the experience on the site. The main roads around the site, especially the bridge, produce a lot of noise on the pedestrian level during daytime. However, the site is located underneath the bridge level, thus the acoustic is not substantially affected.
Especially in the 200 m radius, the area is extremely quiet according to the map.
What needs to be considered though, is the noise of heavy vehicles due to the industrial activities of the zone, where construction machines are usually working, boats passing by and loading and unloading activities on the quay.

Usually, the noise level in areas that are not fully urbanised is low, as in this case, therefore would be desiderable to respect and keep the acoustic pollution at the minimum possible with the new designs.



*ill. 51 - Noise map - scale 1:10000*

= *Design parameter: green mobility*

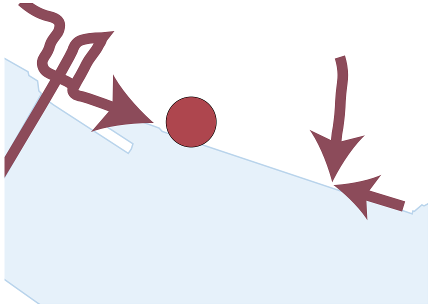
### 5.2.6 Accessibility

Two ranges of 200m and 500m are set on the plan to analyse the area around the site concerning accessibility and transport.

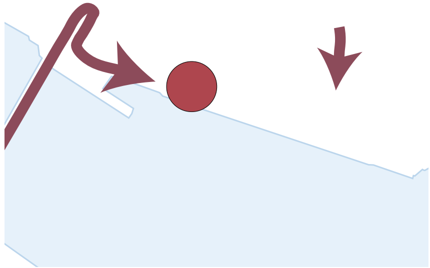
Cars can travel on the majority of the area, in large lanes for the main roads, while smaller lanes are provided in the more quiet residential zone. Usually the network created allows the cars to move freely, in opposition to only 3 roads which are dead ended.

Further, a pedestrian friendly area is present on the North-West side of the area. It is characterised by different kinds of pavements as concrete tiles and stones, which helps to reduce the car speed. In fact, due to the different materiality of the ground, the driver can feel the change in tactility, from the smooth drive given by the asphalt to the bouncing stone drive.

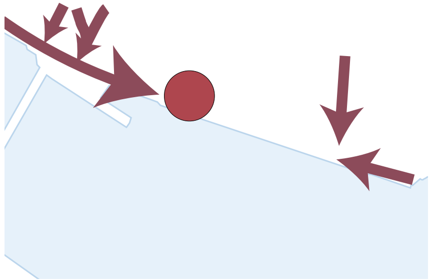
Bicycle lane are present in all the area and only two of the get closer to the site, however the majority of the lanes suddenly stop.
Pedestrians can walk almost freely in all the area until the orangy arrow, which represents the only direction from where people can reach the project site. Nevertheless, when approaching the it, some barriers forbid the access to the site.
Nowadays, the site is used as a big open-air storage from the companies that are surrounding the area, in perticular, the business concerns all the products for the farm industry, from animal feed goods to seeds.



*ill. 52 - Cars closest access -*

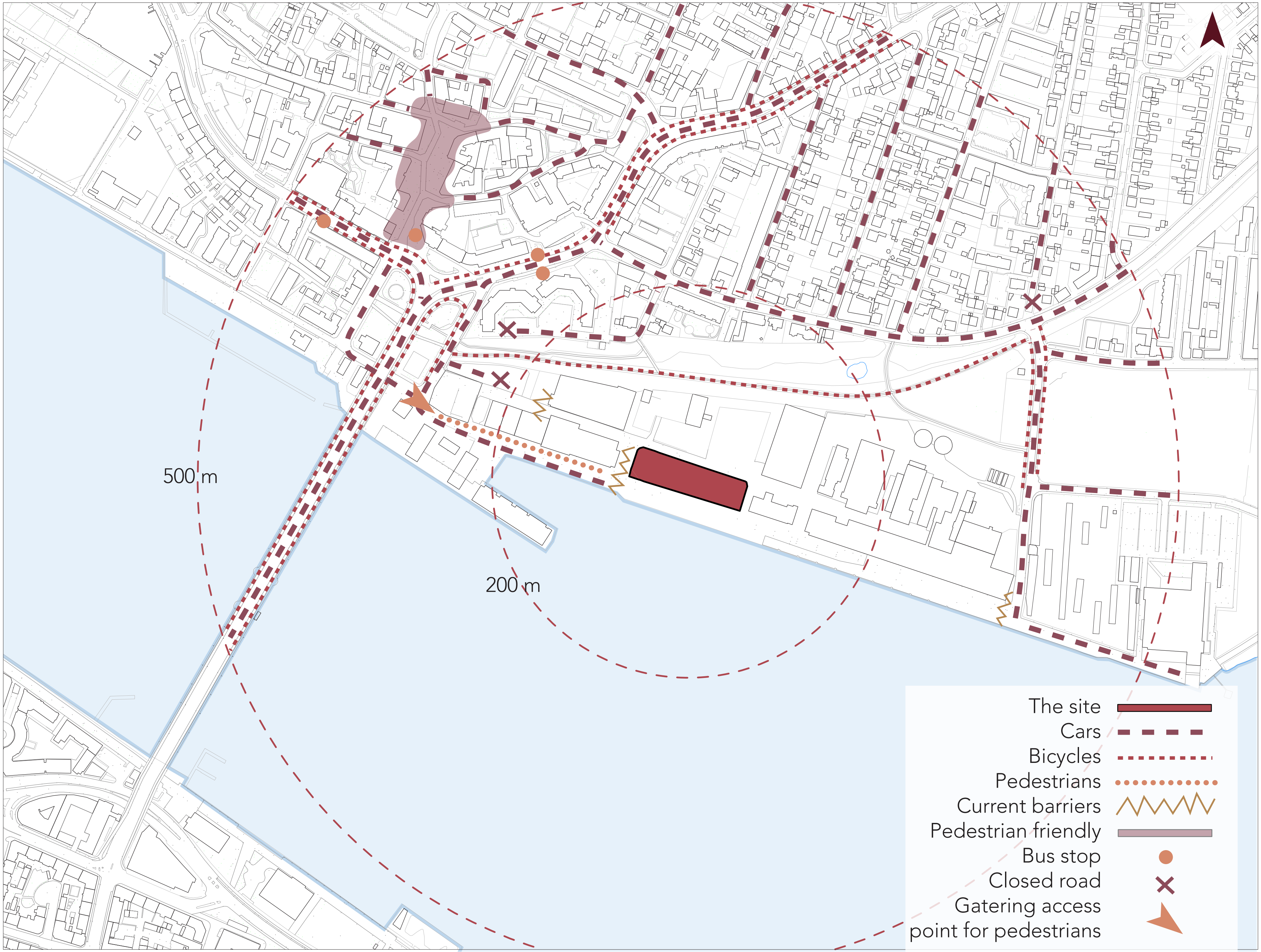


*ill. 53 - Bikes closest access -*



*ill. 54 - Pedestrians closest access -*

*ill. 55- Accessibility to the site - scale 1:5000*


500 m
200 m
The site
Cars
Bicycles
Pedestrians
Current barriers
Pedestrian friendly
Bus stop
Closed road
Gatering access point for pedestrians

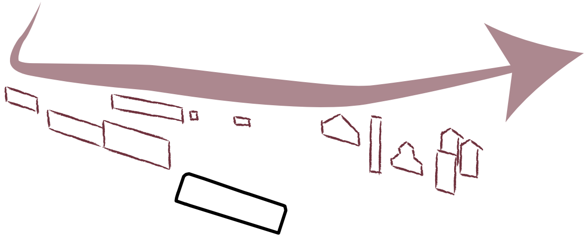
# 5.3 BUILDING CHARACTER

## 5.3.1 Building height

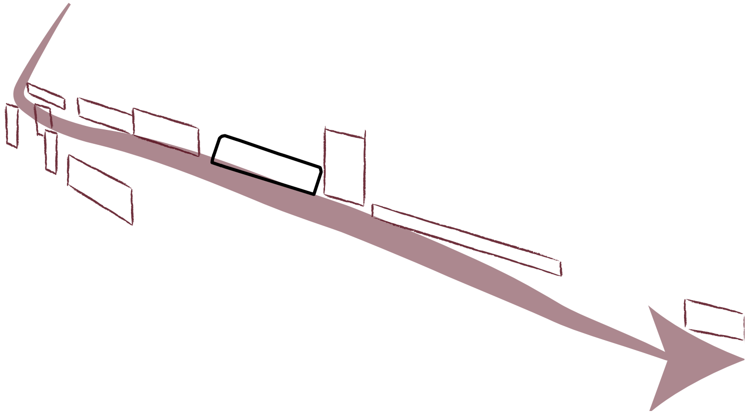
The study of the building height helps to understand the scale of the urban fabric from a volumetric point of view.
The highest buildings are in the Eastern part of the area, in the industrial part facing the fjord. Then, a high concentration of tall constructions is on the other side of the bridge, where there is a concentration of residential fabric.

Five and four storeys are spotted along the main streets and usually define the urban blocks or are facing the water.
Smaller constructions of two and one storeys are in the inner part of the blocks, well shield from the wind.

Finally, tracking the height of the surrounding buildings, shows how much the height of the construction vary greatly in the area. In fact, from two storeys to more than six, further, if considering the vision of the local plan, the buildings facing the fjord in this part of the city, should be from four storeys to eight, number that will be considered later on in the process.



*ill. 56 - Building North profile, walking in the green structure -*



*ill. 57 - Building South profile, walking along the fjord -*

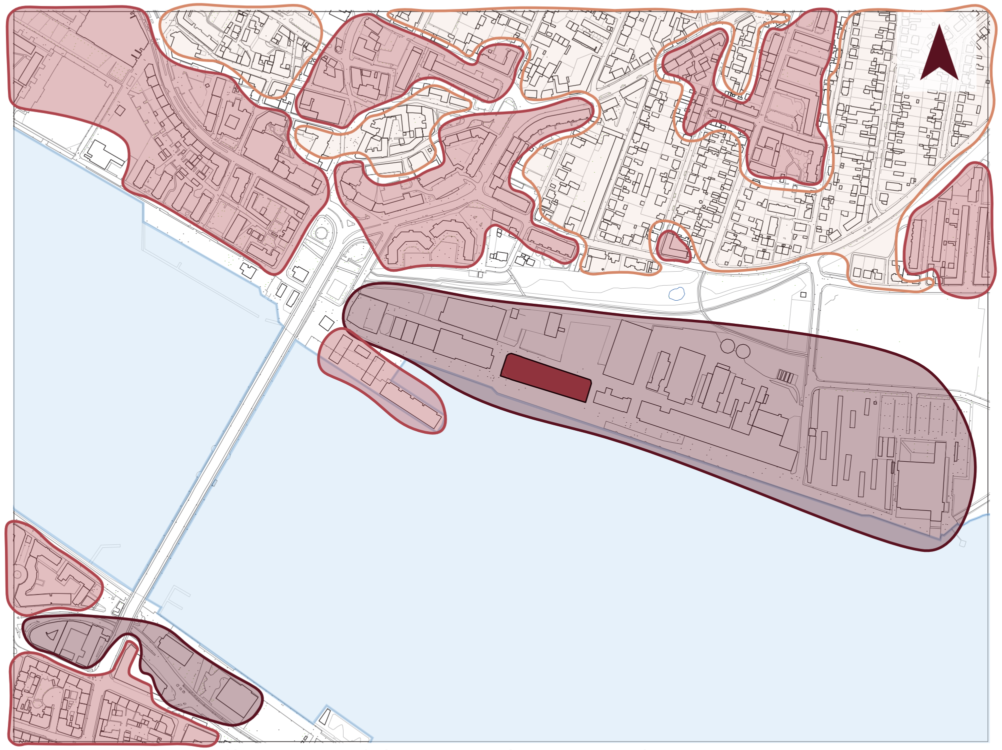
*ill. 58 - Building height - scale 1:5000*


+ Six storeys
Six storeys
Five storeys
Four storeys
Three storeys
Two storeys
One storey

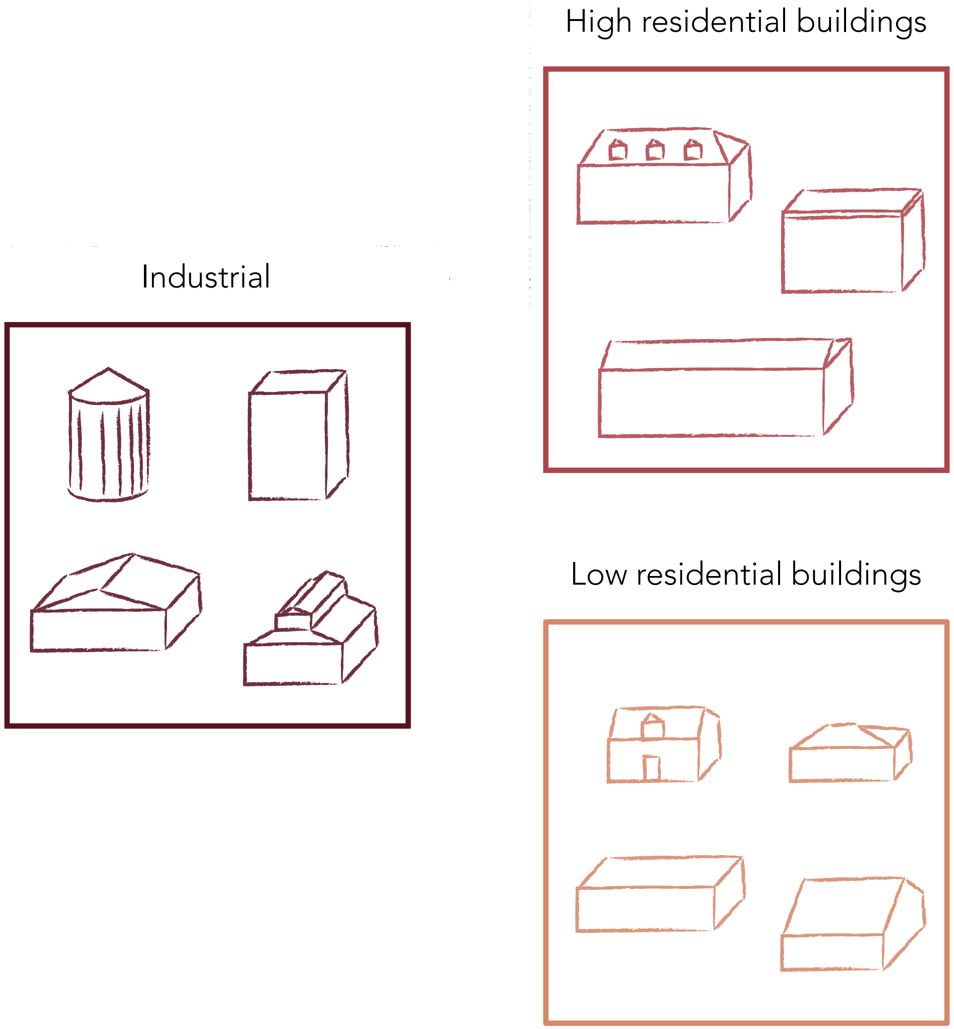
## 5.3.2 Building typology

Three main building typologies are chosen, based on function -industrial or residential- and volume in order to have a fast overview of the area's features.

The industrial buildings are gathering in the areas facing the fjord from both North and South. The area toward West is characterised by new residential buildings, while on the East smaller detached houses with their private garden.



ill. 59 - Building typology - scale 1:10000

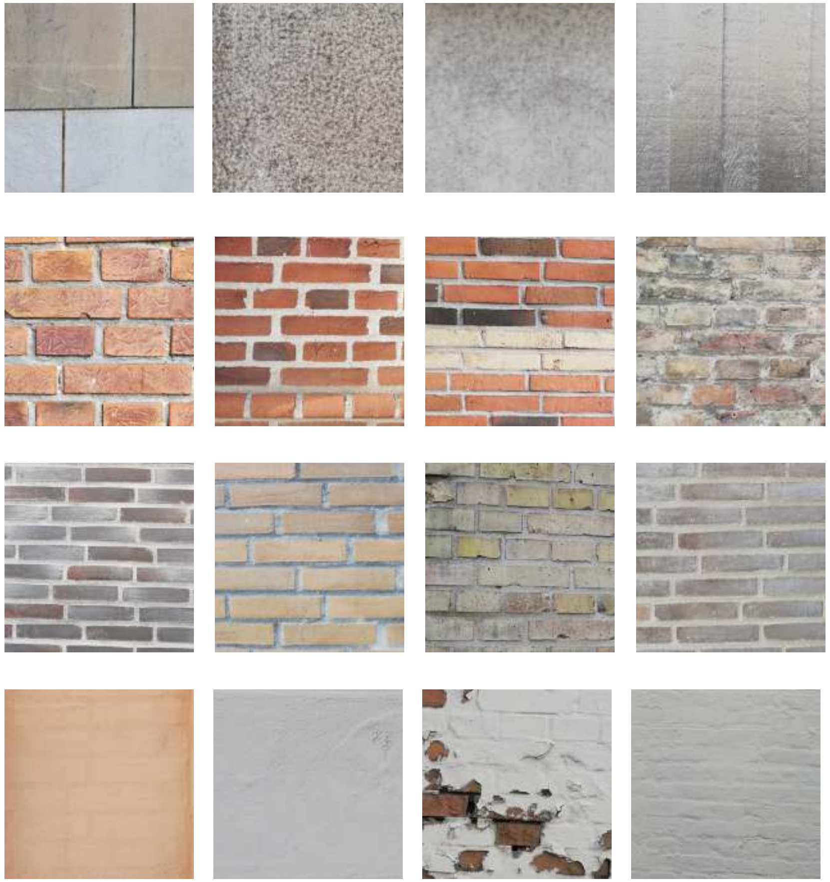


ill. 60 - Building typology diagrams -

# 5.4 TOMOGRAPHIES

## 5.4.1 Material mapping

The materials visible in the site context were photographed to create a material palette that portrays the theme around the site. The materials captured have been used for building facades and pavements; and have been assessed in different criteria. the most common facade material is brick, and for pavement is cement concrete.



ill. 61 - Materials as facades -

### Aesthetics and Haptics

The material members on the facade are mostly visible when untreated- for instance in exposed brick and stone. This exposure of materiality in the building is aesthetically more pleasing than the painted or treated facade. The tactile nature of the material is expressive for the case. Moreover, bricks with engraved patterns was particularly interesting, since it was aesthetically pleasing in expressing depth, as well as tactility.

### Treatment and Weathering

Plastered bricks on the facade showed weathering and exposed the concealed layers. The concrete and stone pavement with large members and tarmac had cracks and sign of breaking. Timber used for pathways near the dock were slippery due to algal growth on the surface. The exposed brick surface becomes a plethora of shades after rains due to varied dampness of bricks.

### Conclusion

The facade materials are majorly a variety of exposed bricks, which can be considered when designing site integration. The pavements using relatively smaller cement concrete and stone members require negligible replacement and repair.

ill. 62- Materials as pavement -

## Material Interface

The material observations made on the site also examine the physical and visual interaction between different materials. Similar to the site material analysis, the material interface documented exist on building facades and pavements. The types of interface can be categorised as the combinations on pavements, building- pavement and within built facades.

## Contrast and Pattern

In the constructions, by juxtaposing material of similar nature, different contrasts have been created. In pavements they were observed as alignments and configuration, while on built facades there was more liberty with color contrasts and different materials.

The use of different materials can create contrasting or similar patterns.

## Conclusion

With contrasting colors and materials, facade features in a building can be highlighted. The materials will not require finishes in the use of materials. In pavements, contrasts can be created to demarcate areas. The base- pavement interface is an opportunity to design aesthetically and treatment against rainwater and splashing is important due to being prone to weathering.

*ill. 63 - Material combinations on pavements -*

*ill. 64 - Material combinations between facade - pavement on facade -*

## 5.4.2 Facade study

### Facade Features/ treatment

The site context has a variable facade palette, from diverse industrial and residential buildings. Residences have plastered facades as well as red, yellow and black exposed brick construction. Contrasts have also been created with different materials such as metal-brick and brick- concrete; as well as with colors. The building styles also vary from modernist and neoclassical buildings to postmodernism.

### Windows

Windows also vary corresponding to their buildings- with sizes industrial brick and concrete building with small windows, residences with larger glazing. The glazing is lesser with smaller glass panels in older construction windows, as compared to glazing in more recent

*ill. 65 - Types of building facades in the site context -*

construction.

### Entrances

The approach to entrances are directly into the buildings in most industrial and older construction. While the entrance in residential and commercial buildings are through imbibed lobbies or external glass entrances.

### Conclusion

Since the design of the workplace will attempt to maximise daylight, glazing will be more and consequently correspond to the residential buildings in the context. Further, due to the commercial function, the entrance will have to be profound with a buffer to prevent the building's loss of heat. Also, due to the user need to promote business, visibility of the ground floor and its functions could be intriguing. The graffiti on the PPH industrial building on the site east will also capture a viewer's attention from across the fjord, a feature that can be utilised and corresponded with on the design's southern facade.

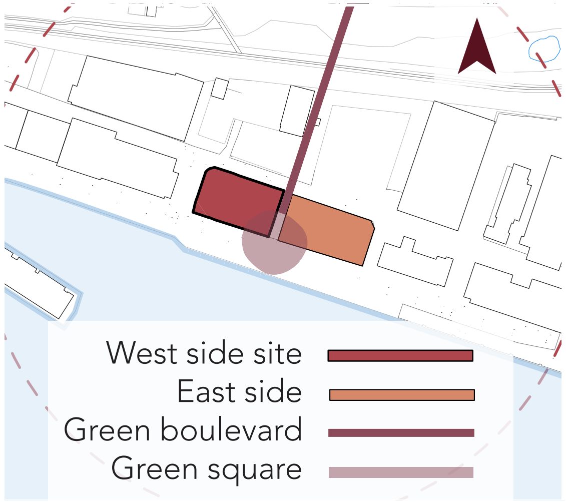
*ill. 66 - Types of windows in the site context -*

*ill. 67 - Types of entrances in the site context -*

## 5.5 CONCLUSION

The site analysis is carried out on different spheres and scales, in fact from a general introduction of the site, it concludes with comparison of textures.
In fact, it outlines the urban vision for the area, which is the sum of the local plan wishes and of the group's considerations.

The local plan will be followed for some aspects of the urban fabric planning. Thus, the road will divide the site in the middle, creating two separate lands, each of them dedicated to the design of one construction per side. The Thesis's project will focus on the part toward West, having a closer relation to the lower buildings rather than to the high rise industrial buildings on the East, imagining an approach in height more gradual for the East side.
Then, the overall funcion of the Thesis's project slightly differs from the local plan. In fact if on one hand, startups and small business companies are taken into account, on the other one, the image is to address a mix-use to all the building facing the fjord. Thus, the side



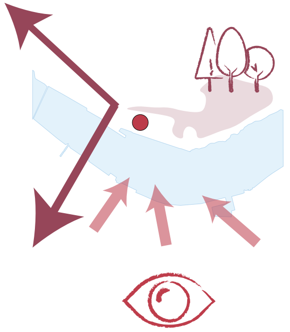
*ill. 68 - Plan conclusion -*

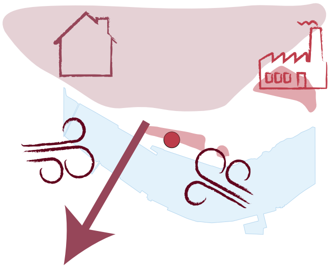
toward East will accomodate the local plan wish of having a mix-functions building, commercial on the bottom floor and residential on the others.

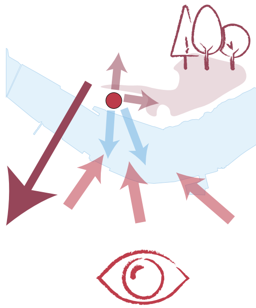
On the other hand, the urban vision will enhance the group's view, where the road that divides the site, will be a green boulevard, which will end with a square on the fjord, in connection to the landscape of the project.
The objective analysis helped to highlight the potentiality of the site, its issues and the starting point for a strategy.
First of all, the site of the project is located in between the park and the fjord, natural attractions that can help to vitalize the area. Then the vicinity to the fjord allows also a primary visibility from the other side of the water, in fact, it is visible not only when approaching it, but all along Aalborg's fjord. This openness toward South will be favorable for designing the apertures and the energetic strategies.
The site is also nearby the main streets, which connect the city to the airport and Nørresundby to Aalborg.

The analysis shows in fragments the issues of the area, which are related to its potentiality as well. The natural elements at the moment are not communicating with the site, the park is not connected and the strip of green structure on the North side is in decay. On one hand the fjord allows a nice view, but on the other one, the cold wind does not decreased its velocity, due to the open water field.
The connection to Aalborg exists, however it is the only one, and in a future plan other connections should be considered. Further, the site is located in the middle of an industrial area and on the North side a quiet residential area is predominant. Thus, the activity of the nowadays network is low and projects for a regeneration are essential, with implementation of ordinary and special activities/events.

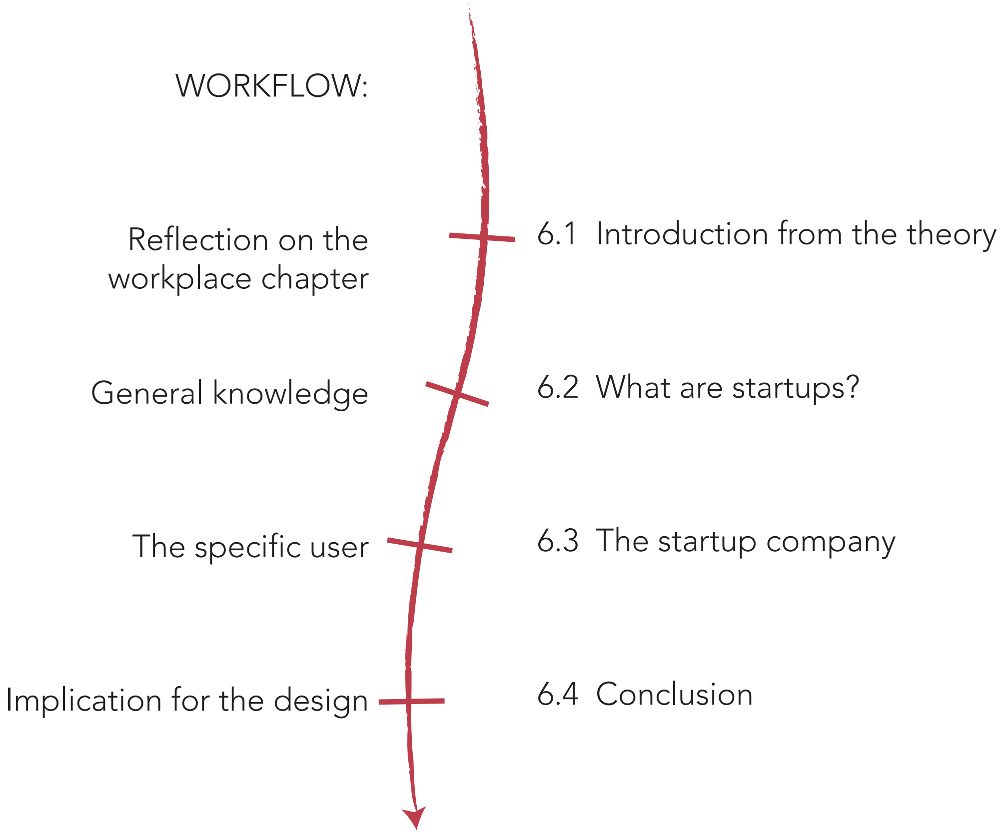
At the end, it is possible to outline the initial strategy. The primary need is the implementation with the surrounding nature, on North and East to create green structures that will be connected to the park, and toward South the relation to the fjord. Also, another connection to the city of Aalborg should be considered, which could be a bridge or another kind of public transport.
Then it is necessary to take advantage of the visibility of the site from the other side of the water. Thus, an eye catching design, because of its architectural expression should work to attract people's attentions and curiosity.


ill. 69 - Potentiality -


ill. 70- Issues -


ill. 71 - Strategy -

# 6| USER



WORKFLOW:

| | |
|---|---|
| Reflection on the workplace chapter | 6.1 Introduction from the theory |
| General knowledge | 6.2 What are startups? |
| The specific user | 6.3 The startup company |
| Implication for the design | 6.4 Conclusion |

# 6.1 INTRODUCTION FROM THE THEORY

The knowledge gained from the theory chapter, gives a clear overview of how the plan layout of the workplaces developed during the years.
The most important insight though, is the reflection on the reason why the architectural process changed, in fact the space is a mirror of the users' needs.
The history can give an input on what the design is focusing nowadays, and it can also help imagining the direction on where it is going to. Elements that allow or contrast the adaptability are the partition walls, consenting the space to change and develop, creating a private enclosed room or a spacious area.

As said, the design is adapting to the users' necessities, since the way of working is changing, the architecture needs to readjust.
Technology is influencing greatly the design, principally laptops that request less space than ever before, then, virtuality, which is already the communication channel. Thus, in this current scenario, different kind of work emerge and diffuse, where the digital stands in the center. What is in common of the new working trend, is the flexibility of the work as well as the space.
Some jobs can born from a day to the other one, challenging themselves, facing other competitors and, when the economy allows it, trying to expand.

# 6.2 WHAT STARTUPS ARE

There are multiple definitions of startups; however, they all sum up to imply that a startup company is a 'fledgling enterprise' or a 'business operation recently begun'. (Webster, 2019) (Heritage, 2019) Since there is no guarantee of whether a startup will be successful in its endeavour or sustain for years, the atmosphere of such setups are anticipatory of growth.
Uncertainty can also be a major cause of work related stress, which is a problem the project aims to alleviate. The startup companies have limited capital, hence are highly dependent on fundings from organisations globally.

Thus, the startup also has to compete for funds and present their ideas; while showcasing the potential benefit to the funding agency.
Moreover, in all startups brainstorming and pitching innovative ideas is a routine. A creative and conducive workplace environment is essential for startups to prosper; in addition for their requirement to promote their company and make their name in the market.

LIFESTYLE
Pursuing own interest to inspire

SMALL BUSINESS
Local outreach

SCALABLE
Entrepreneurship based on expandable model

TO BE SOLD
Plan to build value for selling

LARGE COMPANY
New market branch by large company

SOCIAL
Charitable foundation

*ill. 72 - Types of Startups -*

# 6.3 THE STARTUP COMPANY

## 6.3.1 Why and which startup

The design motive of the project is to create a startup ecosystem that connects professionals who would want to collaborate for business. The Danish government has initiated entrepreneurs to setup their startup companies in Denmark, which creates a need to accommodate collaborative workspaces (Danishbusinessauthority.dk).

Since the thesis research is based on the stress alleviation, the users are thus startups; which are highly stressful jobs due to unpredictability (Virk, 2018). The site further aids in promoting startup companies due to the location and the visibility of the potential building.

The prime motive for the project are to connect startup companies working in sustainable solutions, architects, engineers and IT companies (Bloxhub.com, 2019). Since the building industry involves professionals from diverse specialists in architecture, energy, technology and engineering; a space dedicated to enhance their contacts is essential. Moreover, the IT industry is the third well performing growth industry in Denmark, who can also be accommodated as the users (Copcap.com, 2015).

The users can also benefit from the proximity to the architecture, civil engineering, urban design and media technology students at Aalborg University, Rendsburggade 14; who can collaborate for apprenticeship and professional guidance.
The building premise will also provide a membership system for external users who want to rent the spaces and benefit from utilities, along with the startups. The ground floor workshop space will be designed with flexible visual privacy, giving the user a choice to opt for view outdoors or have private events.

In conclusion, the different users of the building between startup employees, members of the community created and visitors has to be managed with diverse access to the functions. Moreover, the variable workers in a startup need flexibly designed spaces; accommodative to the expansion and contraction of the startup firms.

Thus, the main design criteria is to have a flexible plan, addressing the varying number of people and the unpredictable growth in number of members in startups.

### 6.3.2 Structure and needs

The building will be composed by two hierarchical areas, one dedicated to the regular employees of the startup and the other one to the members. Some zones though, will be accessible and common for both the users, in order to optimize the built area.
In fact, bigger zones where they can develop prototypes and building models, should be available for whoever needs it, for instance booking the required space, in order not to exceed the maximum number allowed.
The startup zone will have a special design care, since the space represents its daily office. The vision is to host two newborn startups of 26 people each, and a space that can accommodate all the employees at the same time should be designed. Other function such as meeting rooms are indispensable, due to the necessity of democratic communication, especially at the beginning of the startup launch. In fact, a lot of effort characterise this period, along with gathering all the ideas and being competitive with the already accomplished companies.
The expected initial period is about adjustments on the market, because of the unstable original economy, where saving fund is fundamental. In fact, the role of the membership access works along with this aspect. Being a member of the building allows the renting of rooms for meetings or bigger spaces to create its own projects.

It would become also a way of meeting people who are working in the same field and creating, then, a professional network.
Students as well would be facilitated in the process of future integration, using the space to get to know people, dynamics and ongoing projects. For this ambitious reason, the maximum capacity of members should be around 75, where the space can be adapted if another startup would like to rent the space, subtracting the number of possible members.

# 6.4 CONCLUSION

The functioning will be in sync with the concept of creating a noteworthy exterior building form to benefit from the visibility of the site, for instance- Aalborg centrum, Aalborg harbor; while promoting the startup. Startups also benefit from architecture, engineering and urban design students at Create, Aalborg University to network and promote. Due to the linear northwest to southeast axis, the building users will benefit from view to the fjord on the South and greens on the North.

The entrance of the building will be towards the North-West of the site due to easier accessibility, based on site analysis. To accommodate the fluctuating number of members in startups and the multiple functions to operate, flexible plan is the design concept. Moreover, the startup workspaces will follow a hybrid plan; along with zoning between members of the building and 52 regular startups employees. The workspaces will also provide personal storage spaces for the startup workers. Workshops will be provided for making models, along with showroom showcasing the startups' promotional works.

Conference rooms will be provided for business meetings and providing the user more opportunity to network. Due to high workload in startups and the concept of designing a stress alleviating workplace, a self service kitchen is essential to accommodate overtime work as well as social events which can involve cooking. The building will also provide recreational rooms for the users to take breaks and regain focus for work, while providing an interactive platform between the occupants. Further, terraces for interaction and courtyard to accommodate larger outdoor gatherings are inculcated in design.

The building will thus be a milieu of private startup function, semi- private function for members and visitors interested in the building functions or showroom exhibits.

# 7| PROGRAM

WORKFLOW:

| | |
|---|---|
| General design implications | 7.1 Volume studies |
| Specific needs | 7.2 Room program |
| Needs' interrelation | 7.3 Functional program |
| Architectural requirements | 7.4 Design criteria |
| Design statement | 7.5 Concept |

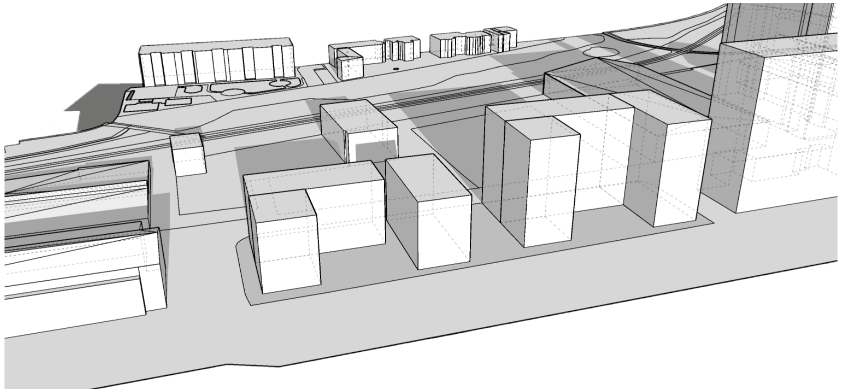
# 7.1 VOLUME STUDIES

As an architectural analysis of the site, massing is important to gauge a built structure and the urban connection with the site context. With the number of storeys considered from the local plan, volumes have been digitally experimented with in the site. The volumes are five storey high with approximately 250 sq m per floor, arranged with west to east axis along the site. The total floor area per person in an office is 10 sq m- inclusive of services. Thus, the volume study is conducted for an occupancy of approximately 130 users, including members and visitors of the site.
The structures on the west and east of the site contrast in volume distribution; with five storey high to the west and towering thirteen storeys on the east. Since the project intent is pivoted to quality of spaces and multiple functions, the volumes tested are horizontally explored than vertical; assuming that the future neighbor development on the east of the site will be six to eight storey high and along with the project, act as intermediates between the contrast.

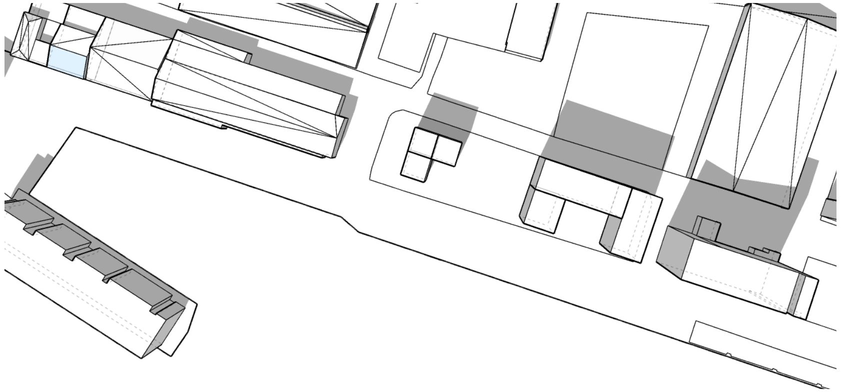
With the initial concept of creating a boulevard to the east, designing a welcoming interface between the two segments of the site; combination of smaller built volumes are iterated in diverse configuration to reveal the shadows, contextual interaction of the buildings and the massing. Three blocks of equivalent volume sourced from the local plan, reordered further linearly, to progressing diagonally to the site axis.
The volume study act as the first stage of analysis to an architectural problem, and used to commence the sketching phase. The study also aids in visualising the outdoor- indoor space creation and the visual interaction of the mass with the built urban fabric. The shadows simulations, illustrated in both pages, are calculated for 21 June at 15.00.

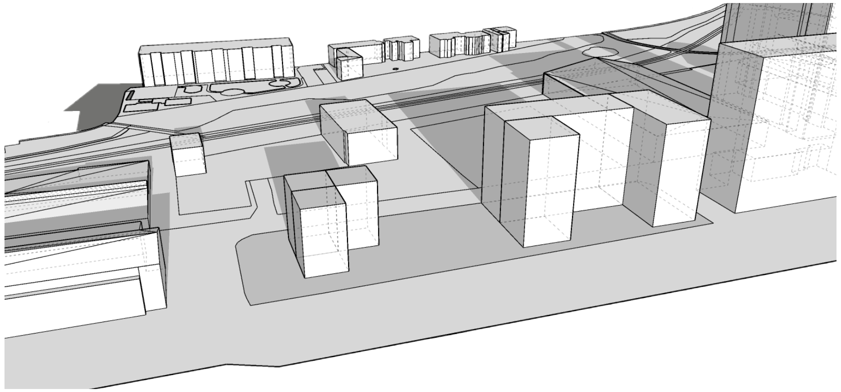
In conclusion, the six storey block volume along with the intended project volume act as stepped intermediate between the contrasting buildings on the west and east of the site, as viewed across the fjord. The number of floors was then considered to decrease to four storeys with the height of five storeys, and developed to spread horizontally due to the functions and concept.

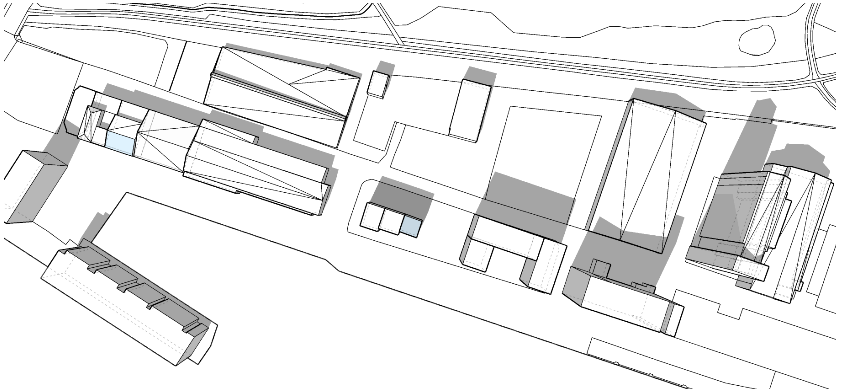
*ill. 73 - Fjord front heights following local plan and project vision -*

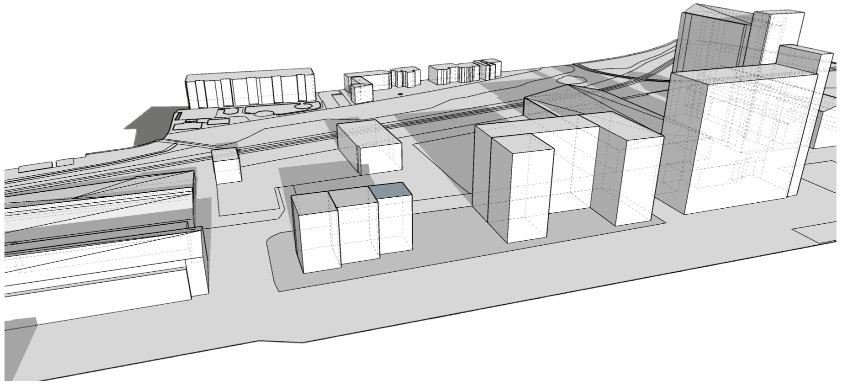


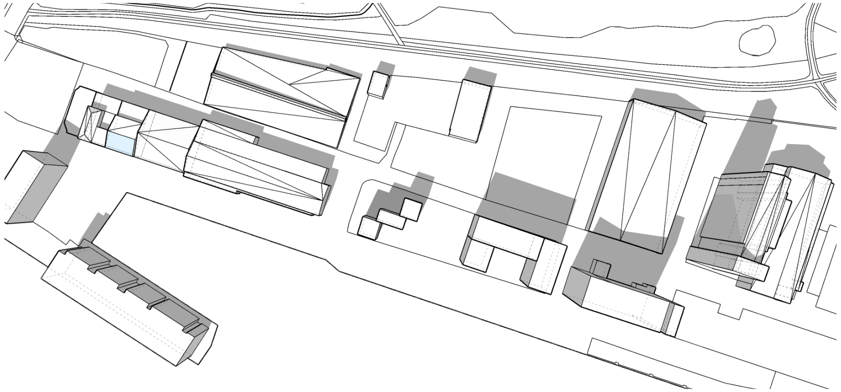
*ill. 74 - Volume 1 - Footprint according to Local plan -*

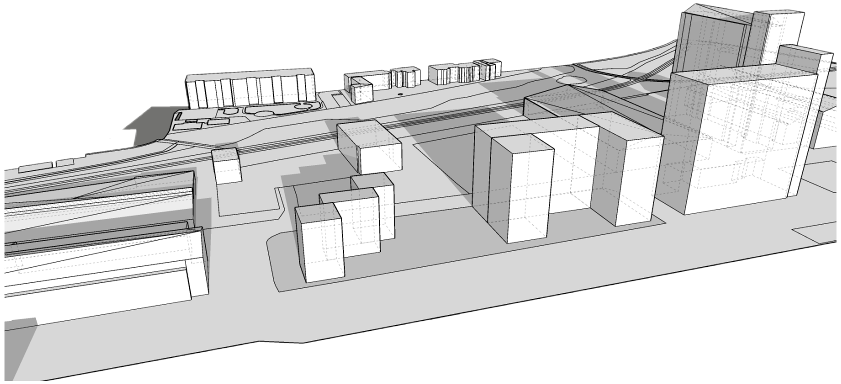

ill. 75 - Volume 2 -


ill. 78 - Visualization volume 2 - Adjusting the height according to project area -


ill. 76 - Volume 3 -


ill. 79 - Visualization Volume 3 -


ill. 77 - Plan cluster type 4 -


ill. 80 - Visualization cluster type 4 -

# 7.2 ROOM PROGRAM

▨ Combined in open space
▨ Private enclosed area

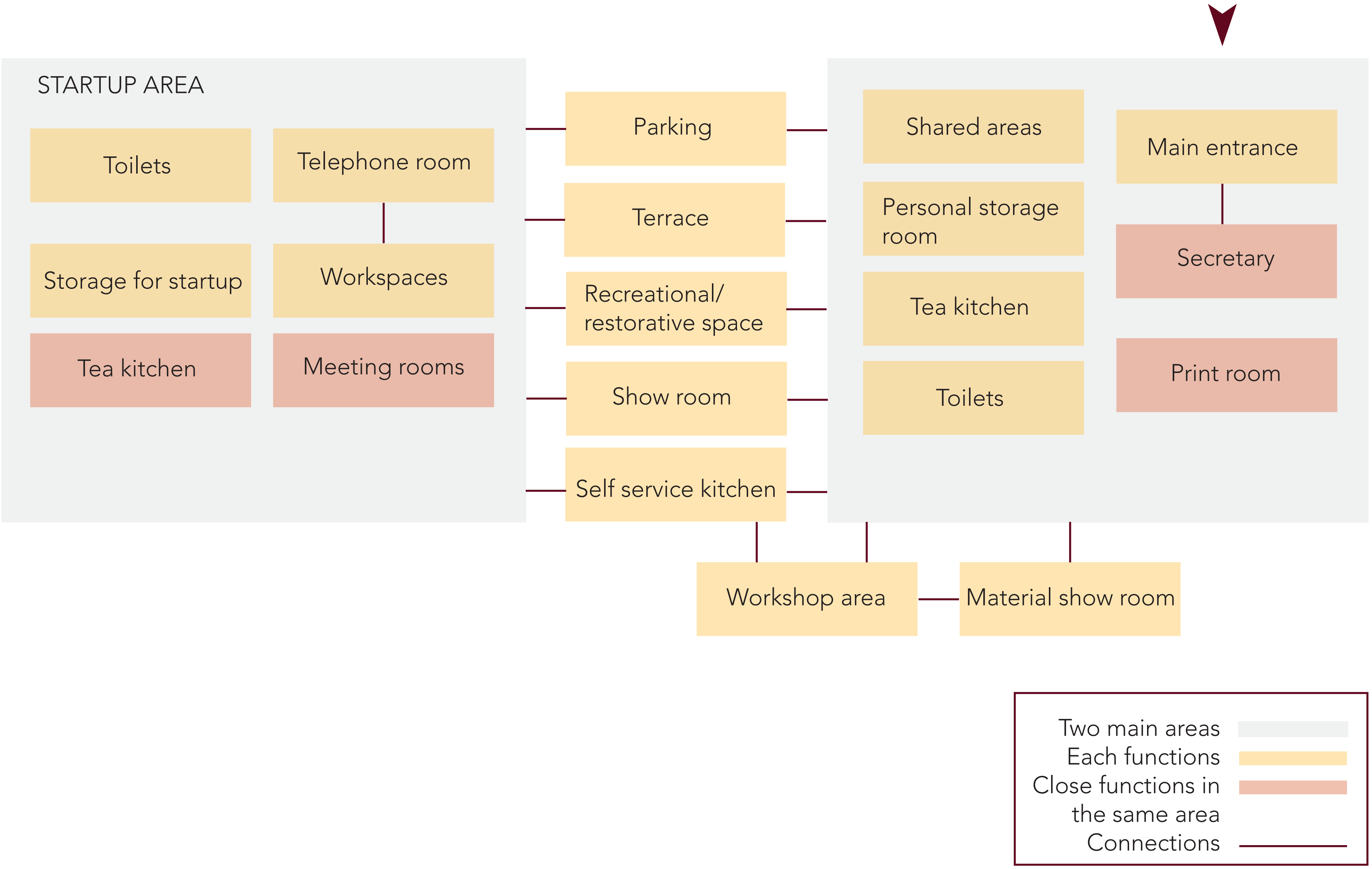
S Startup
M Members
N Natural light
N/A Natural/artificial

▨ EN_12464-1
▨ DS_CEN_CR-1752_2001
▨ EN 13779
▨ DS/EN 15251

| | Room | Notes | Occupancy | View | Access | Capacity | Average occupancy | N° | m² | Light | Lux | Temperature | dB | Ventilation rate l/m sq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indoor | Entrance | - | Brief | Yes | All | - | - | 2 | - | N | 100 | - | 35 | - |
| | Secretary | - | Most hours | Yes | All | 2 | 1 | 2 | 10 | N/A | 100 | 22-24,5 + /- 1 | 35 | 3 |
| | Print room | *Small and big plotwares* | Brief | No | S, M | 4 | 2 | 2 | 12 | A | 300 | - | - | 5 |
| | Workspaces | *Hybrid plan, flexible space for informal meetings* | Most hours | Yes | S | 100 | 52 | 1 | 500 | N, task | 300-500 | 22-24,5 + /- 1 | 30-40 | 4 |
| | Meeting room type 1 | - | Temporary | Yes | S, M | 20 | 10 | 1 | 50 | N | 500 | 22-24,5 + /- 1 | 30-40 | 4 |
| | Class space | *Courses/classes after work time* | Temporary | Yes | S, M | - | - | - | - | N | 500 | 22-24,5 + /- 0,5 | 35-45 | 4 |
| | Meeting room type 2 | *Can also be booked by the members* | Temporary | Yes | S, M | 16 | 8 | 3 | 45 | N | 500 | 22-24,5 + /- 1 | 30-40 | 4 |
| | Meeting room type 3 | *Can also be booked by the members* | Temporary | Yes | S, M | 12 | 5 | 3 | 36 | N | 500 | 22-24,5 + /- 1 | 30-40 | 4 |
| | Telephone room | *Private for 1/2 people* | Temporary | No | S, M | 9 | 3 | 6 | 18 | - | 100 | 22-24,5 + /- 1 | 30-35 | 2 |
| | Shared areas | - | Most hours | Yes | M | 75 | 40 | 1 | 350 | N | 200 | 22-24,5 + /- 1 | 35-50 | 4 |
| | Workshop | *Light glazed area* | Temporary | Yes | All | 16 | 4 | 1 | 100 | N | 500 | 20-22 | 35-45 | 5 |
| | Material show room | *Next to the facade* | Temporary | Yes | All | 5 | 1 | 1 | 25 | N | 500 | 20-22 | 35-50 | 3 |
| | Self service kitchen | *Central location, dining* | Temporary | Yes | S, M | 2 | 0,5 | 1 | 40 | N/A | 500 | 22-24,5 + /- 1 | 35-50 | 5 |
| | Tea kitchen | *1 near meeting rooms* | Brief | Yes | S, M | 6 | 0,5 | 3 | 30 | N/A | 200 | 22-24,5 + /- 1 | 40 | 5 |
| | Toilets | *1 every 15 people, within 100 m of workstation* | Brief | No | S, M | 12 | 2 | 12 | 52 | N/A | 200 | 22-24,5 + /- 1 | 40 | 6 |
| | Personal storage | | Temporary | No | S | - | - | 1 | - | N/A | 100 | 20-22 | 40 | 4 |
| | Show room | *Walk in, open space* | Temporary | No | All | 5 | 1 | 1 | 25 | N | 500 | 20-22 | 35-50 | 3 |
| | Storage | *Next to workshop* | Brief | No | S | 3 | 1 | 1 | 50 | N/A | 100 | 20-22 | 40 | 2 |
| | Recreational space | *Physical and mental restoration activities* | Temporary | Yes | S | 10 | 4 | 2 | 95 | N | 300 | 20-22 | 30-35 | 4 |
| | Service core | - | - | No | All | - | - | - | 92 | N/A | 150 | 20-22 | 40 | - |
| | Circulation area | - | Brief | Yes | All | - | - | - | 400 | N/A | 100 | 22-24,5 + /- 1 | 40 | 4 |
| | Cafè | *Attractive to activate area* | Temporary | Yes | All | 35 | 10 | 1 | 70 | N/A | 500 | 22-24,5 + /- 1 | 40 | 4 |
| Outdoor | Terrace | - | Temporary | - | S, M | - | - | 9 | 270 | - | - | - | - | - |
| | Parking | - | Brief | - | S, M | - | - | - | 700 | - | - | - | - | - |
| | Total | | | | | 332 | 145 | 54 | 2970 | | | | | |

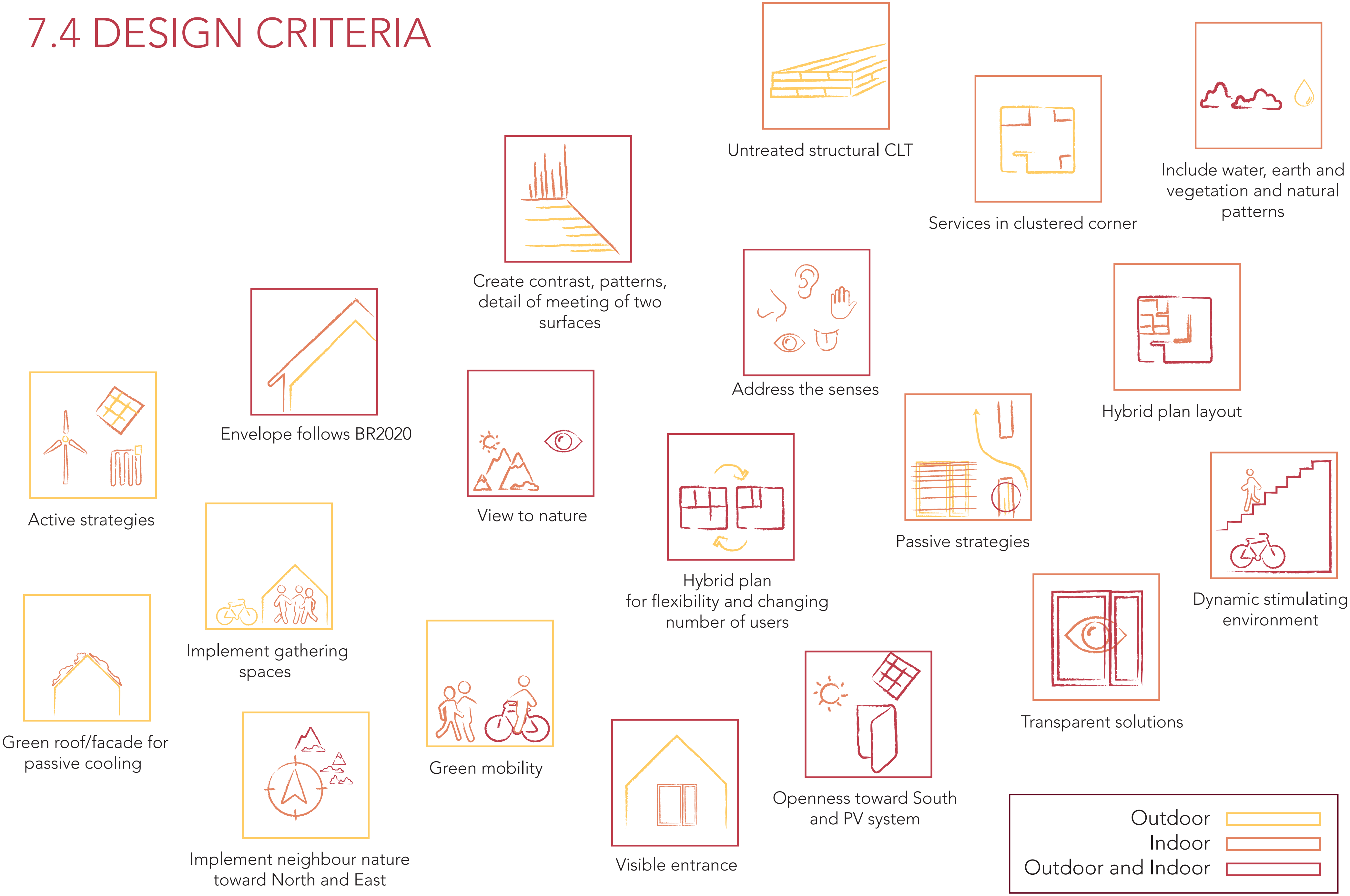
*ill. 81 - Room program -*

# 7.3 FUNCTIONAL PROGRAM



*ill. 82 - Functional program diagram*

# 7.4 DESIGN CRITERIA



Untreated structural CLT

Services in clustered corner

Include water, earth and vegetation and natural patterns

Create contrast, patterns, detail of meeting of two surfaces

Address the senses

Hybrid plan layout

Envelope follows BR2020

Active strategies

View to nature

Hybrid plan for flexibility and changing number of users

Passive strategies

Dynamic stimulating environment

Implement gathering spaces

Transparent solutions

Green roof/facade for passive cooling

Green mobility

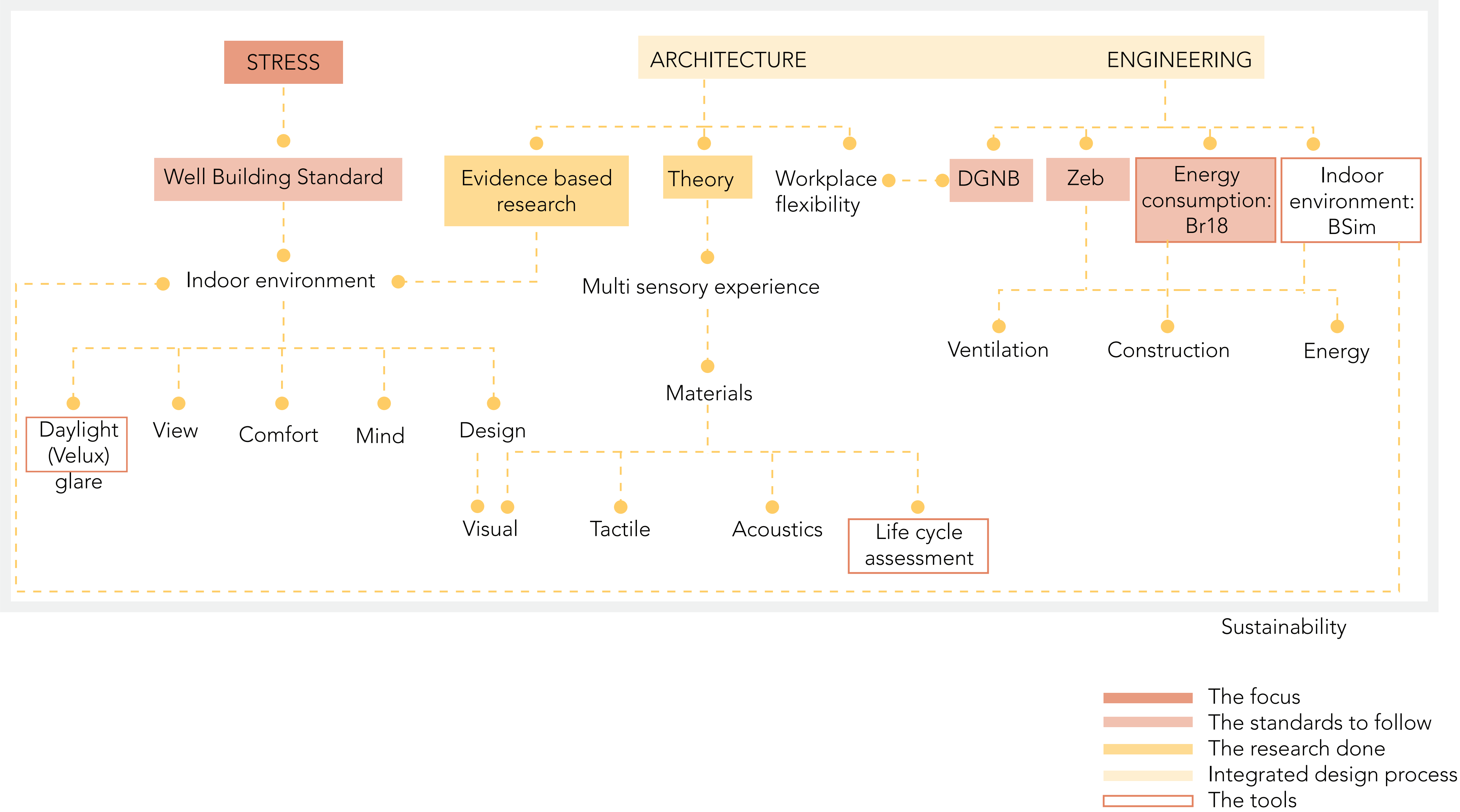
Implement neighbour nature toward North and East

Visible entrance

Openness toward South and PV system

*ill. 83 - Design criteria -*

# 7.5 CONCEPT



*ill. 84 - The interrelation of the aspects to take into account -*

The project rises from the combination of the use of natural materials and the design of a workplace that can fit in the identity of the site. As mentioned, the aim is to create a space which alleviates stress and psychological problems.
Moreover, the overall concept is to create a place that can attract people, in order to meet, communicate, share ideas and projects together.

The initial step it to create a space for the startup employees and for the members of the building. It should accommodate their specific needs and foreseeing the possible future requirements.

Further, the hub should be flexible with internal partitions to allow work related events, implementing its promotion. The focus is the working-user perspective, that should be part of an active and stimulating environment, which should be able also to attract the students and
new workers.

The previous chart shows how all the studies and features related to the project are linked and how they will be analysed. They are the result of the main aspects to consider, relevant for the project.

On the first row the main Thesis focus is placed along with the architectural and engineering aspects, which comprehend the technical considerations. All the mentioned considerations will be addressed in synchrony, as an Integrated design approach.

# 8| SKETCHING PHASE

WORKFLOW:

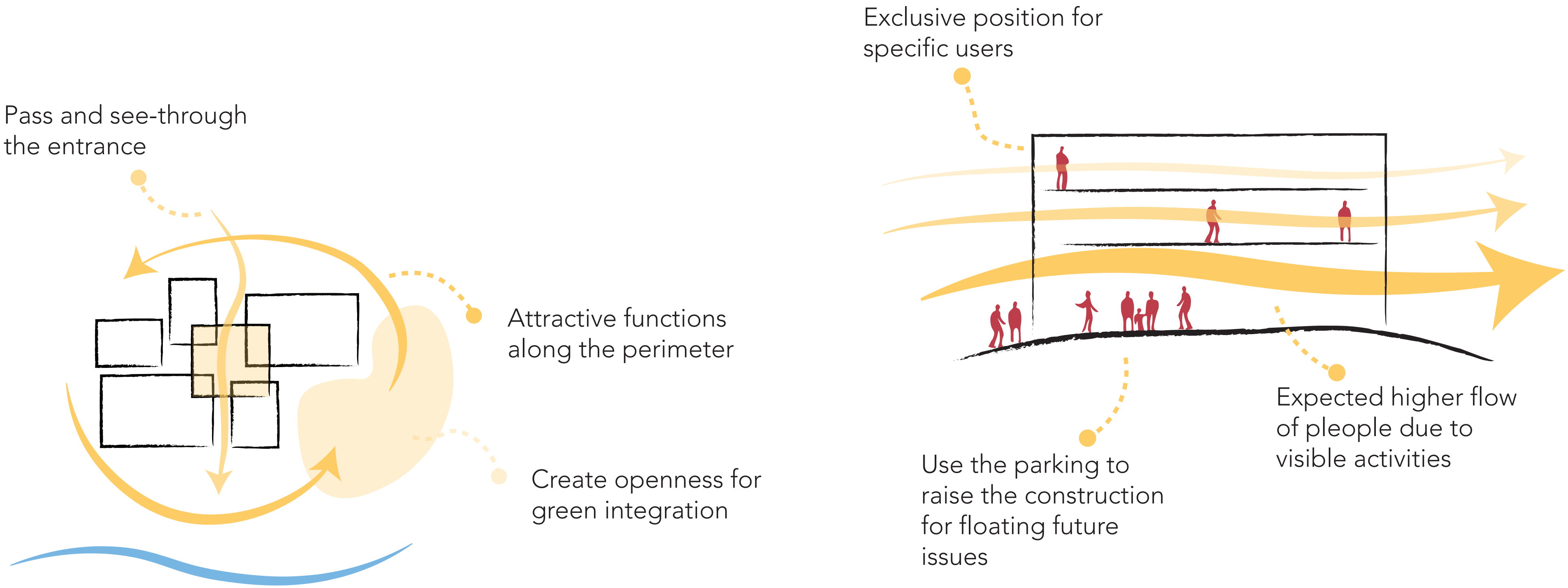
| | |
|---|---|
| The applications of design criterias | 8.1 Plan and section concepts |
| | 8.2 The initial proposals |
| The design starts to shape | 8.3 Plan process |
| Investigation of daylight | 8.4 Velux studies |
| Apply daylight studies to the design | 8.5 Evolution of window shape |
| | 8.6 Facade material study |
| Life cycle assessment studies | 8.7 LCA and U-values |
| | 8.8 LCA cotton and cork |
| Energy iterations | 8.9 Energy consumption: Be18 |
| Indoor environment iterations | 8.10 Indoor environment: BSim |
| The milestones that accompanied the process | 8.11 Pinboard |

# 8.1 PLAN AND SECTION CONCEPTS

The vision for the plan configuration and internal organizations follow the idea of implementing the visibility of the building for the Startup's promotion.
Thus, the most attractive functions should follow the perimeter to catch a pedestrians' attention. Further, the transparency and the visual permeability would help reach the objective; especially the visual and physical accessibility from the entrance of the building on the North to the fjord on the ground floor.

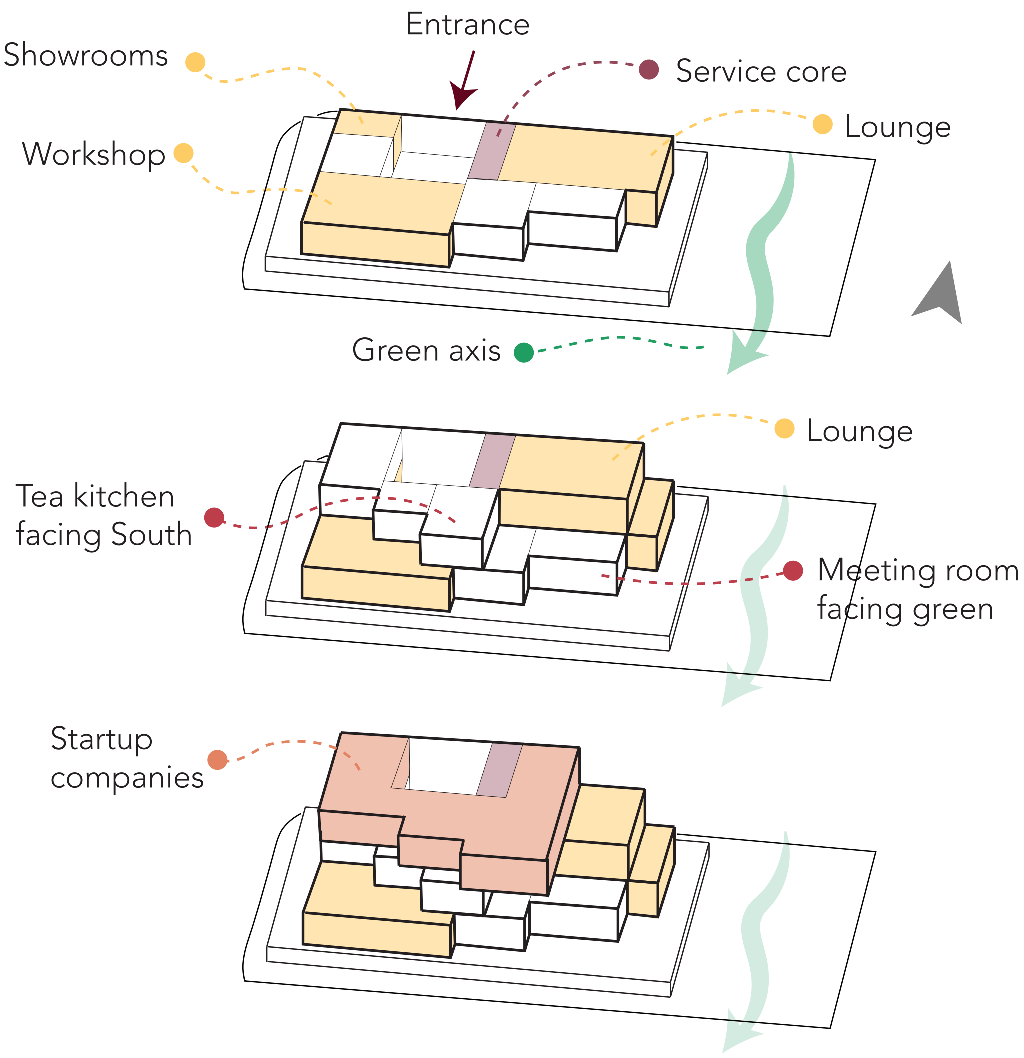
On the other hand, they will all be placed along the perimeter of the entrance, which should have a distinctive solution.

The sectional distribution is also combined to the plan vision, layering the building vertically by zoning private and public spaces.

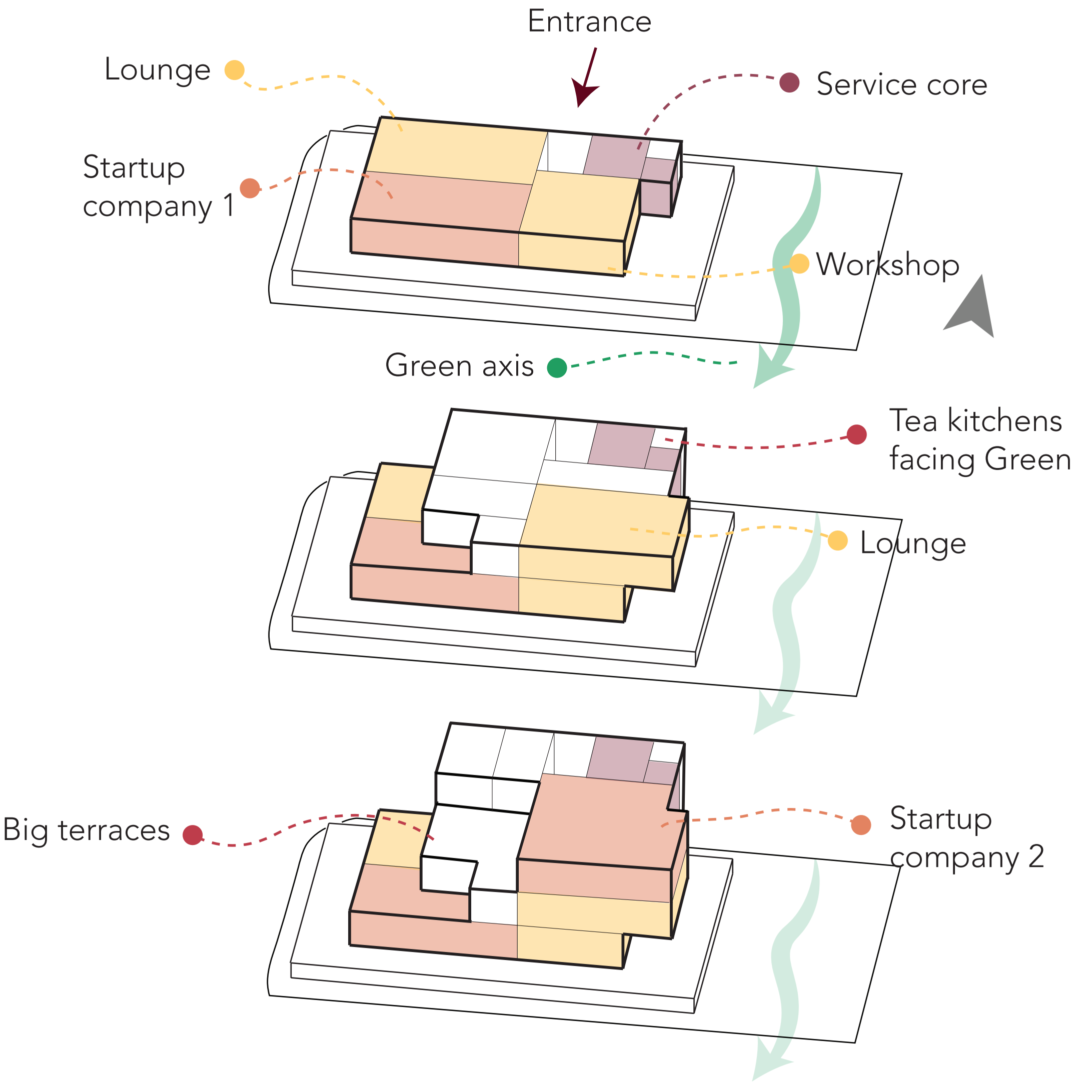


*ill. 85 - Plan and section concepts -*

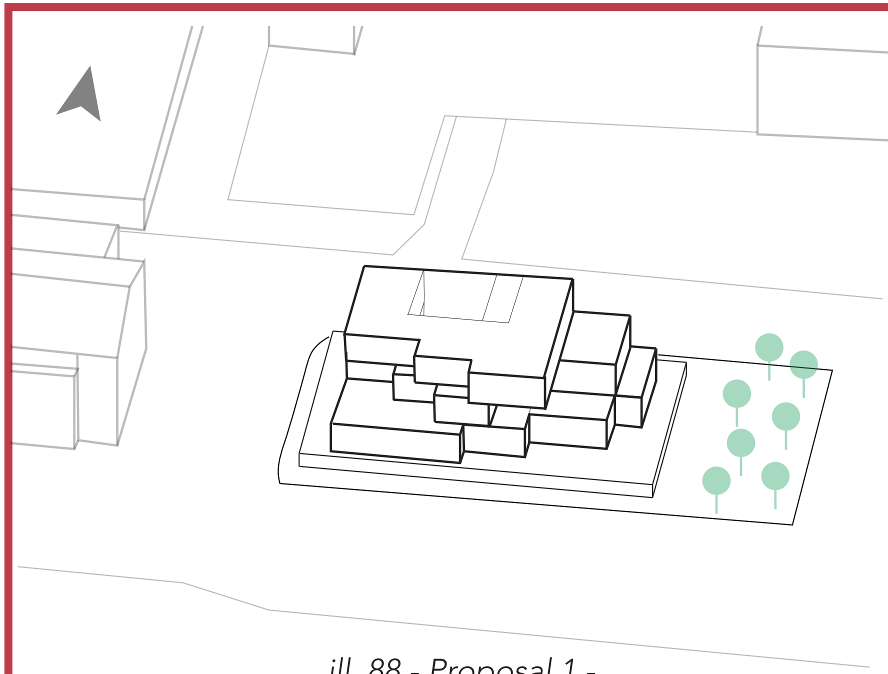
# 8.2 THE INITIAL PROPOSALS



*ill. 86 - Proposal 1 -*



*ill. 87 - Proposal 2 -*



*ill. 88 - Proposal 1 -*

*ill. 89 - Proposal 2 -*

| | | |
|---|---|---|
| Last floor for Startup only<br>Lounge spaces one on top to the other<br>Facade's recess facilitate good daylight<br>Bigger atrium for daylight<br>More open toward the East green | positive | Bigger terraces facing West, which can be used also for events<br>Non central service core, can help for flexibility<br>Kitchens facing the green |
| Central service core, can be used to separate the interior without adding extra partitions | neutral | Separation of Startup companies |
| Scattered terraces<br>More cold bridges given by the facade's recess | negative | More compact facade toward South, more difficult to reach an optimal daylight<br>More difficult to deliver materials to workshop without distrurb grenn and pedestrians |

# 8.3 PLAN PROCESS

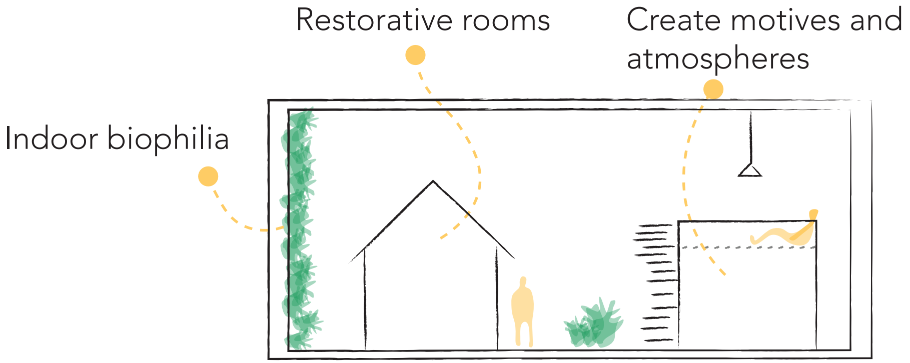
## 8.3.1 The sketches

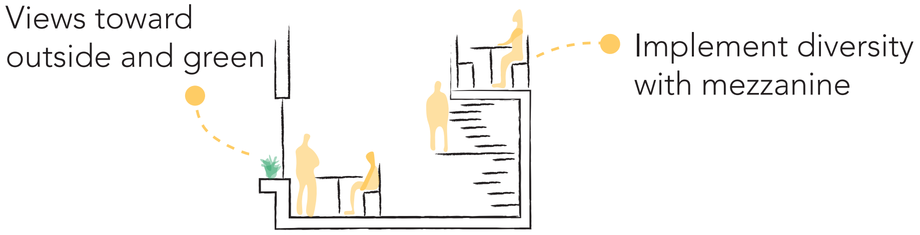
After initial plan studies and strategies, a compromise between the two proposals was found. However, because of the Integrated Design Process, the following plans represent an iterative project's growth with the initial sketches.

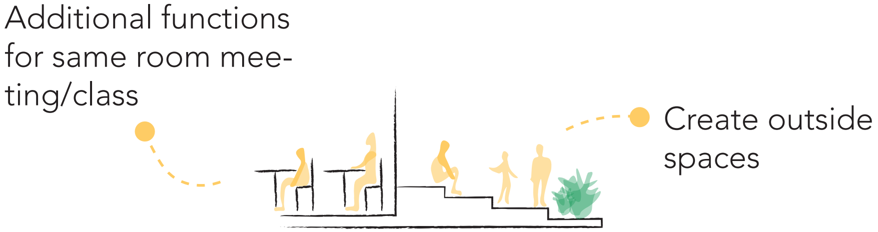
Indeed, they helped to test the rooms and spaces according to technical aspects, such as daylight and indoor environment. Further, the materials are chosen because of their architectural expression, Life cycle Assessment results and U-values.

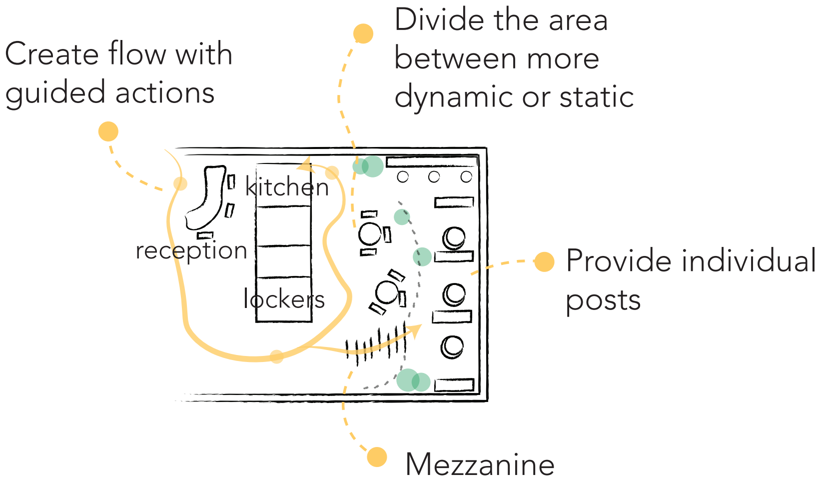
The plans are also the preliminary integration of certification principles that are relevant for the project, as Well Building Standard and DGNB.

The atrium with an open staircase implements thermal buoyancy and stack ventilation. More features include views toward the outdoor for way finding, integration of plants inside and outside the building, adding related necessary functions as a cafè and a multifunctional room on the ground floor which can be used as a meeting room in working hours and classroom in the closing office hours.
One of the most important criteria is the daylight factor that contributes greatly for a healthy environment.

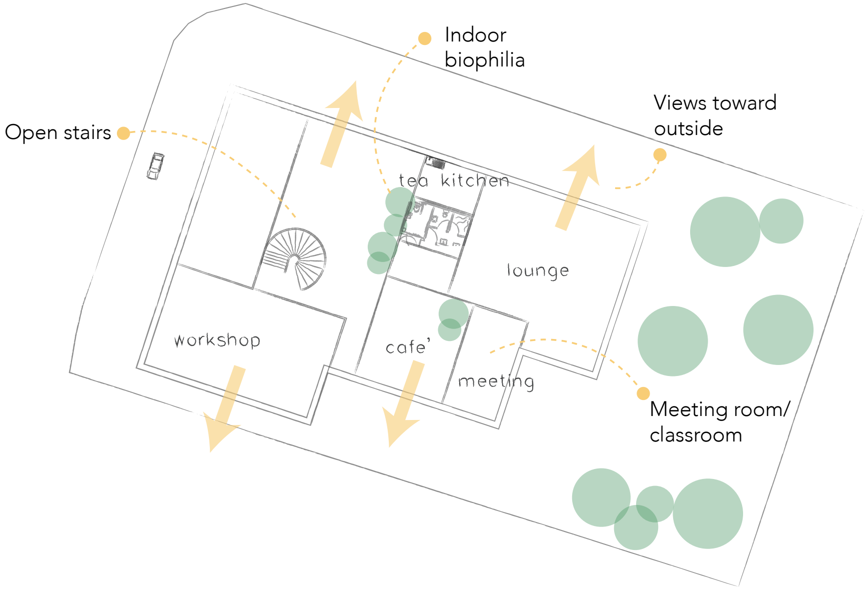




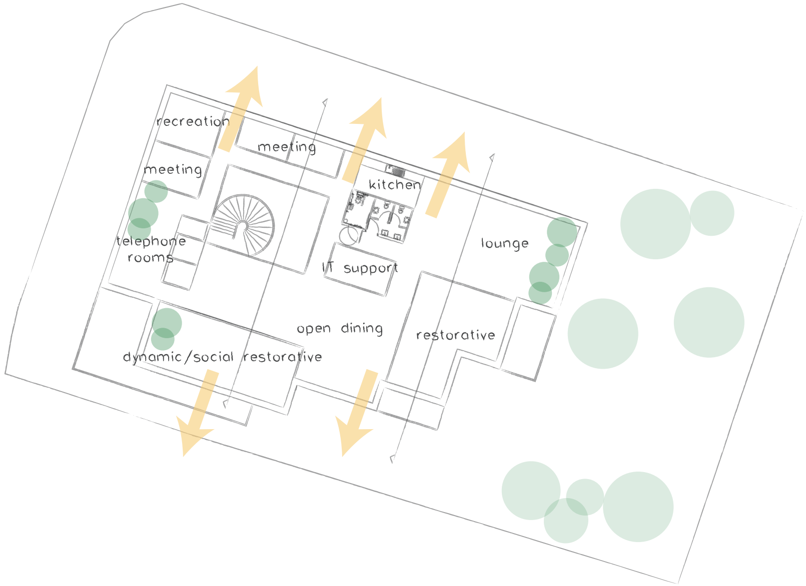




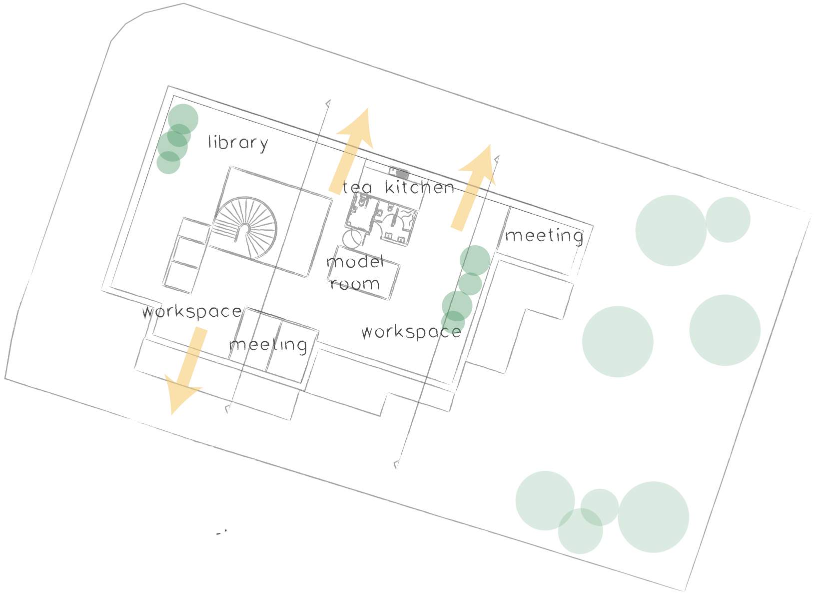
*ill. 90 - Initial sketches -*



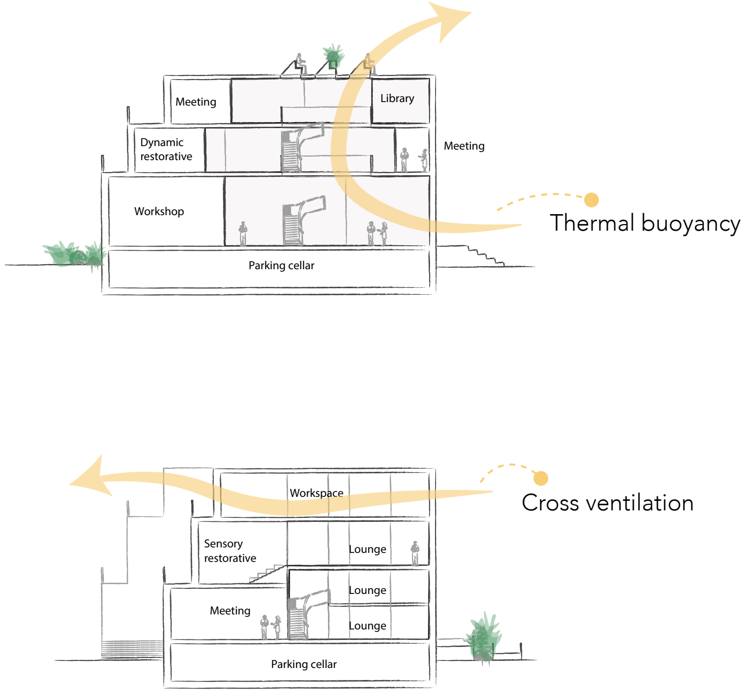
ill. 91 - Ground floor -



ill. 92 - First floor -



ill. 93 - Second floor -



ill. 94 - Sections -

# 8.4 VELUX STUDIES

## 8.4.1 Window height and orientation

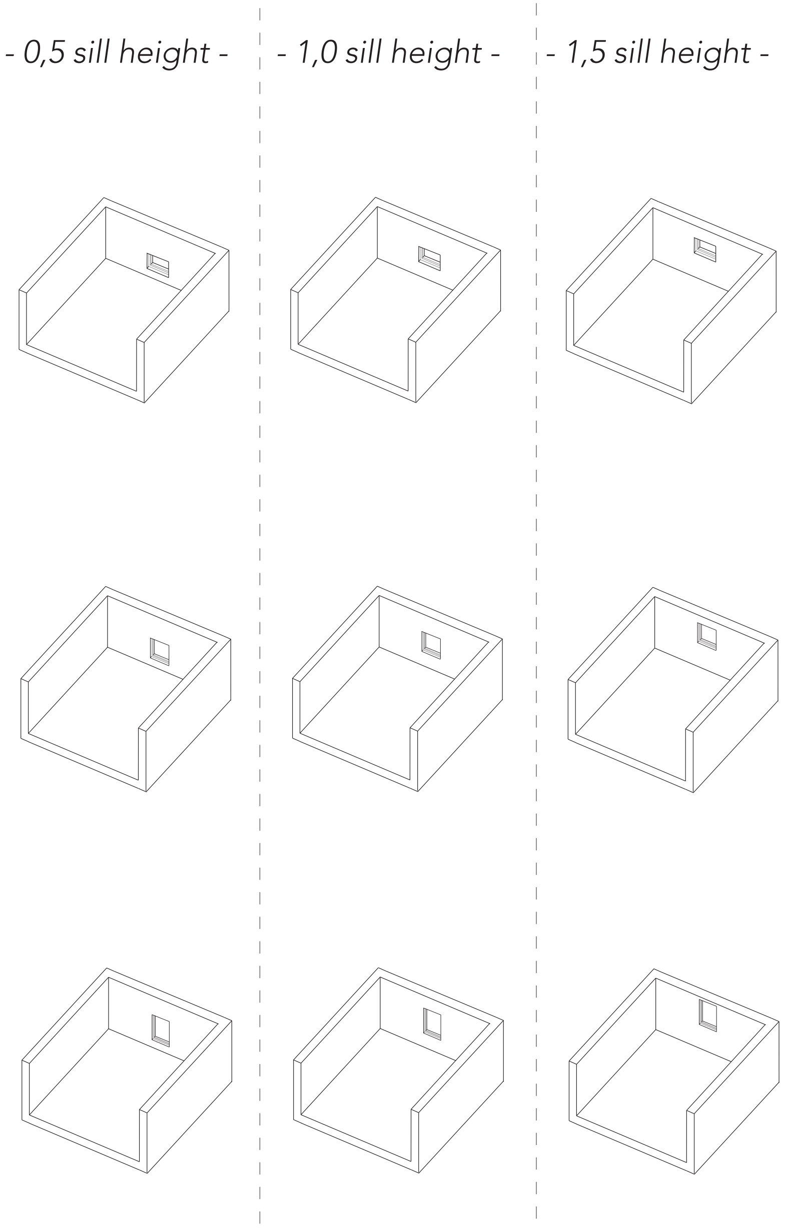
The daylight study is of focal importance for the project, thanks to the high beneficial for human architectural experience and health.

The decision making for the openings shape is determined by technical proofs.
To attain effective daylight in the interiors, the window sill height and orientation need to be determined before implementation of facade design. The study focuses on the highest daylight factor that can be attained in a 7 x 7 m room with a constant experimental glazing area of 1,5 sq m.

The orientation of the window are horizontal, vertical and square of dimension 1 x 1,5 m, 1,5 x 1 m and 1,22 x 1,22 m respectively.
The windows are placed at sill levels of 0,5 m, 1 m and 1,5 m.

The windows at sill level 1,5 m deliver the maximum light level in the interior with square glazing configuration (Annex 1).

| ORIENTATION | SIZE | SILL HEIGHT | DAYLIGHT |
|---|---|---|---|
| horizontal | 1x1,5 m | 0,5 m | 0,4 % |
| | | 1,0 m | 0,4 % |
| | | 1,5 m | 0,5 % |
| vertical | 1,5x1 m | 0,5 m | 0,5 % |
| | | 1,0 m | 0,5 % |
| | | 1,5 m | 0,6 % |
| square | 1,22x1,22 m | 0,5 m | 0,4 % |
| | | 1,0 m | 0,4 % |
| | | 1,5 m | 0,7 % |



*ill. 96 - Horizontal (first row), vertical (second row) and square (third row) window's orientation -*

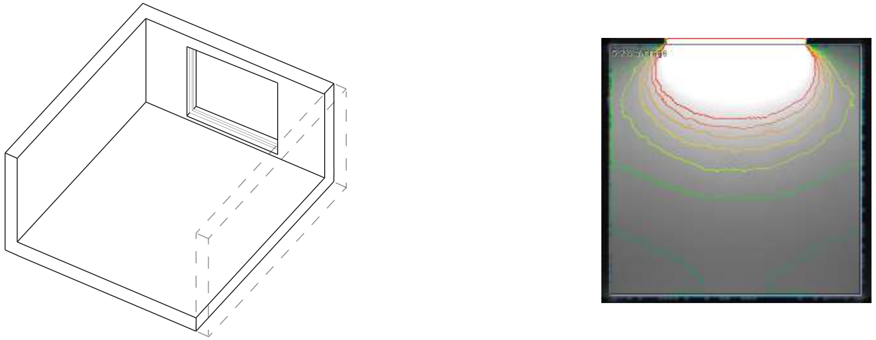
### 8.4.2 The 7 x 7 grid

According to the design grid of 7 x 7 m, given by the building structure, the area of glazing on the external wall needs to be estimated for the daylight factor to be 5%. The finding will result in the implementation of windows in the facade design according to the grid.
The analysis is threefold- with single, double and triple openings. Starting with the single opening, the glazed area is simulated in decreasing order from 15 sq m to 8,75 sq m.

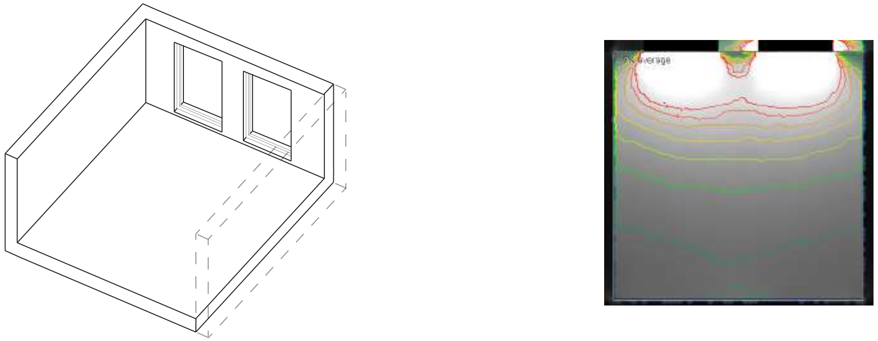
With the window dimensions 3,5 x 2,5 m, the area is large for a single glazing, and the study proceeds to multiple smaller windows. For two glazings, the total area is slightly higher at 9,5 sq m with window dimension of 1,9 x 2,5 m. Further, for three glazing, the total window area is 9,6 sq m with dimension 1,788 x 1,788 sq m (Annex 1).

Combining from the conclusion of window height study, a square window has the best performance. However, a compromise will be found between the best daylight performance and the function of each space.

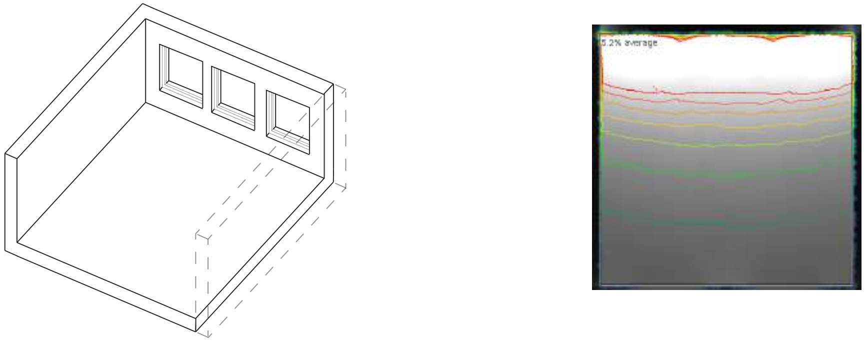
| N° | SIZE | AREA | DAYLIGHT |
|---|---|---|---|
| 1 opening | 3,5x2,5 m | 8,75 sqm | 5,2 % |
| 2 openings | 1,9x2,5 m | 9,5 sqm | 5,0 % |
| 3 openings | 1,78x1,78 m | 9,6 sqm | 5,2 % |



*ill. 97 - 1 opening -*



*ill. 98 - 2 openings -*



*ill. 99 - 3 openings -*

### 8.4.3 The lounge 's mezzanine

The idea of integreting a double height in the lounge is given by the will of creating various working place with different characteristics, but also because lower ceiling height have a good influence on people's concentration.

The mezzanine in the lounge will cause darkness towards the interiors, deeming the area unsuitable for work. Thus, the lounge on the ground floor is analysed with different configurations with same opening area, along with the connecting staircase, in order to select an affective mezzanine design.

The daylight analysis has fully glazed north and east facades to gauge a daylight efficient strategy between fully closed, fluid, chamfered and semi circular openings. The chamfer mezzanine slab is the most efficient for daylight, reaching a peak of 19,7%.

| SHAPE | DAYLIGHT LEFT SIDE | DAYLIGHT RIGHT SIDE |
|---|---|---|
| 1. Closed | 10,1 % | 13,3 % |
| 2. Semicircle | 14,3 % | 16,9 % |
| 3. Arc | 9,6 % | 18,4 % |
| 4. Chamfer | 14,5 % | 19,7 % |

PERFORMANCE

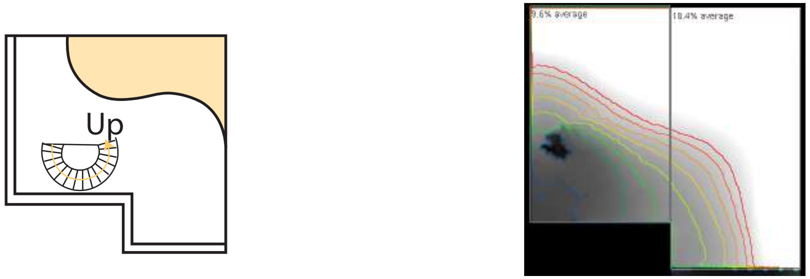
Least

↓

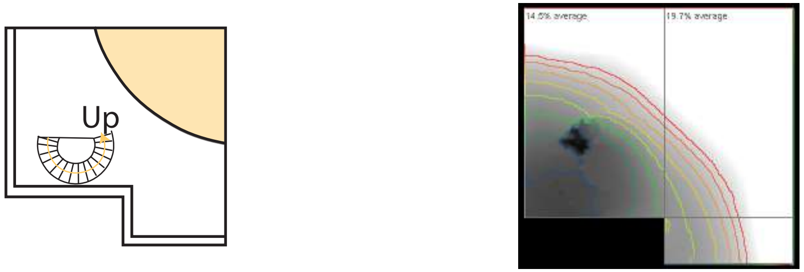
Most

*ill. 100 - Closed mezzanine plan -*

*ill. 101 - Semicircle mezzanine plan -*



*ill. 102 - Arc mezzanine plan -*



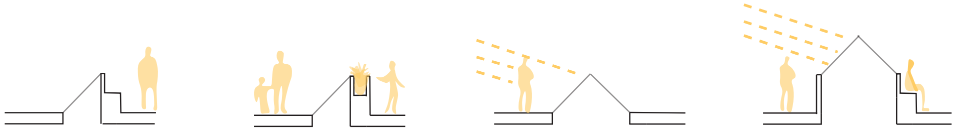
*ill. 103 - Chamfer mezzanine plan -*

### 8.4.4 Atrium

The central atrium is a 14 m high opening of 7 x 7 m as an entrance space. The implementation of skylights aids to the concept of efficient circadian light for user wellbeing. The skylights act as glass integrated solar panels and seating for the roof garden.

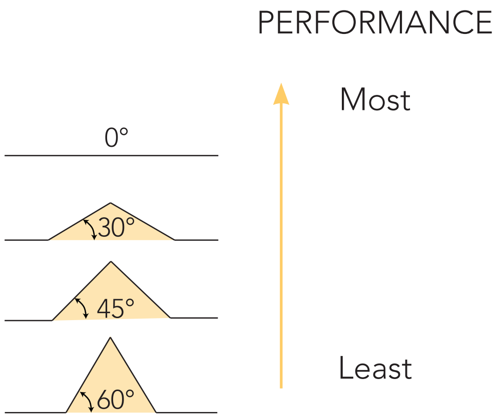
The daylight is simulated at angles 0, 30, 45 and 60; with efficiency in decreasing order for the same. Since the initial concept of designing a skylight has been to ensure daylight penetration while generating energy through photovoltaic cells, the slope of the solar cells was chosen to be towards the south at an efficient angle of 45 degrees.

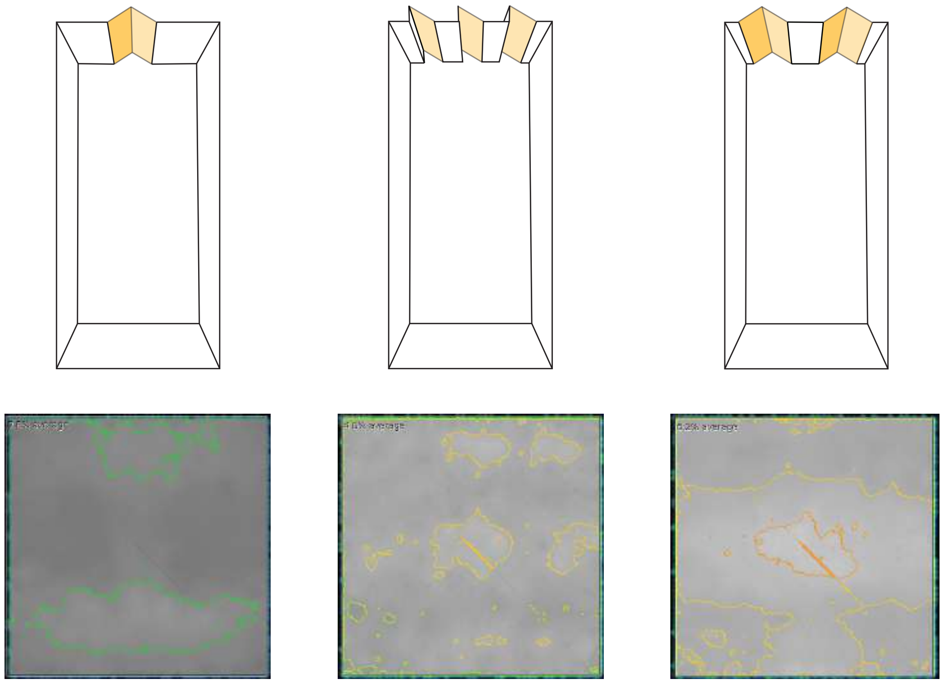
The daylight efficiency is maximum for 0 angle, but due to rain and maintenance of the skylight, the lowest angle 30 was chosen for the north oriented glass. The intended daylight factor of 5% was attained by two skylights with 72% transmittance, and 35% transmittance through the photovoltaics, best compromise between daylight and energy integration.
Initially, the main staircase was blocking the daylight for the atrium and the reception area, along with the enclosing passages in above floors. Thus the staircase was iterated to occupy less atrium footprint to not hinder daylight and enhance the quality of the space.
For lux levels of the three skylight options, see Appendix 1.



*ill. 104 - Skylight's shape process: oriented in one direction with seat, oriented in one direction with plants, double orientation for Pvs integration, rise the skylight to have no light disturbance -*

| ANGLE | DAYLIGHT |
|---|---|
| 1. 0° | 1,6 % |
| 2. 30° | 1,5 % |
| 3. 45° | 1,4 % |
| 4. 60° | 1,3 % |



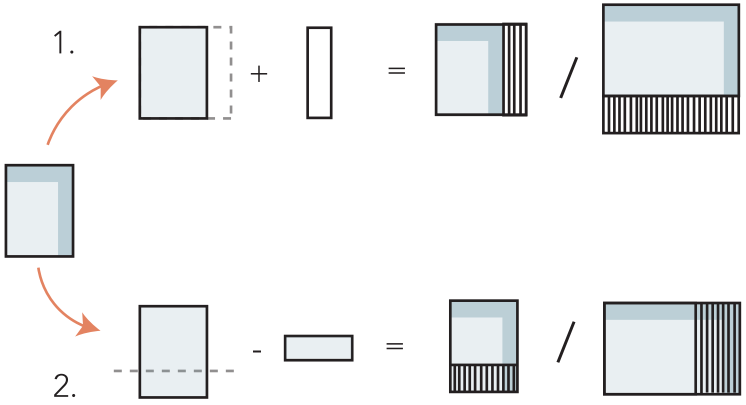


*ill. 105 - Skylight studies of 30°, first and third with different transmittance due to the integration of solar panels -*

# 8.5 EVOLUTION OF WINDOW SHAPE

The resulted window shape has been developed for an external different expression. As said, the windows follow both the daylight study, but also the internal function of the space, for instance vertical windows are used for wayfinding (at the end of corridors and as doors). While the window sill of the rectangular windows follows the possibility of using them as a seat, 50 cm for the floor, or to concentrate while working, 1 m from the floor.

Thus, an external expression is needed to integrate the geometry in the facade. The square shape appears to be a repeating form with ratio 1:1, recalling also to fractals (Annex 2).



1. + Can be used for shadings panels or other purposes
   + No interference with daylight
   - More difficult to recognise the square because of the interference of another material underneath

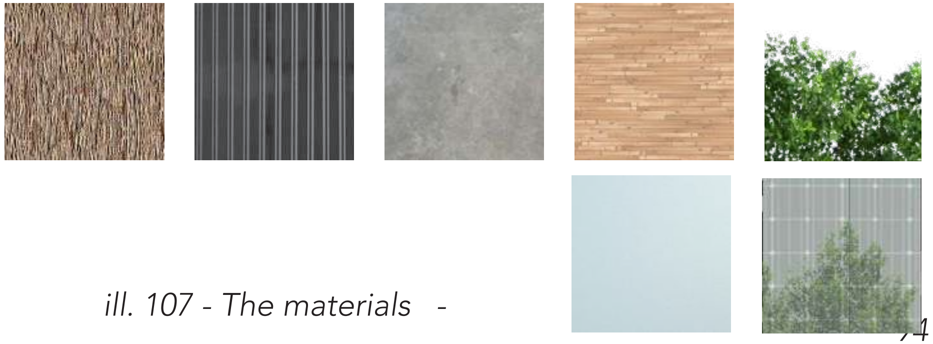
2. + More visible square reference
   - Compromise daylight

*ill. 106 - The materials -*

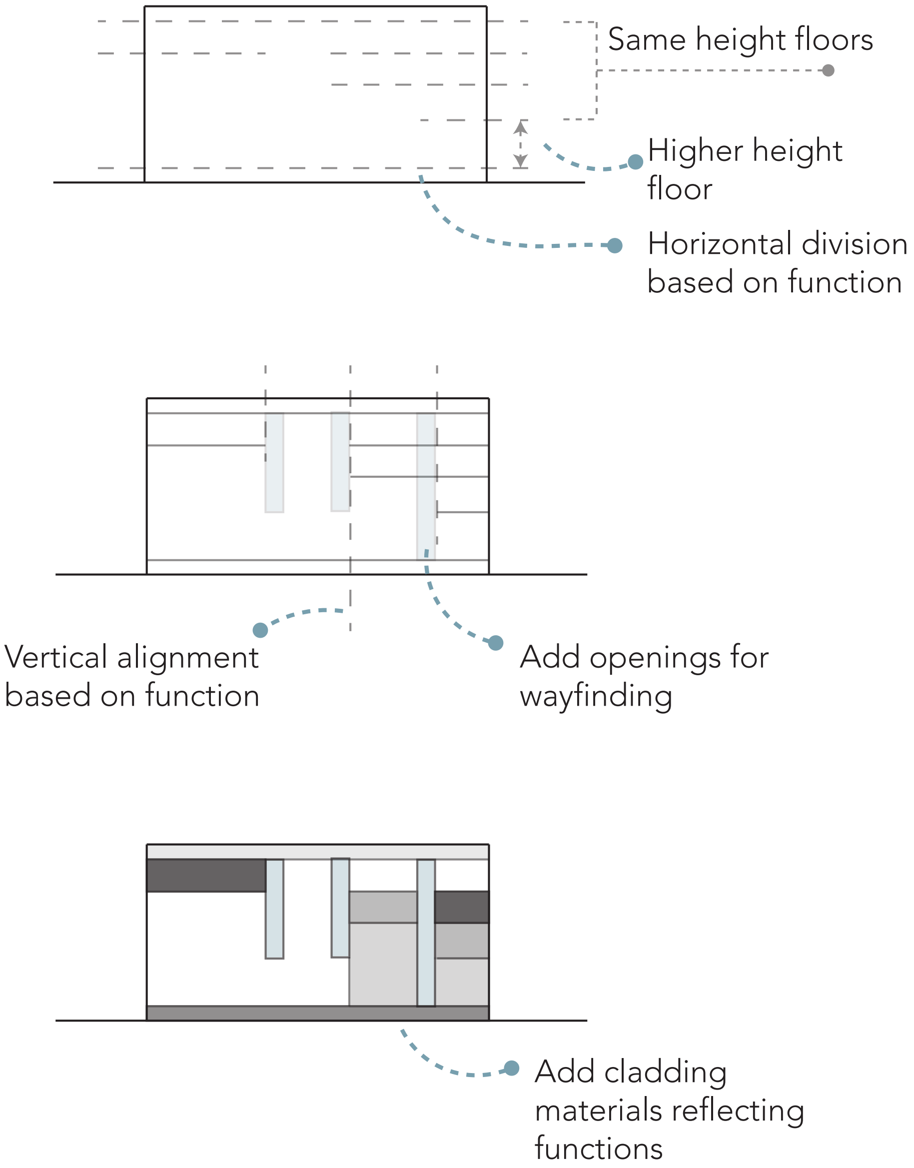
# 8.6 FACADE MATERIAL STUDY

The materials considered for the facades reflect the internal organisation of the building, addressing their function.
For example, for restorative rooms a non common material as hemp, has been studied to clad the exterior of the building, showing to the pedestrians that in that specific part of the building there is more attention to nature related aspects. On the other hand, in oder to reconnect to the industrial context, metal and concrete are considered, one for cladding, the other one to rise the building for flooding due to climate change, creating the foundations of the construction.
Metal is also used for strong functions as storage.
Wood should represent the main material on the facade from a quantitative point of view, to reflect the general idea of the project, where natural materials are central in the stress relieving and Life Cycle Assessment studies.

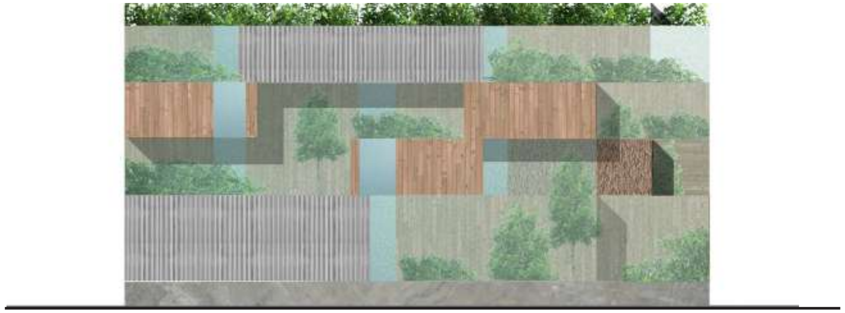
In order to recall the square shape, the previous study concerning the evolution of the window has been added to the facade, to gain an overall expression. From wooden lamellas used as shadings to a green structure, due to the will of integrating more green in the project. Afterwards, green houses directly connected to the main structure have been added, to allow the users to use the terraces shield in this way from the wind. Green roof and Photovoltaic panels will become part of the expression as well (Annex 2).



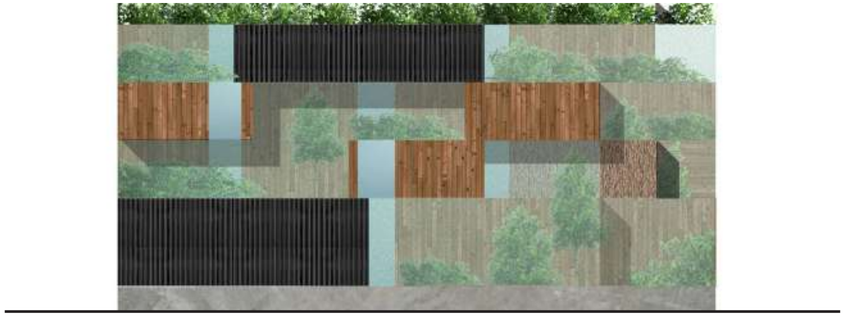
*ill. 107 - The materials -*



*ill. 108 - The study is conducted for each facade -*



*ill. 109 - South facade with silver metal -*



*ill. 110 - South facade with black metal -*

*ill. 111 - North facade study with greenery -*

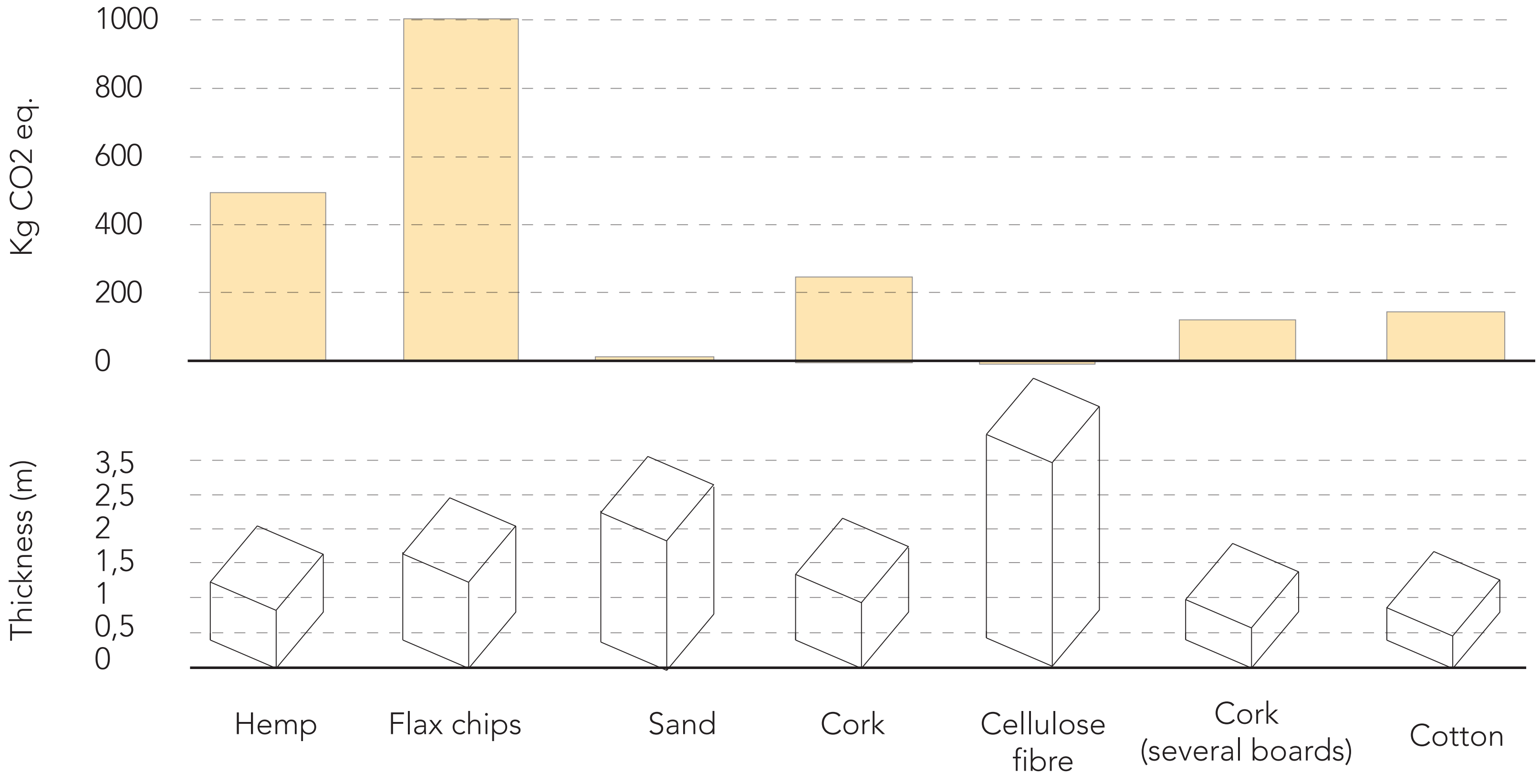
# 8.7 LCA AND U-VALUES

The quantity of insulation represent a big percentage in the construction, due to the rigid weather. Thus, an investigation, which helps the decision making, was a starting point in order to evaluate the most appropriate material for the specific project.
LCA study have been carried out along with the U-value calculations concerning 7 natural insulation materials. Respectively, for undestanding the contribution to global warming and to assess which one is the most performant (Annex 3).

The materials with the same U-value have been analysed and compared for 1 m². The thickness and volume of each of them varies then, according to their individual thermal conductivity and resistance.

The comparison shows how some of them are harmful for the CO2 emissions, while others are too thick or impractible to actually be used.

Afterwards, the ones with more potential, cork (several boards) and cotton have been selected for a deeper study in the wall stratigraphy, considering all the material needed in the overall construction.



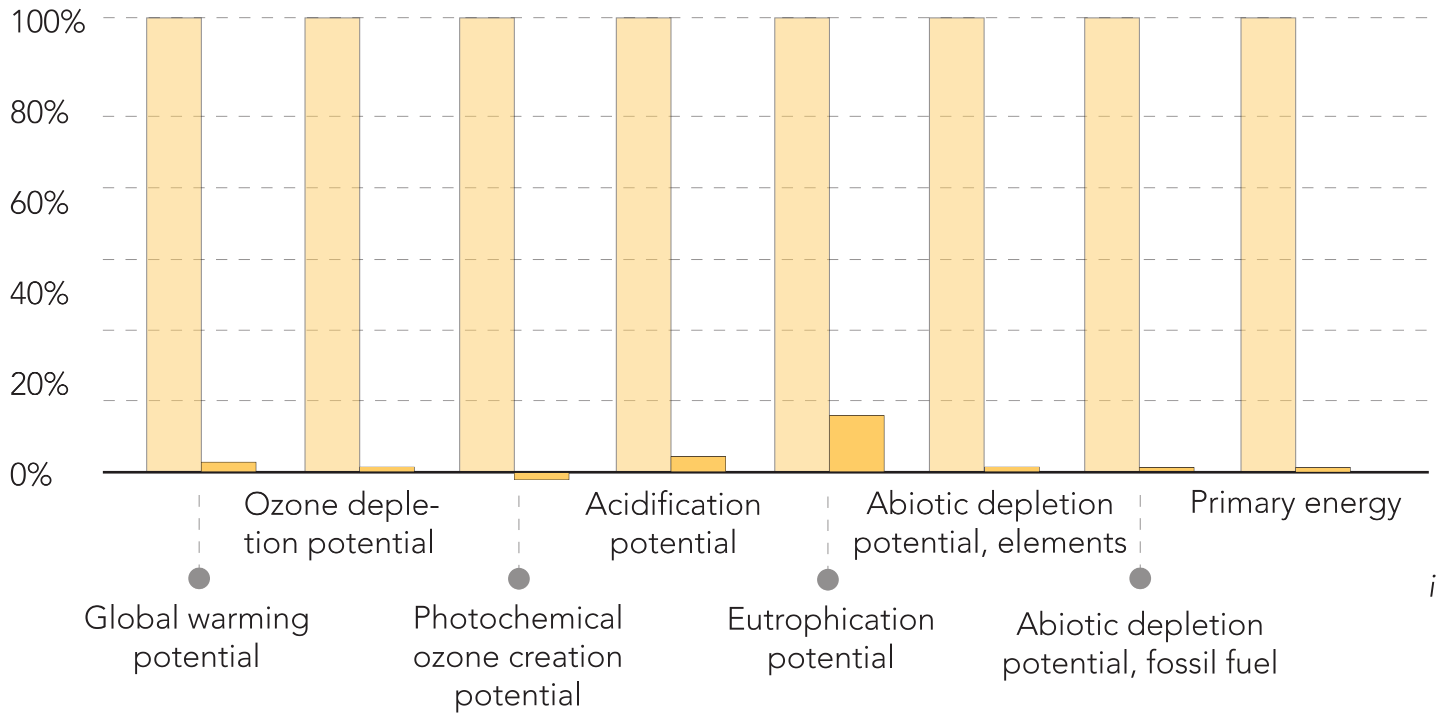
*ill. 112 - Comparison of CO2 emissions and thicknesses -*

# 8.8 LCA COTTON AND CORK

To determine the most efficient and light insulation material, an LCA of cotton and cork was analysed in LCAbyg, calculating the amount of material to be used on the basis of prior U-value based LCA study and insulation required for external wall and roof area of the project (Annex 3).

The thickness of cotton derived from the study is 400 mm thick while 550 mm thick for cork. The weight of cotton to be used was found to be 944 kg while for cork it was 103807 kg for the entire construction. The total carbon dioxide equivalent of cork (cumulative of all greenhouse gases measured in carbon dioxide) used in the project is 34000 kg CO2 whilein case of cotton it is 500 kg CO2.

Moreover, the comparison demonstrated that cotton performed only 2% of cork in the Global Warming Potential criteria; which is weighted the highest according to DGNB (40%). Thus, the following results led to the choice of cotton as an insulation material for the project; with higher efficiency in less volume and weight.



*ill. 113 - Comparison of cork (set to 100% in light yellow) and cotton (darker yellow) for main figures -*

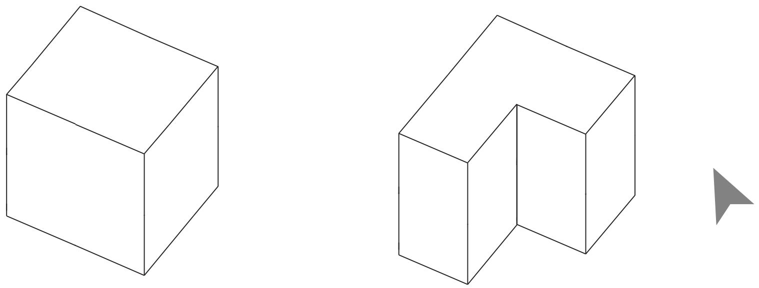
# 8.9 ENERGY CONSUMPTION: BE18

To navigate design decisions with respect to the built form in relation to energy performance, the volume study was further studied in Be18 for the same.

Two forms with the same volume were examined by including the external wall surfaces and respective foundation.
The first volume is a regular block with the area and number of storeys complying to the initial room program and the local plan; while the second volume is volume 2 taken from the volume study experiment.

Volume with the assembly of masses has a higher energy requirement as compared to the solid volume; with values 8.6 and 7.8 kWh /m2 year (Annex 4).

Thus, the design will attempt to maintain a solid volume yet attempt to balance the daylight penetration and view considerations from Well Building Standards; in addition to the quality of indoor spaces and energy.



*ill. 114 - Volume study 1 and volume study 2 -*

# 8.10 INDOOR ENVIRONMENT: BSIM

Two critical rooms were simulated for the project- the recreational room on the second storey and workplace on the fourth storey on the South facade. Inferring from research, indoor environment is crucial for stress alleviation; especially in both the functions for the rooms.
In implementing values from the bsim guide and based on our knowledge of the project specifics, such as the construction, U values and systems; the models were created as isolated thermal zones with designed construction.

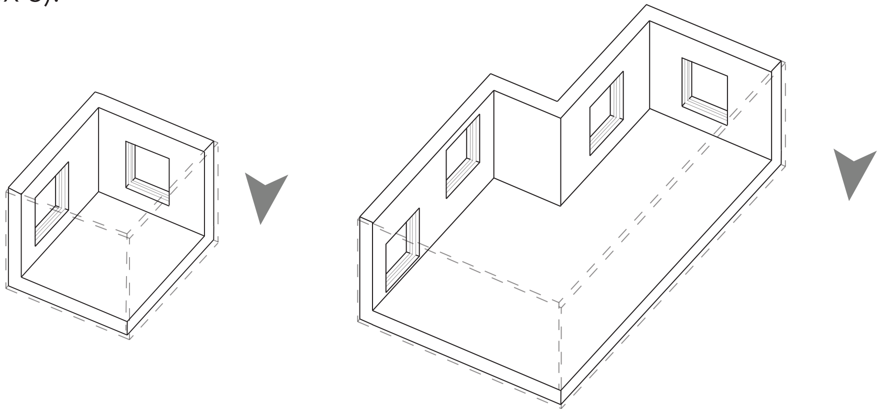
The infiltration for the rooms was derived from the formula- 0,04 + 0,06x q50 litre/sec per heated area where q50 is the ventilation in liters per sec per sq m heated floor area at a pressure test at 50 Pa.

Initially, both the rooms showed overheating in summer months due to the South window openings. The results led to the addition of solar shadings in the windows which improved the temperature.
Also, the venting and ventilation systems caused the CO2 levels to be constant and regulated annually due to the set point. However, the air change rate was very high for both the models; thus different schedules were created for the ventilation system and the window opening percentage was experimented with to determine the optimum opening.

Initially the workplace room had two window openings on the external walls to create a cross ventilation while recreation had three windows on one external wall for single sided ventilation. However, after the removal of one window from both rooms, the temperature further improved and the air change rate drastically decreased. The window levels were raised according to daylight study to fulfill the daylight requirements.

Further, the Afrac value, which is the fraction of the openable window area was experimented with in decreasing order, was found to be optimum at 0.5 for the workplace; and 0.3 for the recreation due to multiple windows.
Further, the window glazing initially was flush with the facade due to the design concept of utilising the window sill for seating purpose. However, the most efficient recess for the simulation results were with the glazing flush with the interior wall. Thus, a compromise of window recessing at 0.2 m from the external facade was implemented to ensure usable sill space and efficiency.

The change of light control in the lighting system lowered the temperature to comfortable indoor standards, from daylight control to light control.
The lighting control is based on solar limit in kW, which accounts for the total solar incidence in the room; and more importantly the indoor temperature. With a maximum temperature set for a room, it switches off in over temperature and is activated in case of low solar incidence (Annex 5).



*ill. 115 - Geometry built in BSim, workplace (15 sqm with two occupants) and restorative (40 sqm with a peak of five occupants) -*

# 8.11 THE PINBOARD

*"...our findings indicate that humans like sharp angled objects significantly less than they like objects with a curved contour, and that this bias can stem from an increased sense of threat and danger conveyed by these sharp visual elements."*
*(Whalen, 1998)*

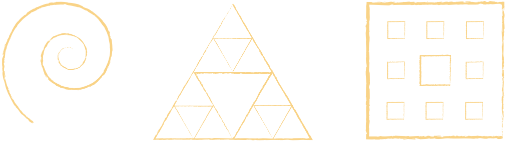
*"Thus blue, tall and curvilinear spaces, with views of the blue sky, are more likely to be pleasant, sociable and creative environments. Conversely, red, low-ceilinged, rectilinear environments are more likely to encourage focus, concentration and study."*
*(Steemers, 2015)*

*ill. 116*

*"Natural daylight is filtered through perforations in a custom skylight made of routed wood, which was parametrically designed. Warm materials, such as Texas walnut and natural stone, help alleviate the "sterile and harsh" atmosphere that is often found in medical facilities."*
*(McKnight, 2017)*

*ill. 117*

*"Fractal visuals influence human beings during the performance of stressful mental work. Beneficial, restorative environments dampen the inevitable rise in physiological stress while performing a necessary task requiring concentration."*
*(Salingaros, 2012)*



*ill. 118 - Fractal diagram -*

*"In a world of architectural commercialism, it has been the most meaningful task to seek employment with spaces, materials and landscapes in the service of psychological and emotional healing processes," said Snøhetta's Kjetil Thorsen.*
*(Davis, 2013)*

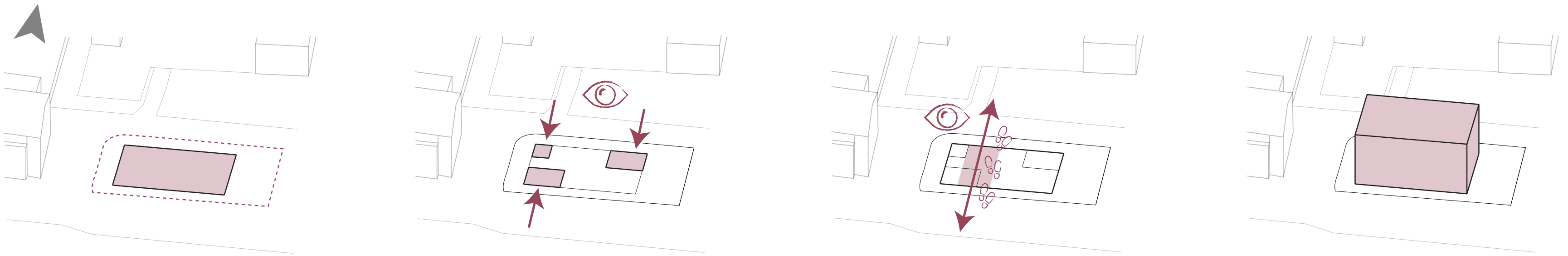
# 9| PRESENTATION

WORKFLOW:

| | |
|---|---|
| The presentation | 9.1 The project |
| The application of the standards | 9.2 Evaluation plans |
| Spotting the features | 9.3 Mapping |
| Life cycle assessment confirmation | 9.4 LCA |
| Detailing the joints | 9.5 Construction details |
| Energy fulfillment | 9.6 Energy consumption: Be18 |
| | 9.7 Photovoltaic panels |
| Indoor environment results | 9.8 Indoor environment: BSim |
| The conclusion | 9.9 Reflection |

# 9.1 THE PROJECT

## 9.1.1 Concept

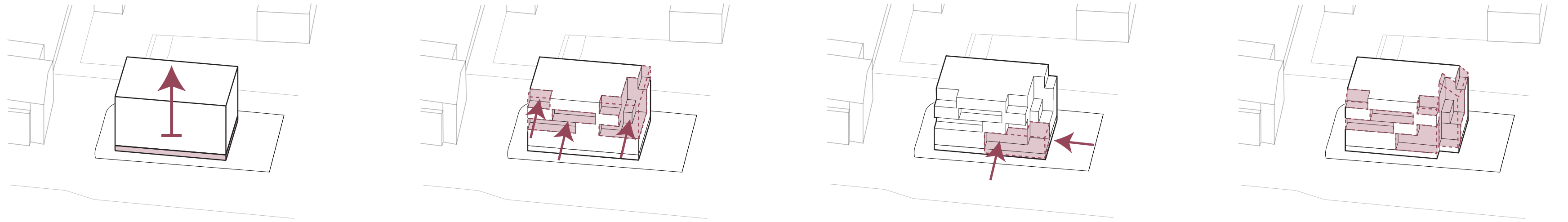


- The site and the rectangular footprint -

- Attractive function along the perimeter to implement the visibility -

- Create a pass and see-through -

- Extrude the building of 4 storeys -

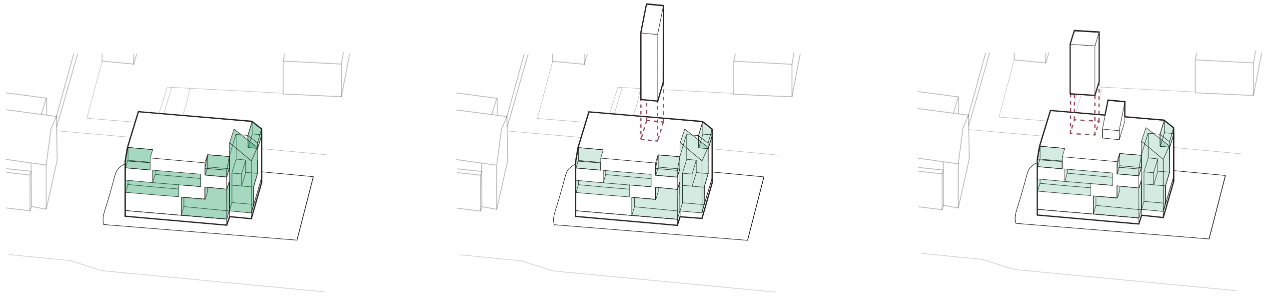


- Rise for flooding due to climate change -

- Recess the facade to create wind protected terraces and increase daylight -

- Recess the facade to create connection to the East green -

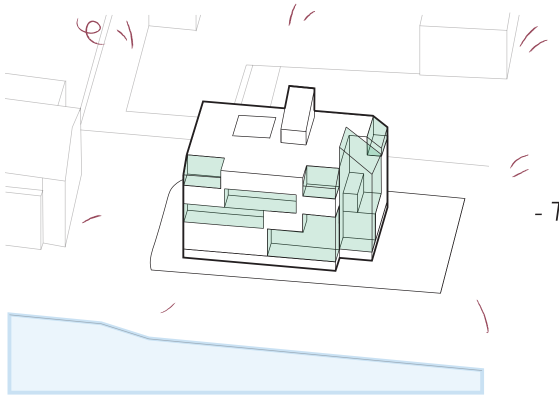
- Close the terraces with green houses to encourage their use -



- Implement plants on the closed-off terraces -

- Addition of service core -

- Inclusion of atrium to increase daylight -

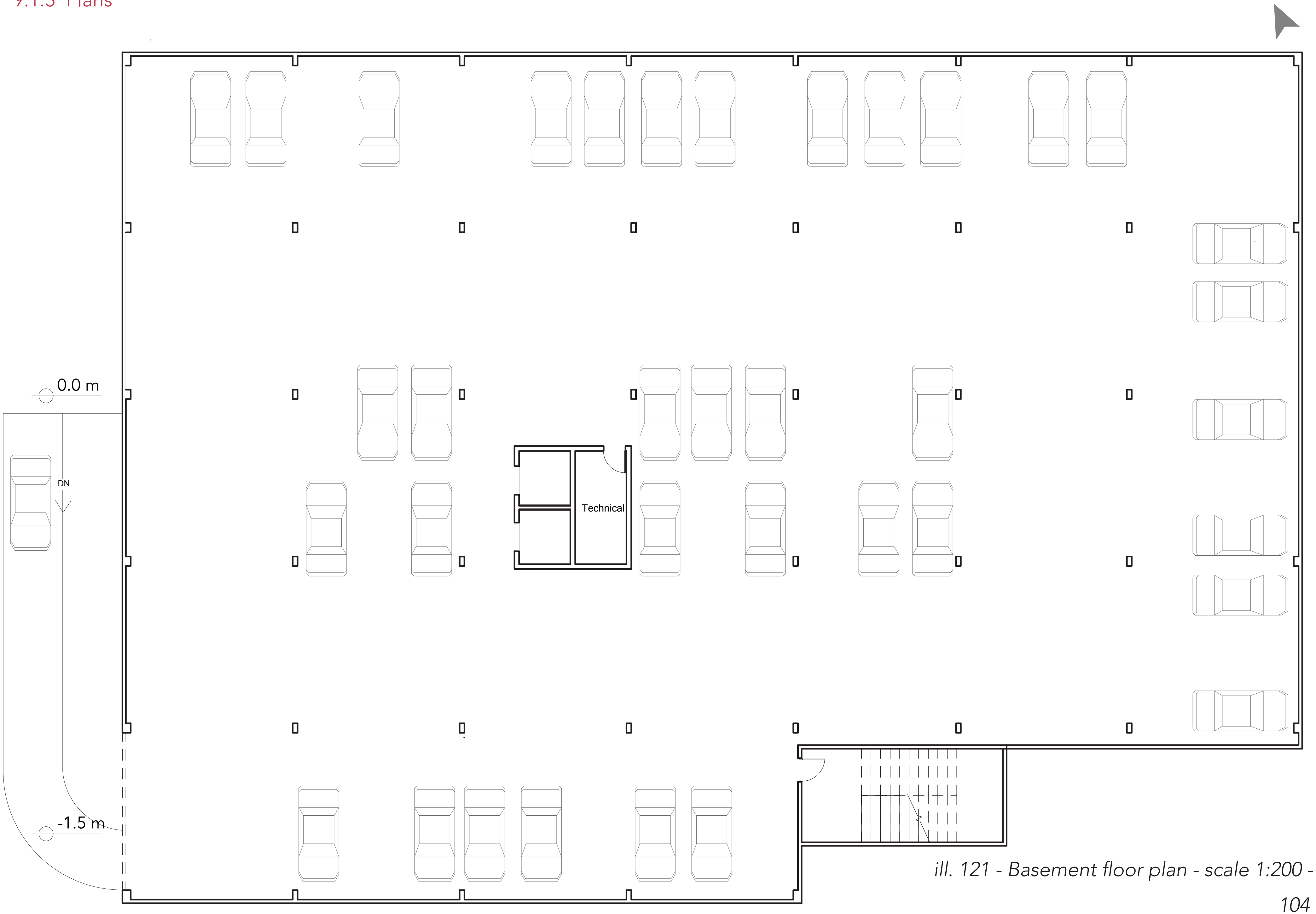


- The final design -

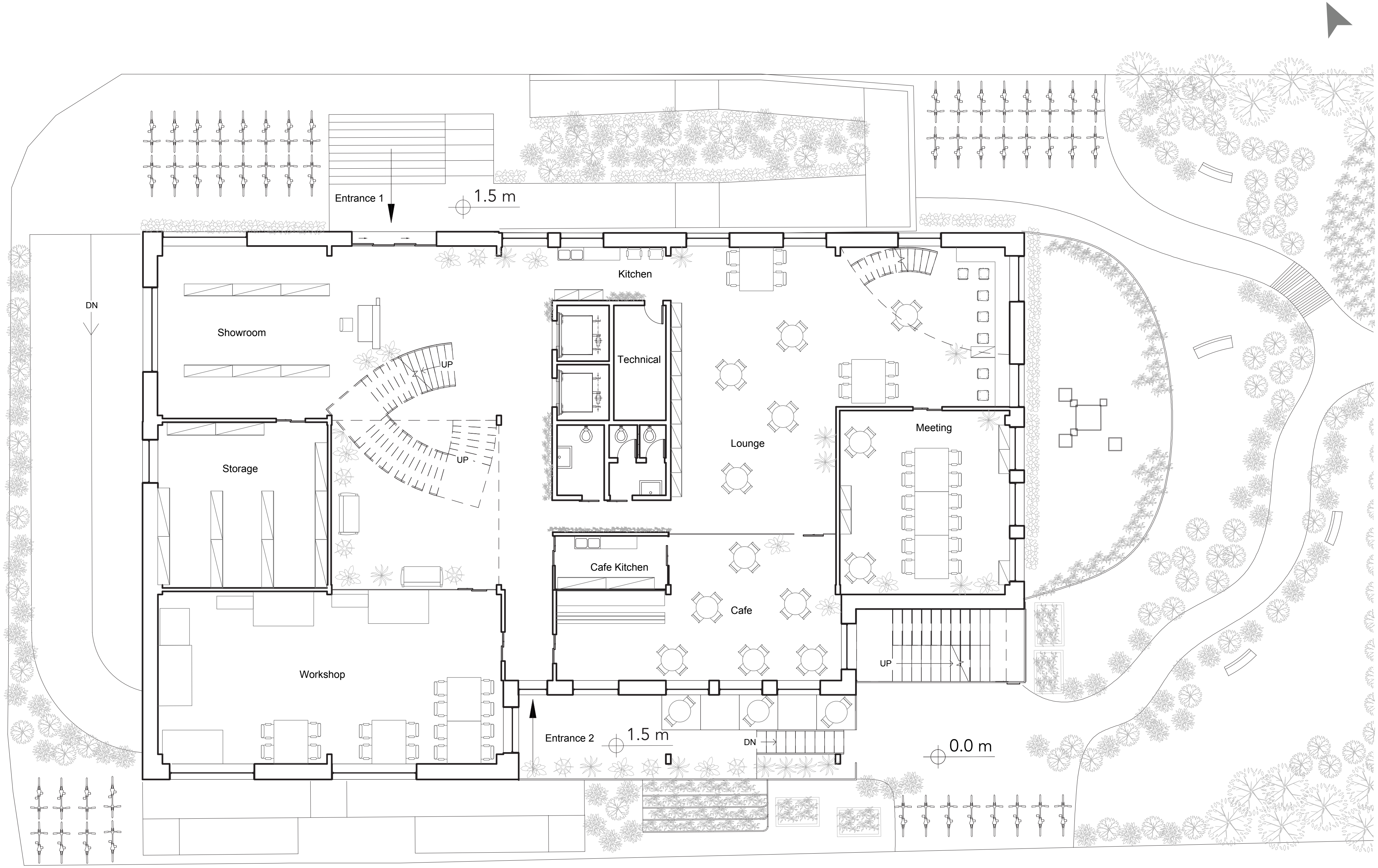
ill. 119 - Concept diagram -

## 9.1.2 Masterplan

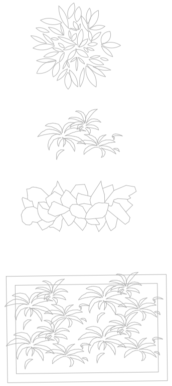
*ill. 120 - Masterplan - scale 1:500 -*



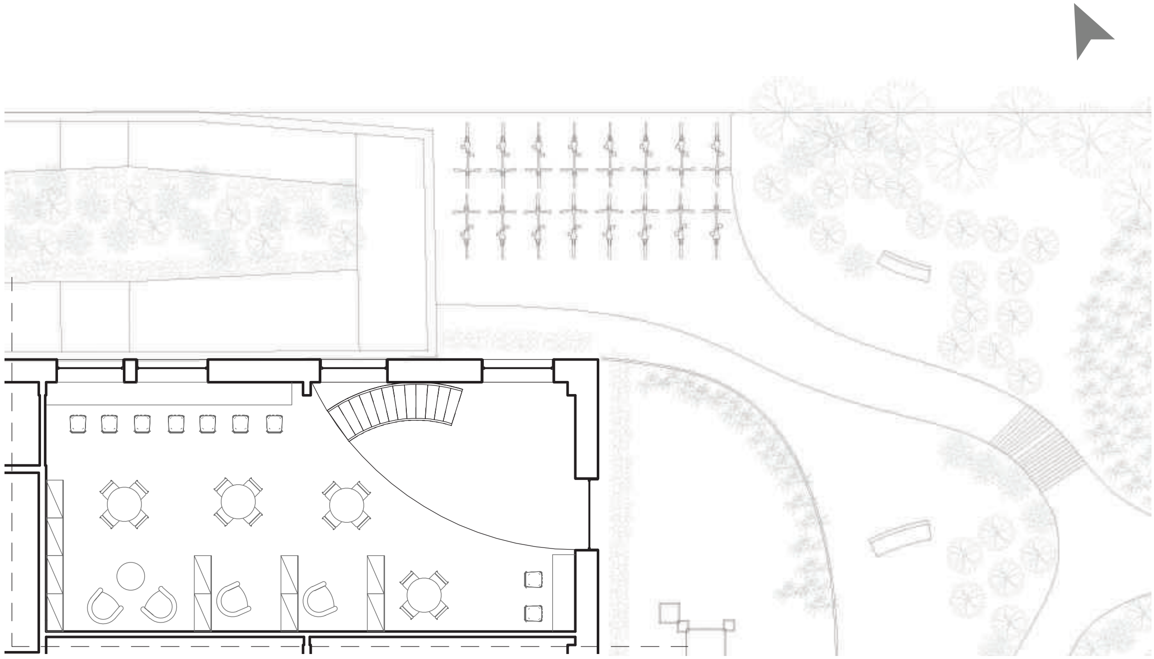
*ill. 121 - Basement floor plan - scale 1:200 -*



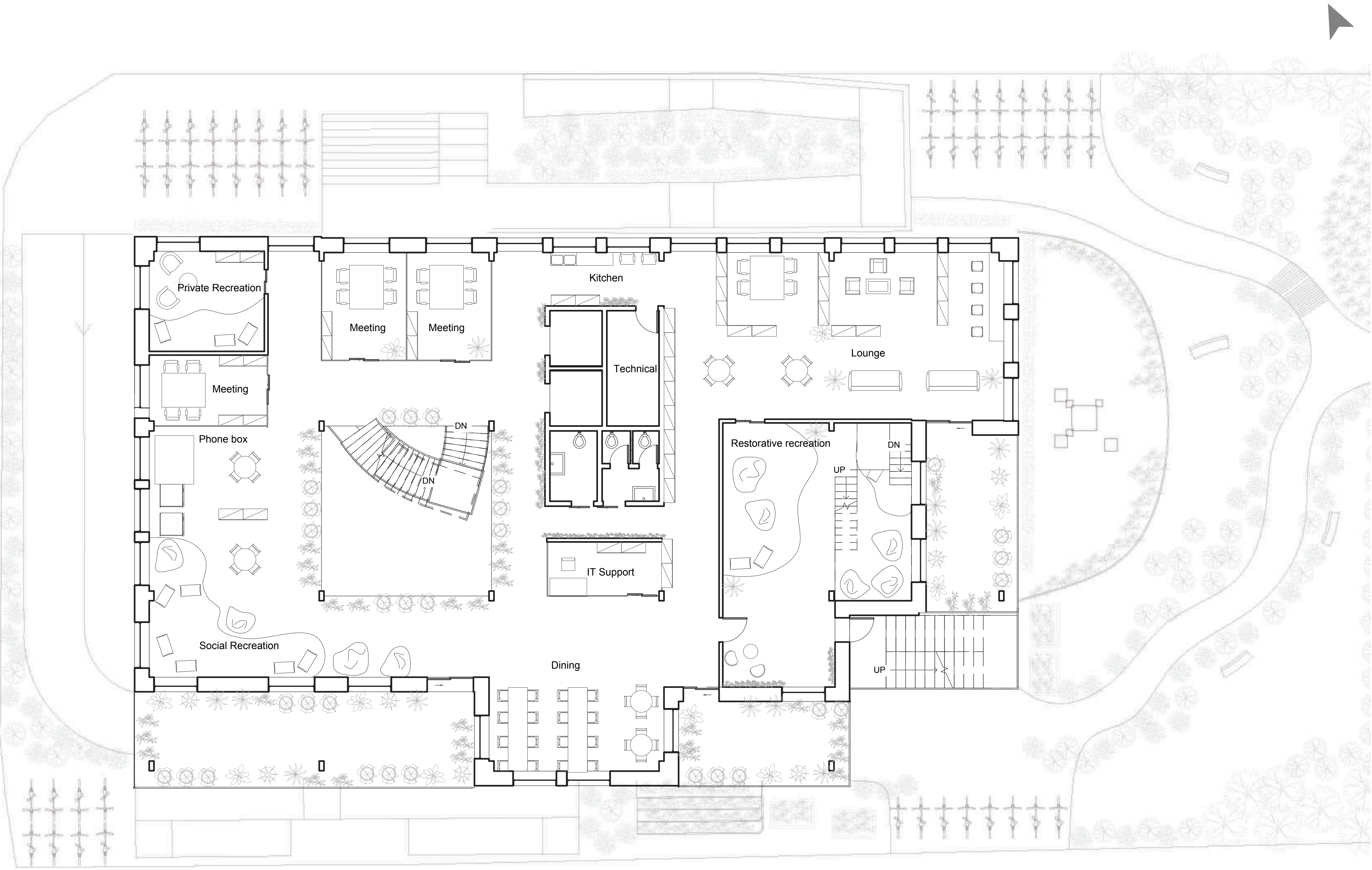
*ill. 122 - Ground floor plan - scale 1:200 -*



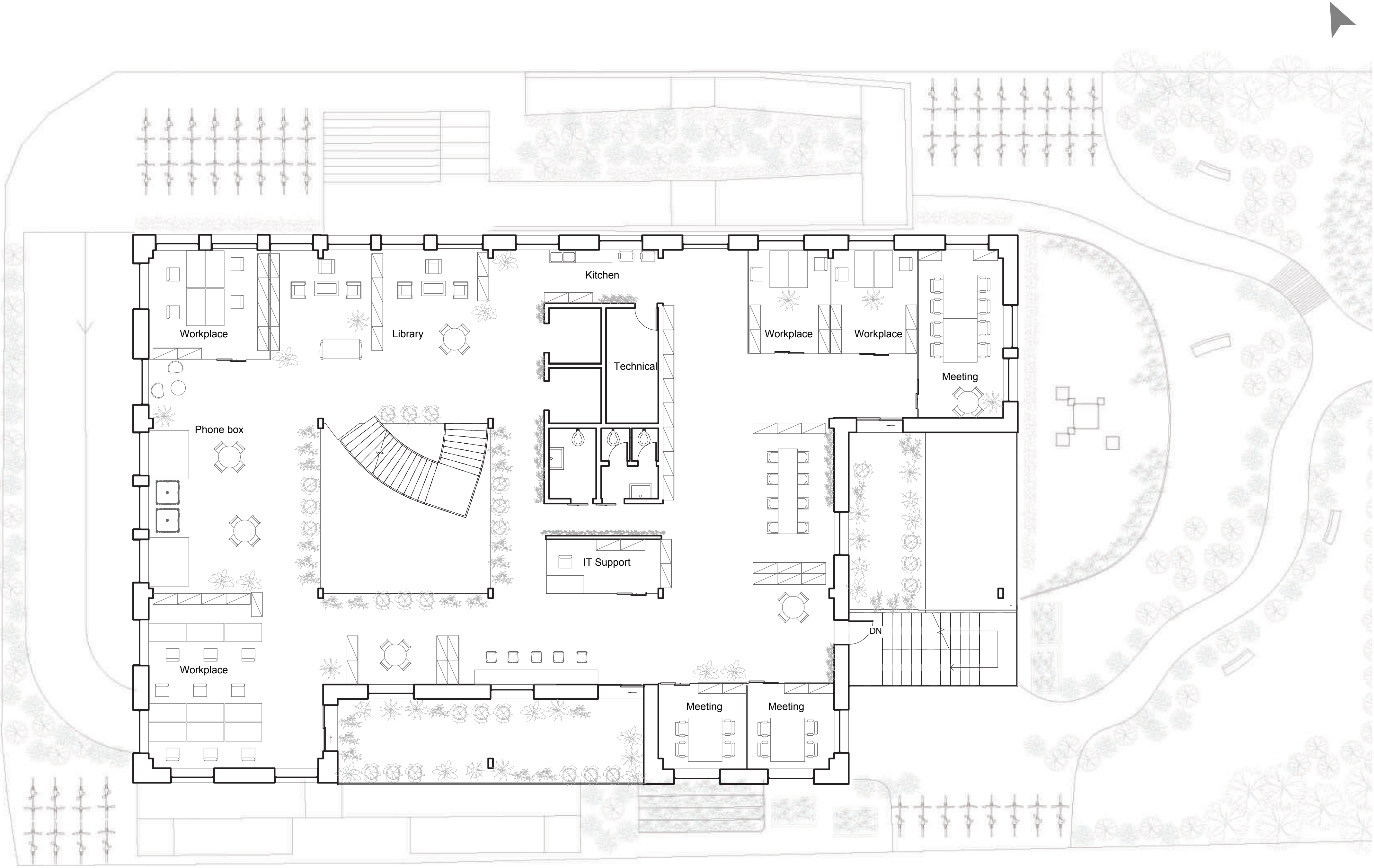
*- Kinds of green:*
*tall seasonal,*
*small ornamental*
*tree,*
*flowers bush,*
*vegetable garden -*



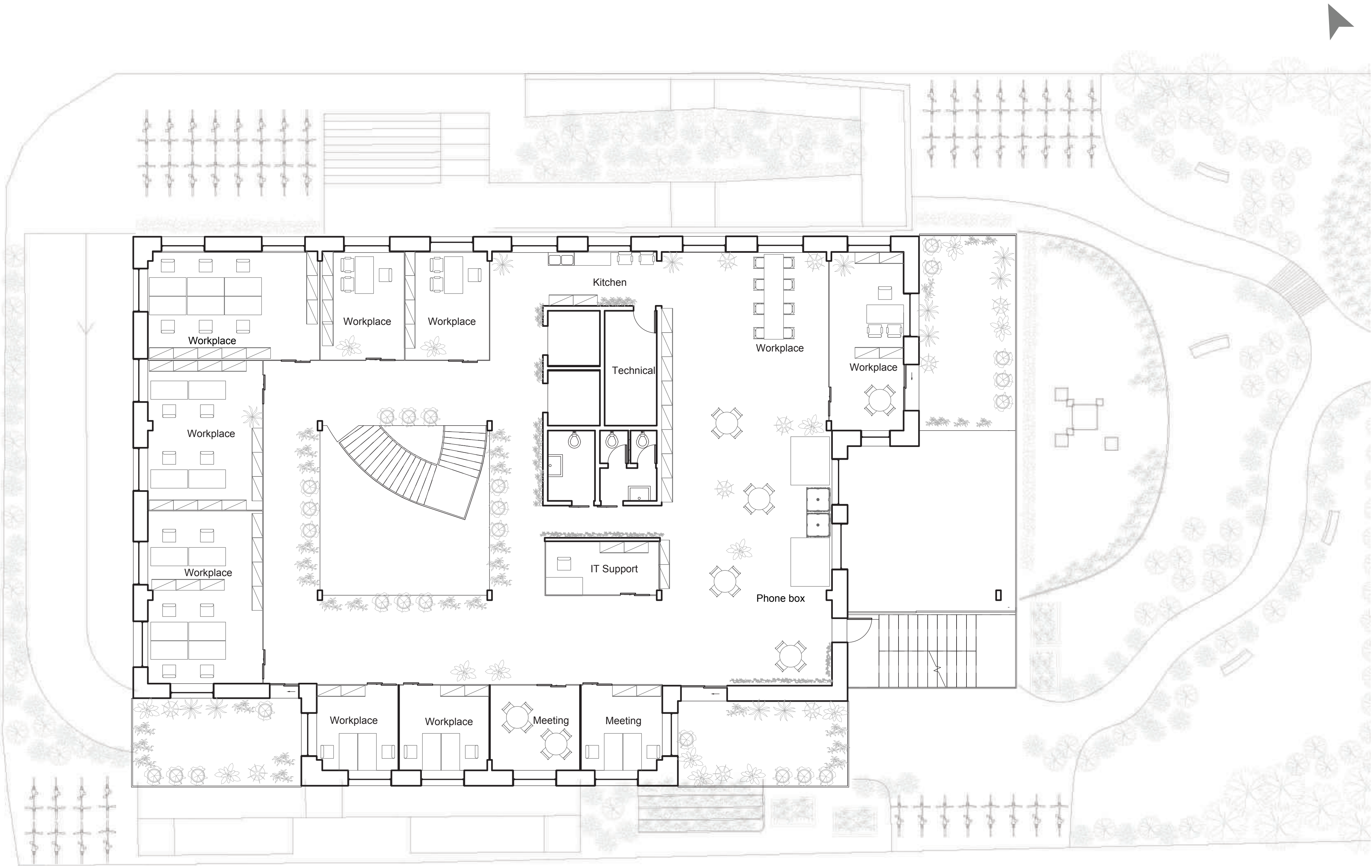
*ill. 123 - Mezzanine plan, aligned with the lounge of the ground floor - scale 1:200 -*



*ill. 124 - First floor plan - scale 1:200* -

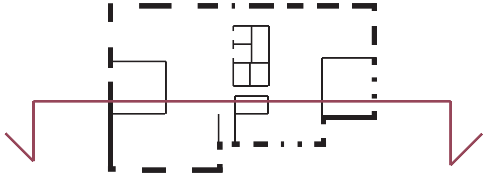


*ill. 125 - Second floor plan - scale 1:200* -

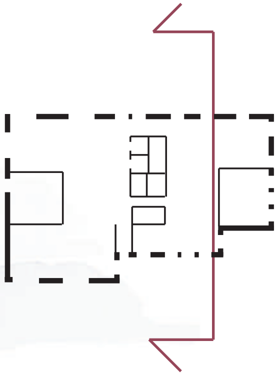


*ill. 126 - Third floor plan - scale 1:200*

## 9.1.4 Sections



*ill. 127 - Section AA' - scale 1:200 -*



ill. 128 - Section BB' - scale 1:200 -

*ill. 129 - Section CC' - scale 1:200 -* ●

## 9.1.5 Elevations

*ill. 130 - South-East elevation - scale 1:200 -*

*ill. 131 - North-East elevation - scale 1:200 -*

*ill. 132 - South-West elevation - scale 1:200 -*

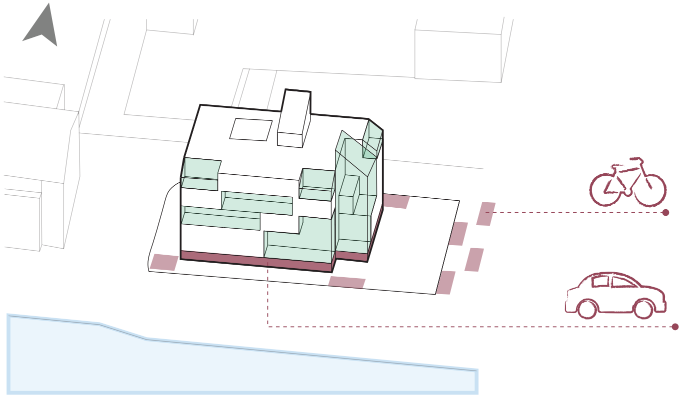
*ill. 133 - North-West elevation - scale 1:200 -* ●

# 9.2 EVALUATION PLANS

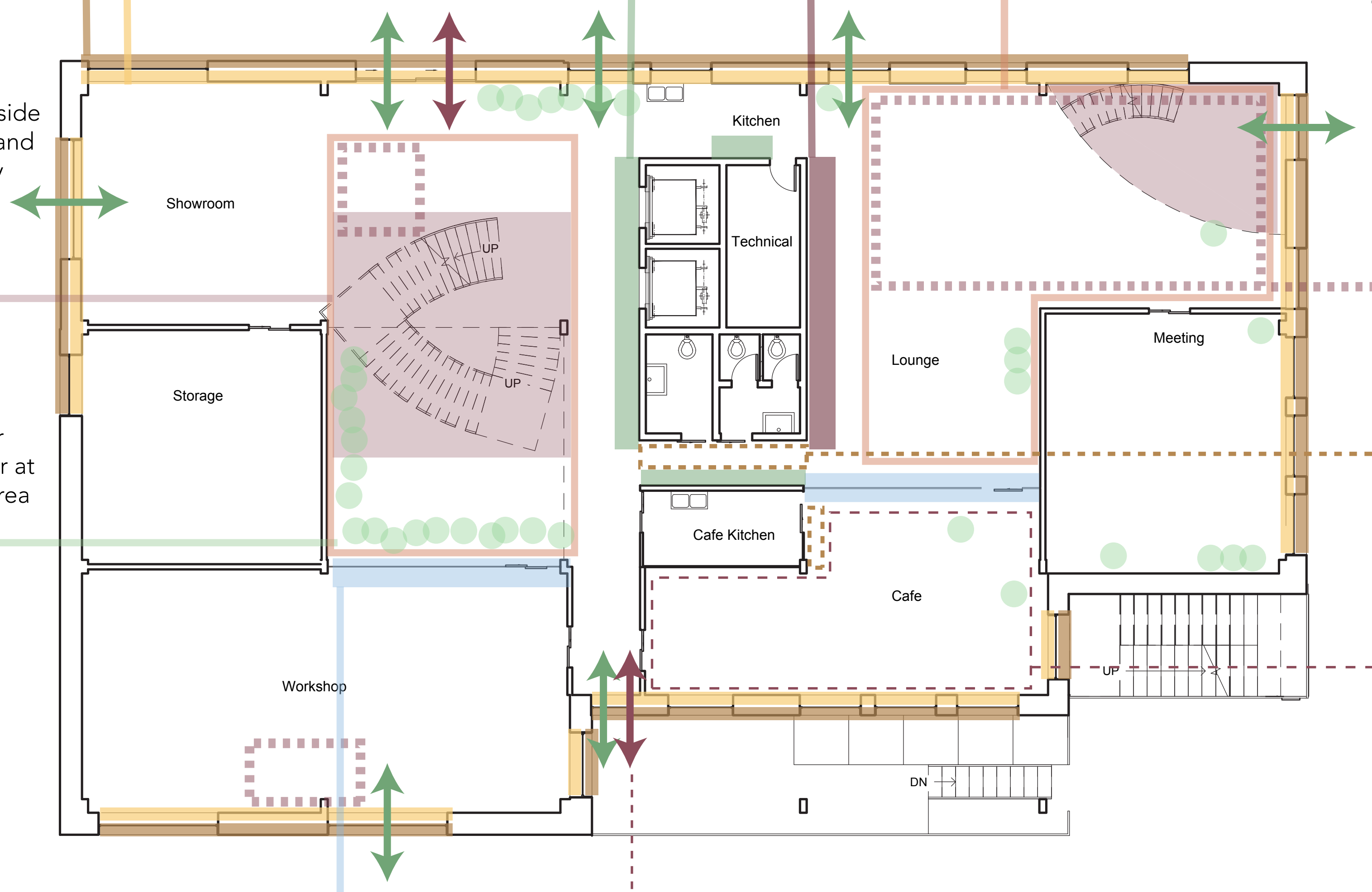
Criterias from the Well Building standards and DGNB have been chosen, according to the project's relevance.
They are part of different certification's sections, some of the main spheres chosen regard views toward the outside, integration of nature and patterns, storage for a comfortable working environment, layout quality and familiarity.

Some of the aspects are quantitative, where it is necessary to reach a minimum requirement to fulfill the criteria. While other aspects are qualitative, so they represent only a qualitative aspect to be integrated.

The heated area of the building is 2347.89sq m, while the gross is 2678.88 sq m.
Parking services are included in the project to increase the mobility comfort of the hub, hosting 80 bicycles and 54 vehicles.
The bike's parking are placed around the perimeter of the building for an easy use, encouraging an active green mobility.
The cars are in the extended basement, according to the local plan and flooding due to climate change, it is accessible from a ramp placed along the West side.



*ill. 134 - Bikes and cars location diagram -*



External shadings to prevent glare

Internal controlled shadings to prevent glare

Environmental elements.
Plant wall covering a wall area equal or greater than 2% of the floor area

Personal locker of 0.1 m³

Visually grouped areas that use the following unifying design components: lighting, furniture color and flooring pattern/color.

75% of the area of all regularly occupied spaces is within 7.5 m of view windows.
75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior.
95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior.

View toward outside for way finding and layout quality

Open stairs

*Hallways.*
*Self-closing doors.*

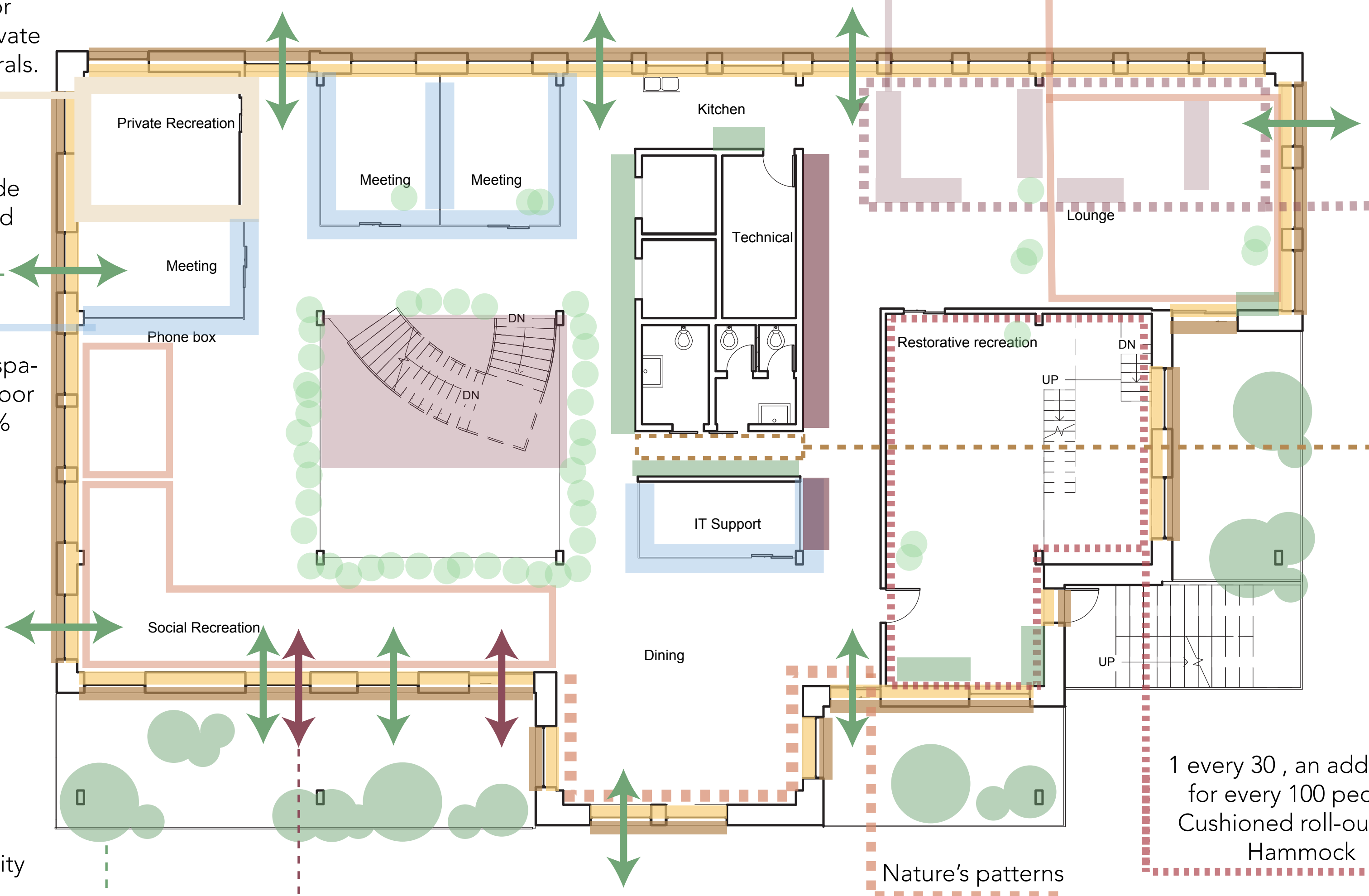
Potted plants or planted beds cover at least 1% of floor area per floor

Additional amenities (cafè)

Proportion of transparent glazing in indoor partitions > 50 %

Link toward outside

*ill. 135 - Ground floor evaluation plan -*



Stress management: qualified counselor offering group or private workshops and referrals.

View toward outside for way finding and layout quality

Proportion of transparent glazing in indoor partitions > 50 %

Direct accessibility to green. Environmental outside elements

Link toward outside

A workstation cabinet at a minimum volume of 0.1 m³ for each regular occupant.

Visually grouped areas that use the following unifying design components: lighting, furniture color and flooring pattern/color.

75% of the area of all regularly occupied spaces is within 7.5 m of view windows.
75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior.
95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior.

*Hallways.*
*Self-closing doors.*

1 every 30 , an additional for every 100 people:
Cushioned roll-out mat
Hammock

Nature's patterns

*ill. 136 - First floor evaluation plan -*

Visually grouped areas that use the following unifying design components: lighting, furniture color and flooring pattern/color.

Nature's patterns

75% of the area of all regularly occupied spaces is within 7.5 m of view windows.
75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior.
95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior.

View toward outside for way finding and layout quality

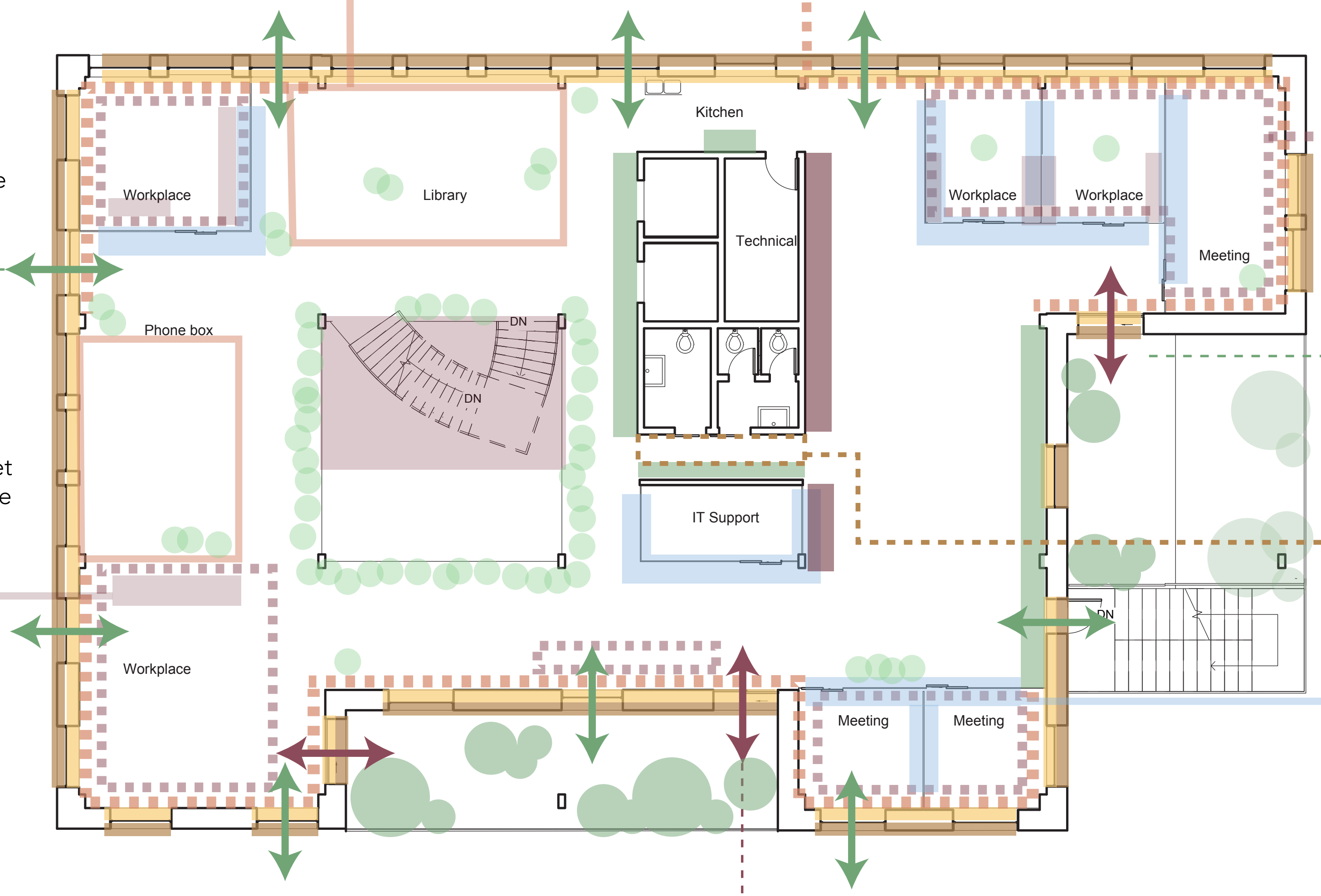
Direct accessibility to green. Environmental outside elements

A workstation cabinet at a minimum volume of 0.1 m³ for each regular occupant.

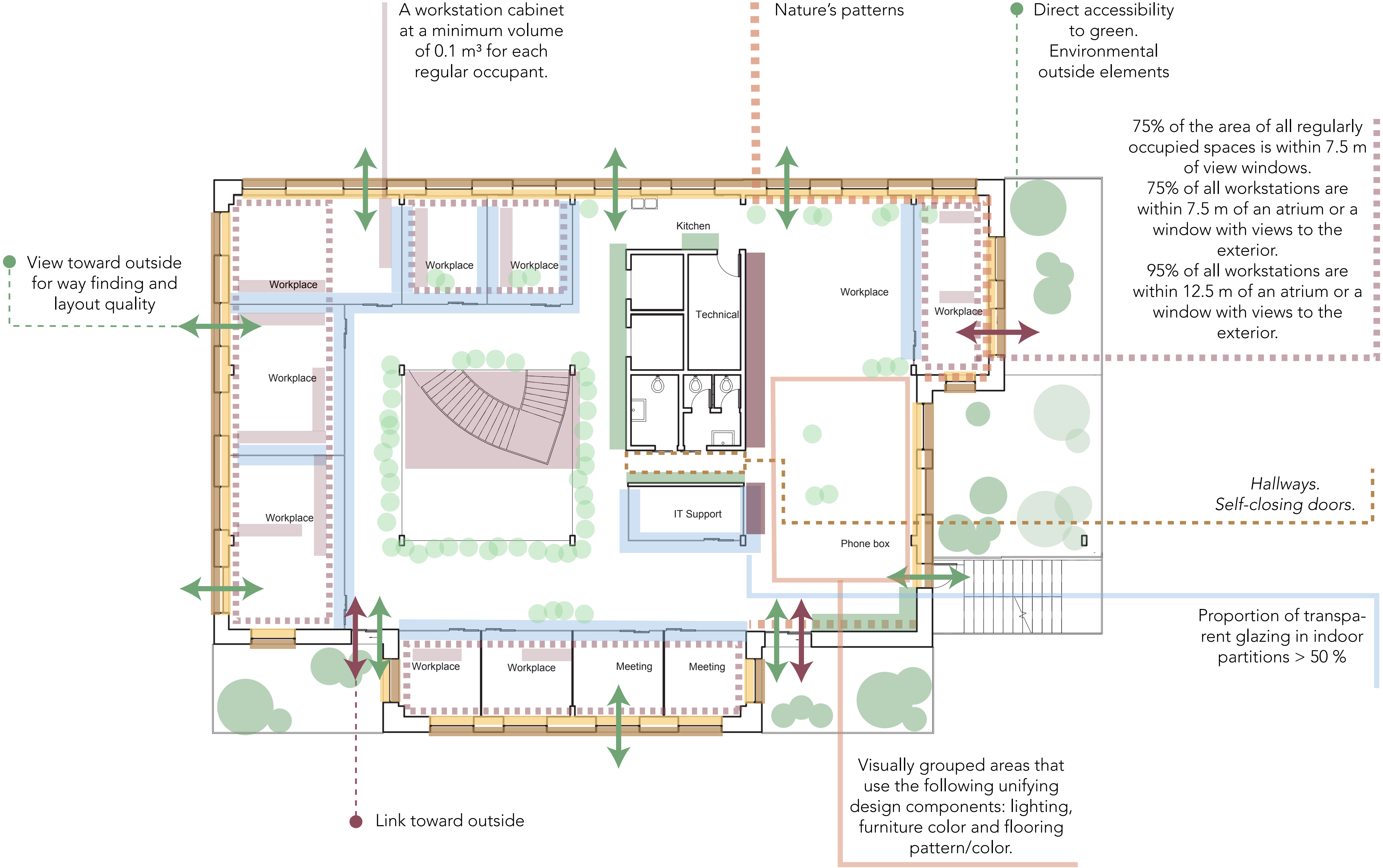
*Hallways. Self-closing doors.*

Proportion of transparent glazing in indoor partitions > 50 %

Link toward outside



*ill. 137 - Second floor evaluation plan -*



A workstation cabinet at a minimum volume of 0.1 m³ for each regular occupant.

Nature's patterns

Direct accessibility to green. Environmental outside elements

75% of the area of all regularly occupied spaces is within 7.5 m of view windows.
75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior.
95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior.

View toward outside for way finding and layout quality

*Hallways.*
*Self-closing doors.*

Proportion of transparent glazing in indoor partitions > 50 %

Visually grouped areas that use the following unifying design components: lighting, furniture color and flooring pattern/color.

Link toward outside

*ill. 138 - Third floor evaluation plan -*

## FULFILLED QUALITATIVE PARAMETERS:

*VIEW WINDOW SHADING and DAYLIGHT MANAGEMENT:*
External shadings to prevent glare

Internal controlled shadings to prevent glare

*NATURE INCORPORATION and NATURE INTERACTION:*

Environmental elements
Within the building.
Within the project boundary, external to the building.

*PATTERN INCORPORATION:*
Nature's patterns throughout the design.

*STRESS MANAGEMENT:*
Qualified counselor offering group or private workshops and referrals.

*SOURCE SEPARATION:*

*Hallways.*
*Self-closing doors.*

*SPATIAL FAMILIARITY:*
Visually grouped areas that use the following unifying design components: lighting, furniture color and flooring pattern/color.

Corridors over 9 m in length end in artwork or a view window to the exterior with a sill height no taller than 0.9 m and with at least a 30 m vista.

*SOC 3.3 (layout quality):*

Communication areas (informal meeting rooms, extended corridor zones, kitchenettes)

Additional amenities

Link toward outside

Open stairs

*BEAUTY AND MINDFUL DESIGN:*

*Celebration of place (industrial materials on facade).*
*Meaningful integration of public art (graffiti towards south site).*

## FULFILLED QUANTITATIVE PARAMETERS:

*LEAST DEPTH:*

75% of the area of all regularly occupied spaces is within 7.5 m of view windows. → 100%

*WINDOW ACCESS:*

75% of all workstations are within 7.5 m of an atrium or a window with views to the exterior. → 100%

95% of all workstations are within 12.5 m of an atrium or a window with views to the exterior. → 100%

*WINDOW SIZES FOR WORKING AND LEARNING SPACES:*

*Window-wall ratio as measured on external elevations is between 20% and 60%* → 33%

*SPACE MANAGEMENT:*

Personal locker of 0.1 m³ — 0.36 m³

A workstation cabinet at a minimum volume of 0.1 m³ for each regular occupant. — 0.45 m³

🟥 *SOC 1.4 (visual comfort):*

View toward outside for way finding and layout quality

9,5 ≥ 4,9
=
1,9 times more

🟥 *SOC 3.3 (layout quality):*

Proportion of transparent glazing in indoor partitions > 50 %

60%

🟥 *ECO2.1 (flexibility):*

Space efficiency:
S eff = UA / GFA
(usable and gross area).
Pathways must be at least 80 cm wide.

S eff ≥ 0,75
=
S eff = 0,86

1.3 cm wide minimum

🟫 *WORKPLACE SLEEP SUPPORT:*

1 every 30 , an additional for every 100 people

several in the building:
couch
in restorative room:
5 cushioned roll-out mat
2 fully reclining chair
1 hammock

🟫 *OUTDOOR BIOPHILIA:*

At least 25% of the project site area meets the following requirements:
a. Features either landscaped grounds or rooftop gardens accessible to building occupants.
b. Consists of, at minimum, 70% plantings including tree canopies (within the 25%).

29,4 %

79 %

🟫 *INDOOR BIOPHILIA:*

Potted plants or planted beds cover at least 1% of floor area per floor.

Ground floor: 2,5%
First floor: 2,6%
Second floor: 3,2%
Third floor: 4%

Plant wall covering a wall area equal or greater than 2% of the floor area.

Ground floor: 7%
First floor: 6,3%
Second floor: 7,3%
Third floor: 6,4%

⬜ Criteria not shown in the plans
🟫 Well Building standards
🟥 DGNB

ill. 139 - Visualization of the entrance -

*ill. 140 - Visualization of the third floor -*

ill. 141 - Visualization of lounge of the ground floor -

# 9.3 MAPPING

### 9.3.1 Hierarchy of walls

The walls can be divided into three categories, depending on the possibility of displacing them.
Thus, the external envelope and the service core (violet) are fixed, as well as the storage unit.

The vision is to give different opportunities to the users per each floor, thus, some walls can open up (yellow) on the ground and first floors, allowing flexibility of the space, depending on the usage.

The strategy is implemented in the lounge area to enable promotional events. While upper floors assigned to the Startups are divided by glazed walls (blue), to assure internal views and allowing the daylight to penetrate.

The company on the second floor is equipped with minor partitions, to encourage the initial discussions that may take place among small Startup that might seek to expand.
The last floor is dedicated to a company which is more established than the one on the second floor, thus, more walls are provided to guarantee more privacy to the material produced.

*ill. 142 - Hierarchy of walls diagrams, ground floor, first floor, second floor and third floor respectively -*

### 9.3.2 Material catalogue

The interior project palette is composed mainly by natural colours of light brown shades.
Untreated oak, cork and hemp, revealing their porosity and texture are directly in contact with the user's sight. The pattern follows fractal guidelines using squares in different sizes. On one hand they help to relax, while providing the possibility of minimize the wastage of material.

The green of the plants is used as an alternative material and colour, often adjacent to the wood, recalling a natural environment, aspect that help in stress alleviation. Plants are used in two different ways, as a compact stress alleviating element mounted on all the wall's height, or in pots hung to the wall, where herbs for the kitchens can be planted to stimulate olfactory and gustatory senses.

Colours on textile grains are chosen based on the perception that the user should be exposed to; for example yellow (a welcoming colour) is combined to blue, for the complementary colours to stand out. Colors are opted in areas such as the telephone rooms and common areas where people seek a distraction from the work environment.

*- Oak fractal patterns, based on square grid -* *- Fractal cork -* *- Green wall -* *- Kitchen's plants -* *- Glass -*

*- Oak pattern -* *- Oak plain -* *- Hemp -* *- Yellow and orange textiles in diverse grains -* *- Matte blue partition -*

*ill. 143 - Material catalogue -*

ill. 144 - Visualization of workplace third floor -

### 9.3.3 Material map

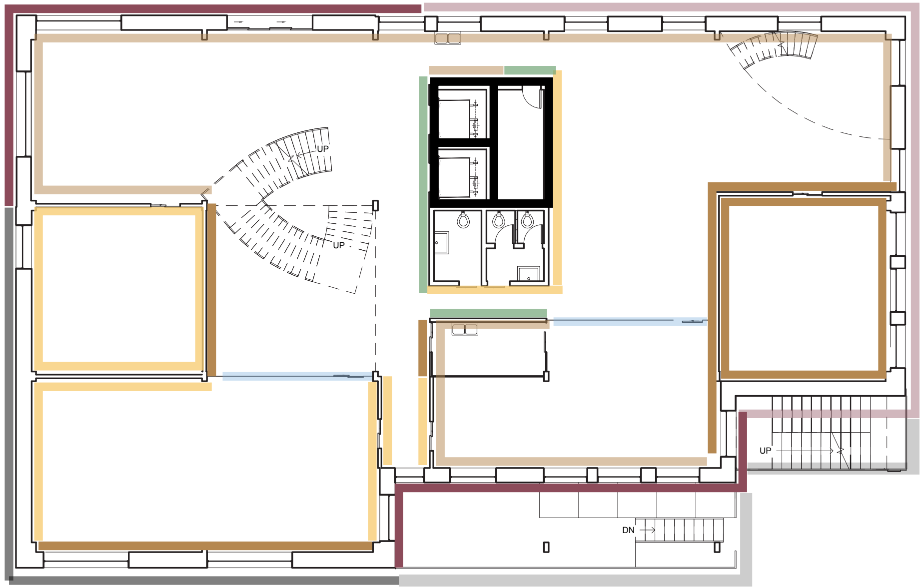
Materials are consciously allocated on the internal cladding following acoustics considerations, level of stimulation that the user should be exposed to, Well Building standard and DGNB; in addition to considering light reflection and demarking the areas. The perceptive and aesthetic attributes of the materials are also accounted in the material application.

External cladding is chosen based on the intent of portraying youth using technological component as Photovoltaic included. In addition the use of metal and concrete attempt to connect with the context while hemp is used to indicate the interior restorative function.

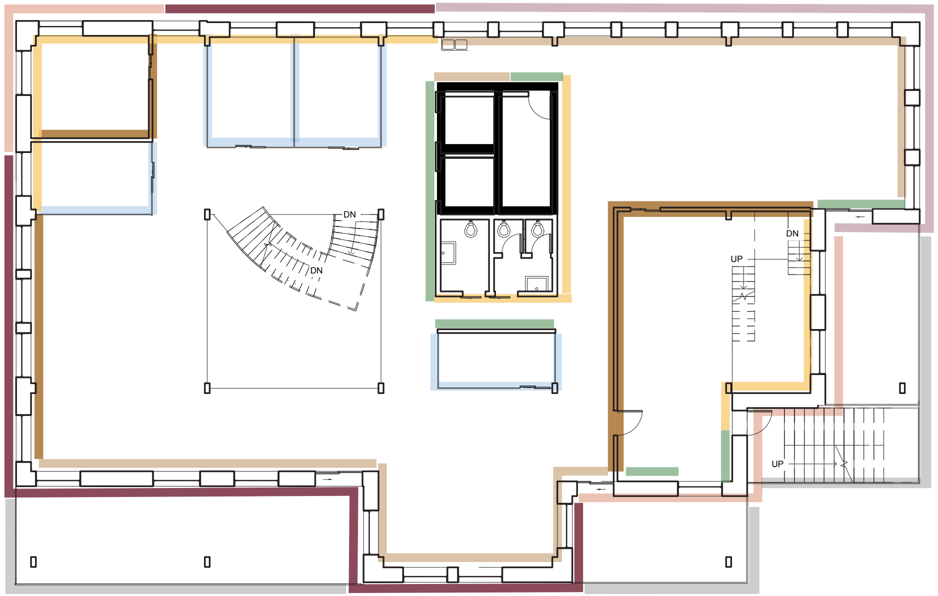
Wall plants are located on the service wall, creating a consistent element of wayfinding for all the upper levels. Aromatic herbs and plants grow in planters hanging on the walls of the kitchens, contributing to a multi sensory experience.

Acoustics is calculated for two crucial spaces, meeting room on the ground floor and the large restorative room, assimilating the spaces to a conference rooms, with reverberation time of 0.6 seconds, according to Well Building standards (Annex 9).

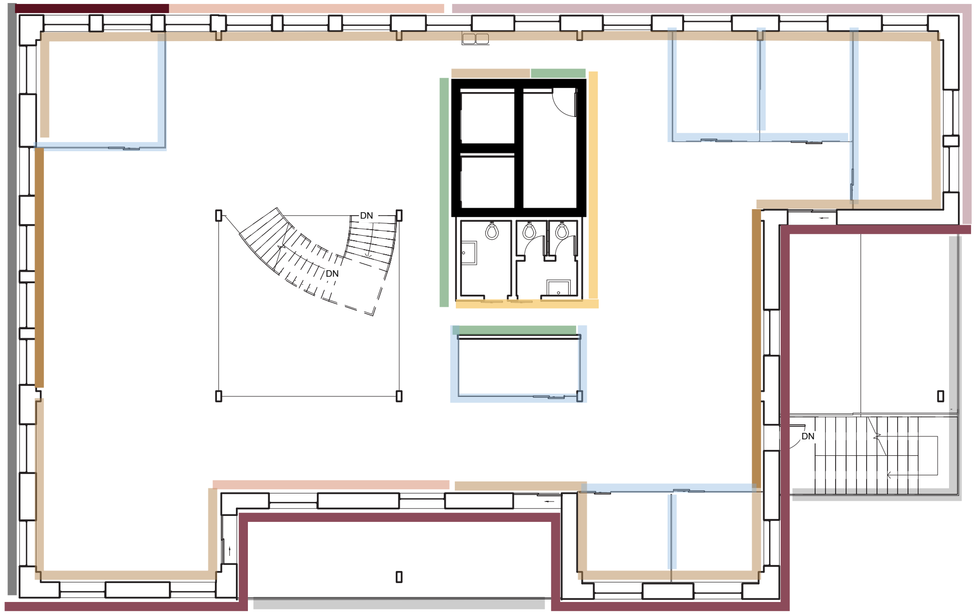
Cork panels are chosen because of the sound absorption properties, since the textured niches help to dissipate sound; especially for the common areas. The panels are implemented in specific areas that anticipate more people and thus noise.



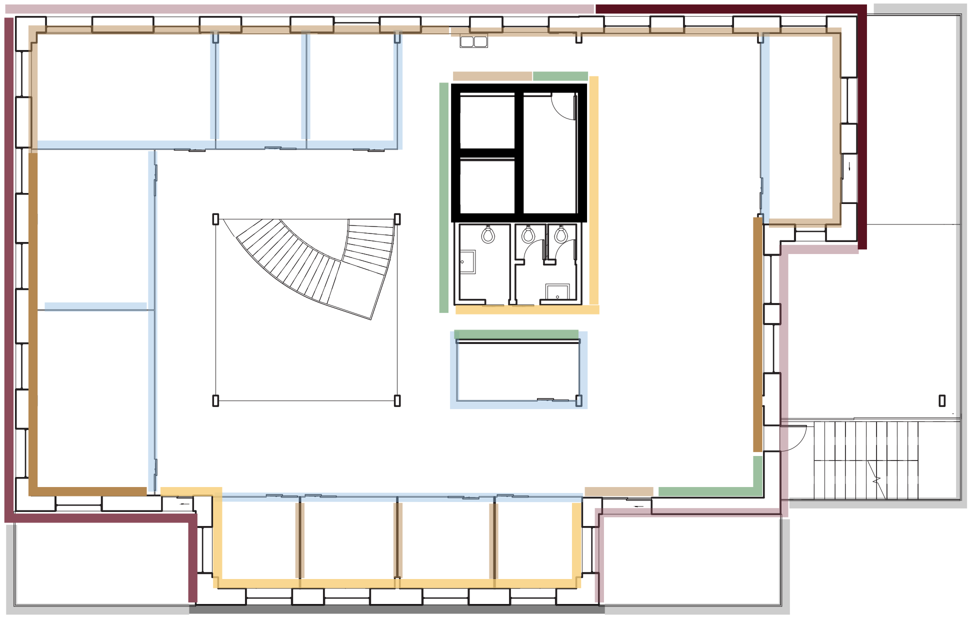
ill. 145 - Material map diagram, ground floor -



ill. 146 - Material map diagram, first floor -



ill. 147 - Material map diagram, second floor -



ill. 148 - Material map diagram, third floor -

EXTERIOR:

- ▬ Wood type 1
- ▬ Wood type 2
- ▬ Metal
- ▬ Transparent PVs
- ▬ PVs cladding

INTERIOR:

- ▬ Concrete
- ▬ Cork
- ▬ Wooden pattern/fractal
- ▬ Plants
- ▬ Oak cladding
- ▬ Glass
- ▬ Hemp

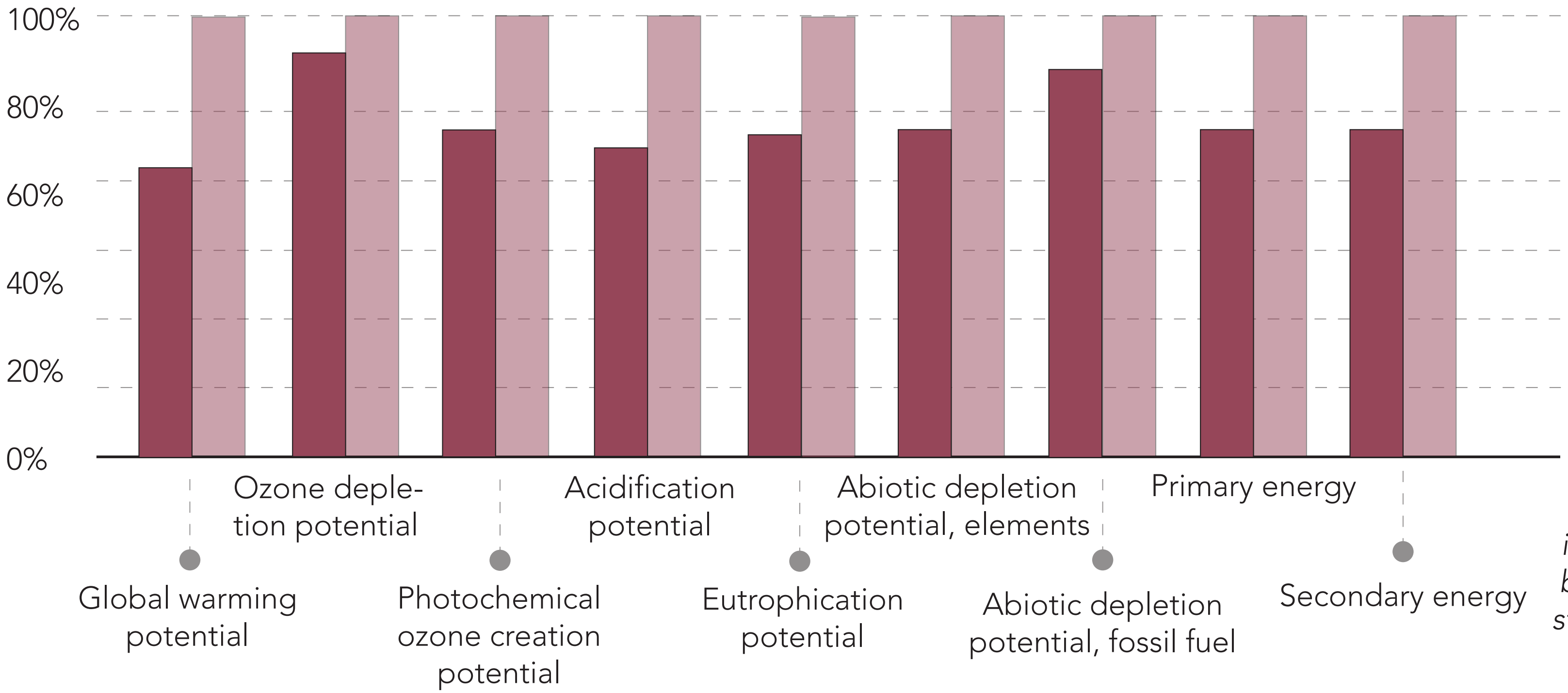
# 9.4 LCA

In order to compare and confirm our assumption of the project being less harmful to the environment in comparison with an industrial material construction such as concrete, with the same specifications; the constructions were analysed in LCAbyg.

In the comparison, some specifications calculated remained the same, due to the components present in both buildings such as the operational energy consumption, concrete foundation, elevators, windows, the floor heating and vapor barrier. However, the structure, facade and internal components of the project were calculated from the process design, the comparison was detailed with the final design and its concrete construction counterpart.

The quantity of the insulation in the concrete building was calculated according to 0.08 W/m2K U value, while the quantity of concrete for the structure was equivalent to the Cross laminated timber structure in the project.

Since buildings cause high CO2 emissions through their lifetime, the analysis focuses on Global Warming Potential of the two buildings, where the project has approximately 37% less emissions than the concrete construction.
The difference is due to the nature of materials, for instance the concrete construction has also steel incorporated to guarantee traction properties to the structure.

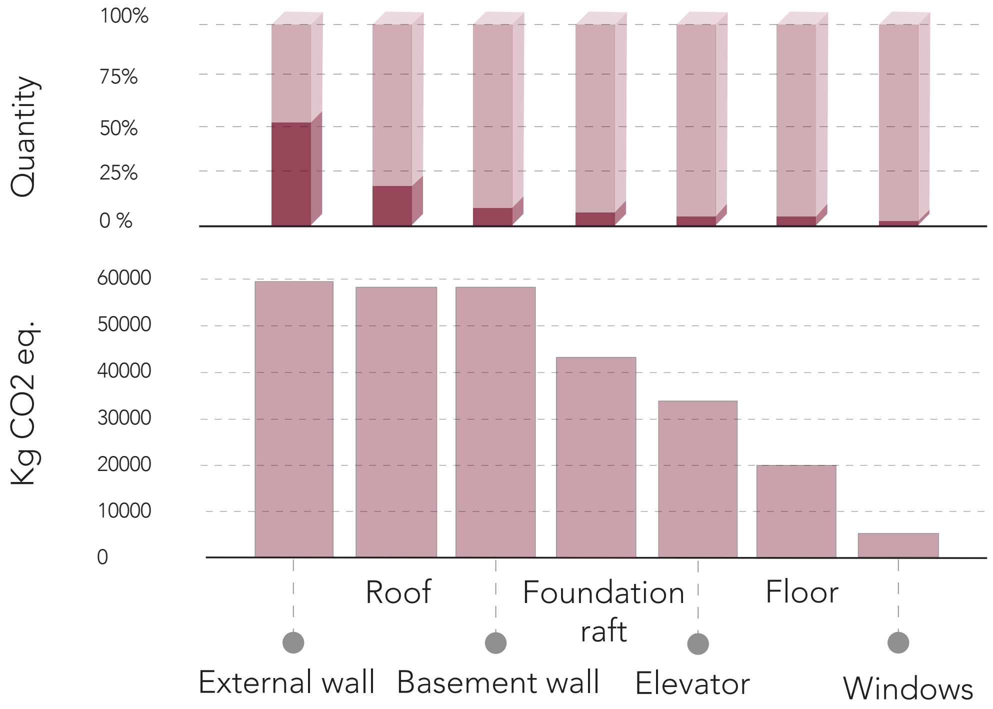


*ill. 149 - Comparison of project building (dark violet) with industrial (light violet), which is set at 100% of the graph -*

Further, in case of industrial building, external walls comprising of concrete blocks, insulation, concrete floor and roof have an higher impact in their overall. Reason why the materials for the project have been carefully chosen based on their CO2 emissions and performance.

With project focus on the environment, the issue is addressed in assuming that the wood used in construction is responsibly sourced according to DGNB standards.

It is interesting to notice the comparison of the CO2 emissions of each component and the quantity of material used in the building, without considering the structure.
For instance, in the life cycle assessment of the project, the elevators have the highest CO2 impact on the environment in proportion to the amount used in the construction, in fact they represent only 4,8 % of the total. The high result is due to the intensive use of resources in manufacturing and on the material used.

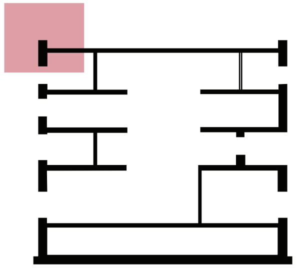


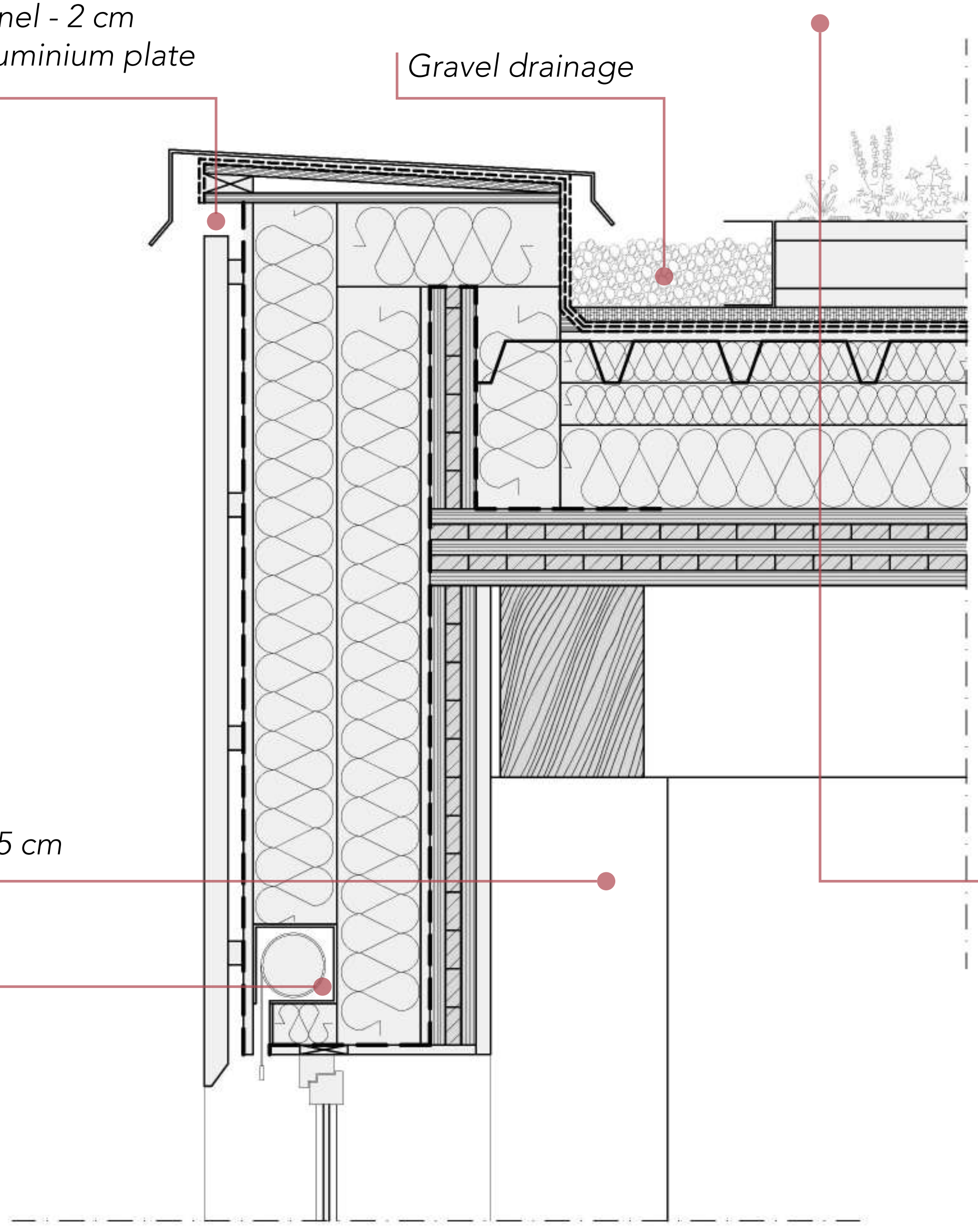
*ill. 150 - Quantities and CO2 emissions of the building's components -*

*ill. 151 - Visualization of dynamic recreation, dining open room and atrium -*

ill. 152 - Visualization of workplace third floor, North side -

# 9.5 CONSTRUCTION DETAILS





Cover - 8 cm:
Wooden panel - 2 cm
Wooden baton - 4 cm
Wooden panel - 2 cm
Covering aluminium plate

Gravel drainage

Wall - 59 cm:
Cork panel - 3 cm
CLT element - 9 cm
Vapour membrane
Plywood panel - 2 cm
Cotton insulation - 35 cm
Plywood panel - 2 cm
Wind membrane
Vacuum - 3 cm
Wooden listels for cladding - 5 cm

External screening system

Roof - 74 cm:
Natural soil - 4 cm
Filter fabric
Substrate - 10 cm
Moisture retantion layer
Water absorbing layer - 4 cm
Root protection
Drainage board - 3 cm
Asphalt layer
Double waterproof membranes
Plywood panel - 2 cm
Cotton insulation - 35 cm
CLT element - 16 cm

ill. 153 - Roof detail, scale 1:10 -

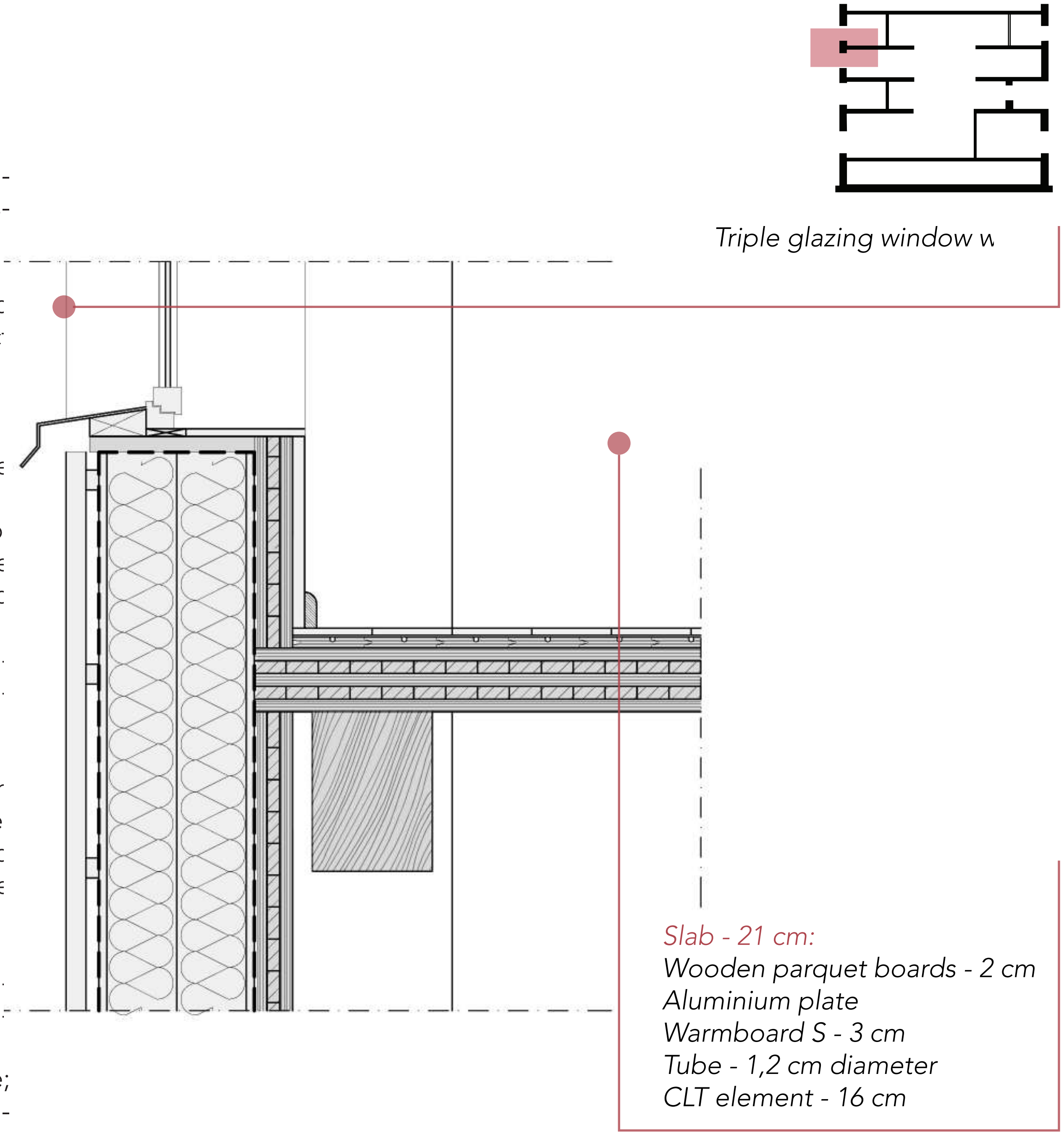
The construction details represent the synthesis of the process, material choice considering construction and the assembly.

CLT is the main material, which is used for the structure anc for the visible elements. The user will be in direct contac with the natural materials, as cork or wood, stimulating the tactile perception.

In some parts of the roof hardy succulent sedum plants are integrated.
Floor heating is part of the slab with parquet planks on top a pleasant material to touch and walk on. The choice of the heating system is due to the intent of saving space anc more effective heating.
The windows recess 20 cm from the facade surface; a measure that has been tested in connection to the indoor environment on BSim.

The insulation is the result of LCA studies, in using cottor that has not only a better performance concerning U-value but least contribution to the Global warming. Beams anc columns on the terraces are insulated to avoid excessive cold bridges.

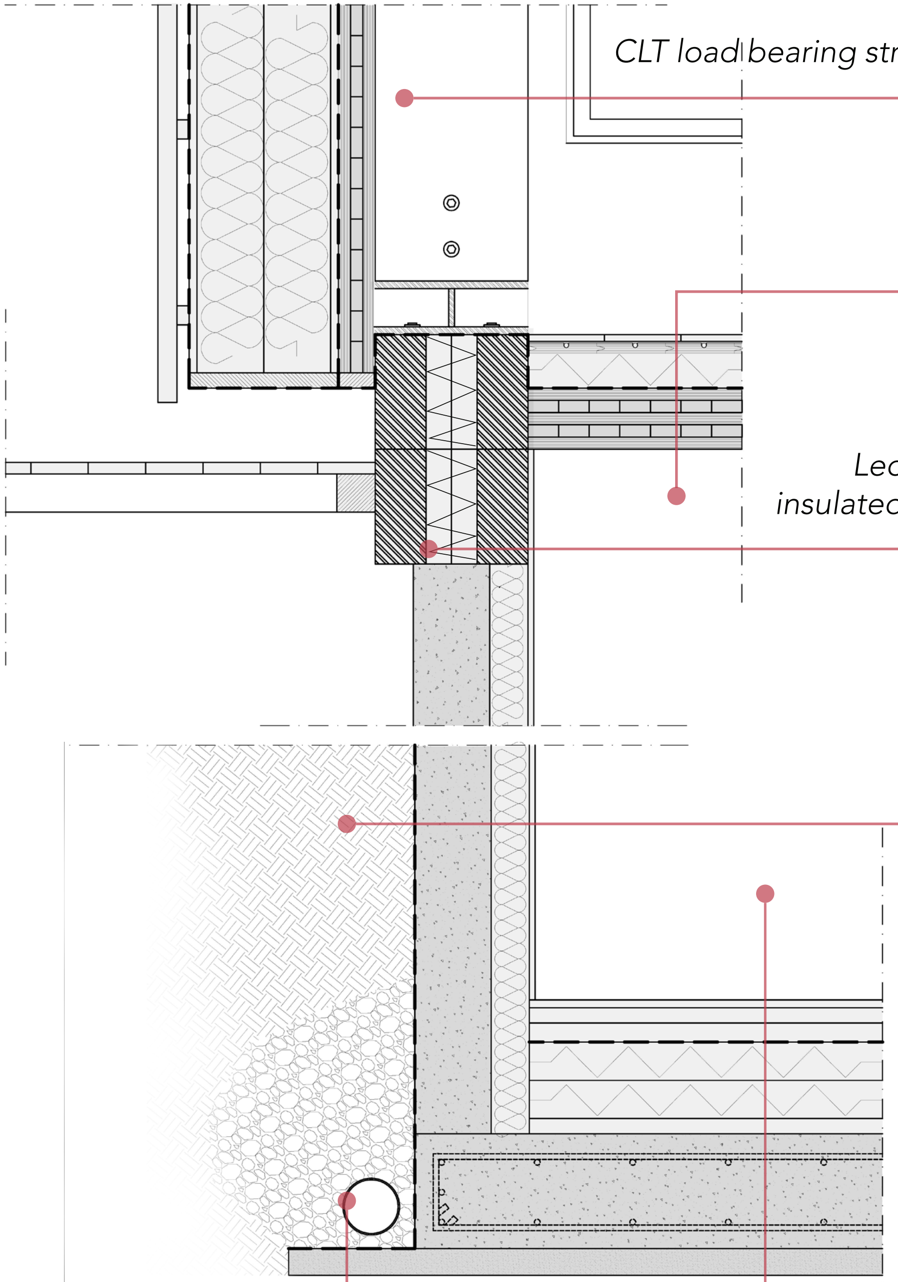
The wooden lamellas are connected with a horizontal substructure, wind and vapour membranes are added to protect the stratigraphy.
The raft with retaining basement wall is made of concrete; a durable material which is separated from the CLT structure by high insulated elements with structural properties.



*Triple glazing window w*

*Slab - 21 cm:*
*Wooden parquet boards - 2 cm*
*Aluminium plate*
*Warmboard S - 3 cm*
*Tube - 1,2 cm diameter*
*CLT element - 16 cm*

*ill. 154 - Slab and wall joint detail, scale 1:10* -



Slab - 30 cm
CLT element - 16 cm
Radon protective membrane
Rigid insulation - 9 cm
Tube - 1,2 cm diameter
Warmboard S - 3 cm
Aluminium plate
Wooden parquet boards - 2 cm

CLT load bearing structure

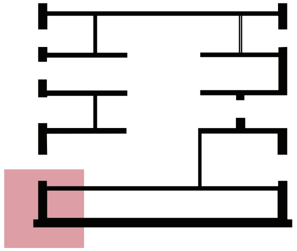
Leca high insulated block

Foundation wall - 31,5 cm:
Water proof membrane
Concrete element - 20 cm
Cotton insulation - 10 cm
Finishing board - 1,5 cm

Foundation slab - 71 cm:
Pavement - 2 cm
Lightweight concrete - 4 cm
Concrete screed - 5 cm
Vapour membrane
Rigid insulation - 20 cm
Sand layer - 4 cm
Foundation plate - 30 cm
Foundation element - 10 cm

Drainage pipe

ill. 155 - Foundation and ground floor slab detail, scale 1:10 -



# 9.6 ENERGY CONSUMPTION: BE18

Be18 has been used to calculate the energy consumption of the building, after reaching the Energy frame, green energy has been added to fulfill the Zero energy standard (Annex 7).

All the input such as area, U-values, orientation, heat loss, g-value for windows, overhangs have been inserted. Some of the values have been simulated also in BSim to have a better overview of the indoor environment.

The technical details of the project construction were added in be18 as the design evolved; and the sbi guide was consulted to implement values according to the software's interpretation of the project. The building's operational hours greatly affect the energy consumption, along with the line loss of the foundation and windows.

The design and number of windows were implemented according to daylight study conducted in velux for 7 x 7 m grid and effectiveness due to sill height. The energy study further guided to change the windows from multiple small to large single windows, and choosing high sill height for daylight effectiveness.

Opting from automatic daylight control to continuous automatic daylight control indicated more energy efficiency in the project. Also the change in mechanical ventilation system from variant to a constant ventilation rate indicated efficiency, which in turn was implemented in bsim ventilation system for recreation room and workspace.

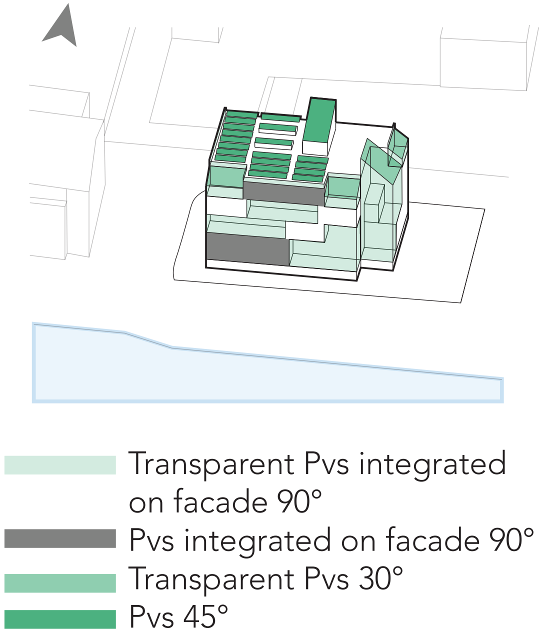
ill. 156 - Visualization of the Startup hub from South -

# 9.7 PHOTOVOLTAIC PANELS

The terraces created on every floor were intended to imbibe plants and their accessibility to the users for alleviating stress. To promote its use the concept is to shelter the terraces from southwest winds while maintaining the view, transparent photovoltaic cells were included since the initial design phase.

Due to prior knowledge of 45 degrees solar cells performing most efficiently towards south, the terrace roofs were tested with the angle. However, due to the angle and the less width of the terraces (approximately 3 m), a considerable portion of the terrace did not have clear height and rendered in inaccessible.
Thus, the roofs were turned to a lower angle to accomodate more usable terrace area, even as it lowered the energy efficiency. Moreover, due to the design focused more on the environment than economy (see illustration 5); thin films were considered for the design due to their low embodied energy and environmental impact (thin films have 67 while monocrystalline has 242 kg CO2 per m2).

The total energy demand was calculated based on the area of the design and number of users. The roof was intended to be completely a green roof with photovoltaic only on the atrium skylight. However, due to the project size and commercial consumption of energy, the energy generated by the mentioned areas were not sufficient even after changing solar cells from thin films to mono crystalline. Thus, the facade material on the west and south was changed from corrugated metal to solar cells, to retain some part of green roof (Annex 7).



*ill. 157 - Pvs location diagram -*

ill. 158 - Visualization of the Startup hub from North-East -

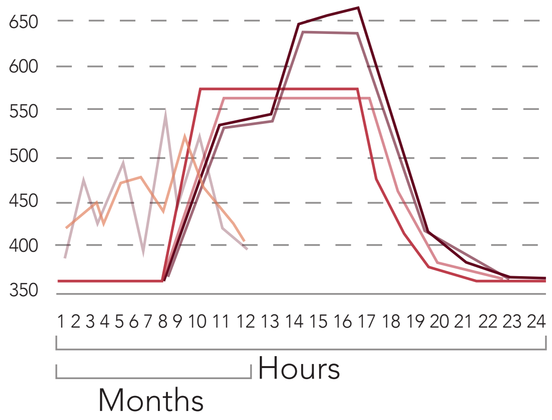
# 9.8 INDOOR ENVIRONMENT: BSIM

The indoor operative temperature was aimed to comply with the standard EN 15251 for category II; with temperatures for workplace and recreation to have 20 degree C minimum heating in winter and 26 degree C maximum temperature for in summer.
Category II was chosen as an ambition for the indoor environment standard since it comprises of a normal expected standard for new buildings. The screen shadings are adopted for all the openings, because of their high performance, compared to other shading.

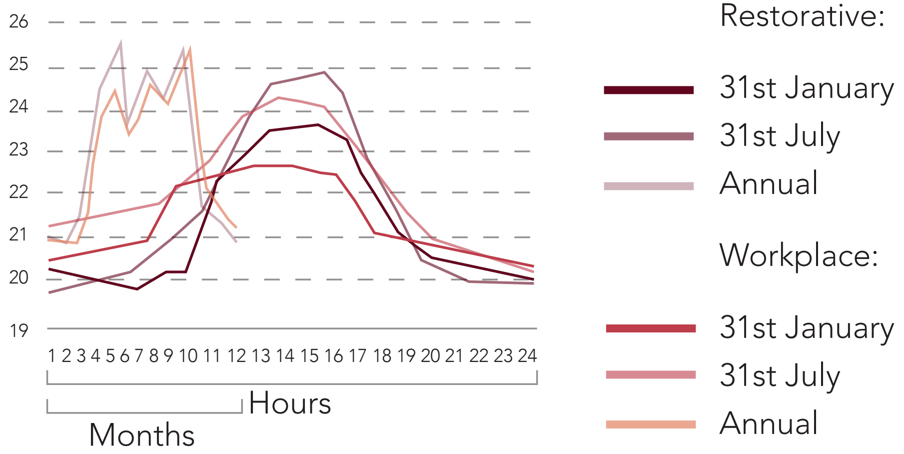
The necessary ventilation for all the rooms in the project were calculated to determine the required air change rate. Since two rooms- workplace and recreation were simulated in BSim, the values from the ventilation table were referred indicating 1.5 l/s per sq m; along with the standard of energy consumption guide (Best practice programme, 2000), which specifies 4 l/s per square m to be ideal in workspaces.
The opening size of the window is set as the result of the process, 0.5 for the workplace and 0.3 for the recreation.

Further, the CO2 levels were aimed at 500 ppm above outdoor CO2 levels, to fulfill Category II standards. Cumulatively observed, the sharp peaks and fluctuation in the ventilation, temperature and CO2 in addition to the indicative scope of values are undesirable especially due to high energy consumption required for regulation.

For instance, if the ventilation system does not operate in the non working hours, it leads to a large leap and decline in CO2 levels; practically resulting in high energy input. Through the simulation process, the intent was to have efficient flow of values within the scope of discussed standards.



*ill. 159 - CO2 -*



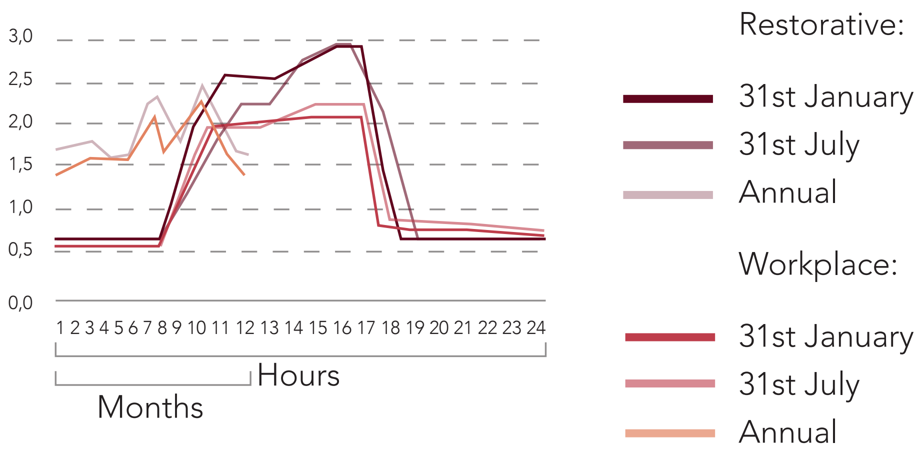
*ill. 160 - Temperature -*

In the lighting system for instance, the general lighting level was 400 lux for the workplace and 200 lux for recreation; with task light of 0.06 kW and the maximum temperature for light control as 28 degree celsius. For the system people, the workplace has 2 people and recreation has 5 people of normal activity level; with calculated heat generation, moisture and CO2 level. The venting system active in summer months addresses the natural ventilation (single sided) with the maximum air change as 4 (Best practice programme, 2000), and venting set point at 23 degree celsius.

The inlet air for the ventilation during Winter is set at 22 degrees celsius, while during Summer at 18 degrees celsius, number that has been lowered due to the overheating in Summer especially for the recreation room. The recess of the windows is at 0.2 m from the outside level, compromise between the BSim process studies and functionality.

For the ventilation system, the supply inlet air flow was derived from the ventilation chart values (Qtotal) into m3 /s units; with values in prime operative hours for workplace as 0.05 m3/s and recreation as 0.03 m3/s. The total efficiency value of 0.7 is taken for medium size fan of 10 kW power. With different schedules for ventilation operation in winter working, non working, the values of supply air vary.

Since the project design imbibes floor heating, the system in BSim has the automatic switcher enabled, with the room temperature intended to be 22 degree celsius. The maximum water temperature is 40 degree celsius with minimum and maximum outdoor temperature to be -5 and 15 degree celsius.



*ill. 161 - Air change -*

# 9.9 REFLECTION

The project attained a considerable level concerning the integration of architectural and engineering aspects, since materials were chosen for human perception and related characteristics, but also for technical considerations. The extensive research addressed the thesis topic and formed a sound knowledge base even about related areas, resulting in conscious decisions for most design components.

The substantial theory can also be a database for awareness in design considerations. The use of technical tools and calculations to design sustainably has been implemented since initial design stages. For instance, Life Cycle Assessment calculations have been integrated from the initial material selections; for instance opting for cotton, highly performant, from other insulation material such as cork and sand. Moreover, the glazing was implemented after calculating daylight for a single grid, and designing the same into the project. Further, Be18 was used to test volumes following the volume study to guide the design to be energy efficient.

However, conclusive part of the project is the critical concerning the process and what could have been studied or researched more. For instance, since the beginning one of the main design criteria was the flexibility of space. However it has not been analysed enough in depth, moveable panels have been considered for some areas as the hierarchy of walls shows. Further, even though multiple design criteria were addressed from well building and DGNB standards, the project did not attempt to fulfill all criteria primarily due to limited time, design concept specific to the project and execution criteria of the standards. For instance, the project assumes the use of responsibly procured construction material as indicated in DGNB.

The focus of the project is the interior actualization- thus materials that have been associated to perceptions and performance, led to analyse and detail the interior. More thorough attempts on exploring exterior material and related systems could have been elaborated. However, the approach of the North and West of the site is more formal compared to the South and East; where the green house terraces and vegetation break the regularity of the spaces.
The integration of solar cells on terrace envelopes were among the initial design concept as an integrated technical and architectural solution. In addition to generating energy, the panels are a visually permeable response to the fjord and the context, extending the interiors to the outside with semi- indoor biophilia and gathering spaces. The terraces shelter and create approachability to view the fjord and view to Aalborg which would otherwise be rendered uninhabitable most of the year due to South Western winds.

The project focus is the wellbeing of users; thus more thermal zones could have been detailed and simulated to ensure comfortable the indoor environmental conditions. However, the rooms analysed are the most critical zones due to high potential of indoor environment problems such as overheating due to their location on the South facade. The assumption is that the other work zones would have comparatively less challenges.

The aspect of odour in the project could also have been detailed with calculations based on experienced pollution load and material emissions, and implemented with ventilation.

Initially, the idea was to implement the entire roof with greens, allowing people to grow their own food and enhancing the outdoor biophilia. However, due to the high energy consumption, the green roof has been reduced. On the other hand, terraced flowers and spots where the users can grow plants has been created on the ground level. Moreover, the project has exceeded the green cover criteria for indoor and outdoor according to the Well Building Standards.

The basement was implemented to raise the building due to its vicinity to water and future flooding threat due to climate change. The basement lighting has not been detailed, with the intention of raising the basement level for utilising daylight. Further, the construction material for the basement was chosen as concrete, due to structural, life cycle and water resistant considerations. However, since the thesis focuses on materials, an alternative material for the same could have been explored and implemented.

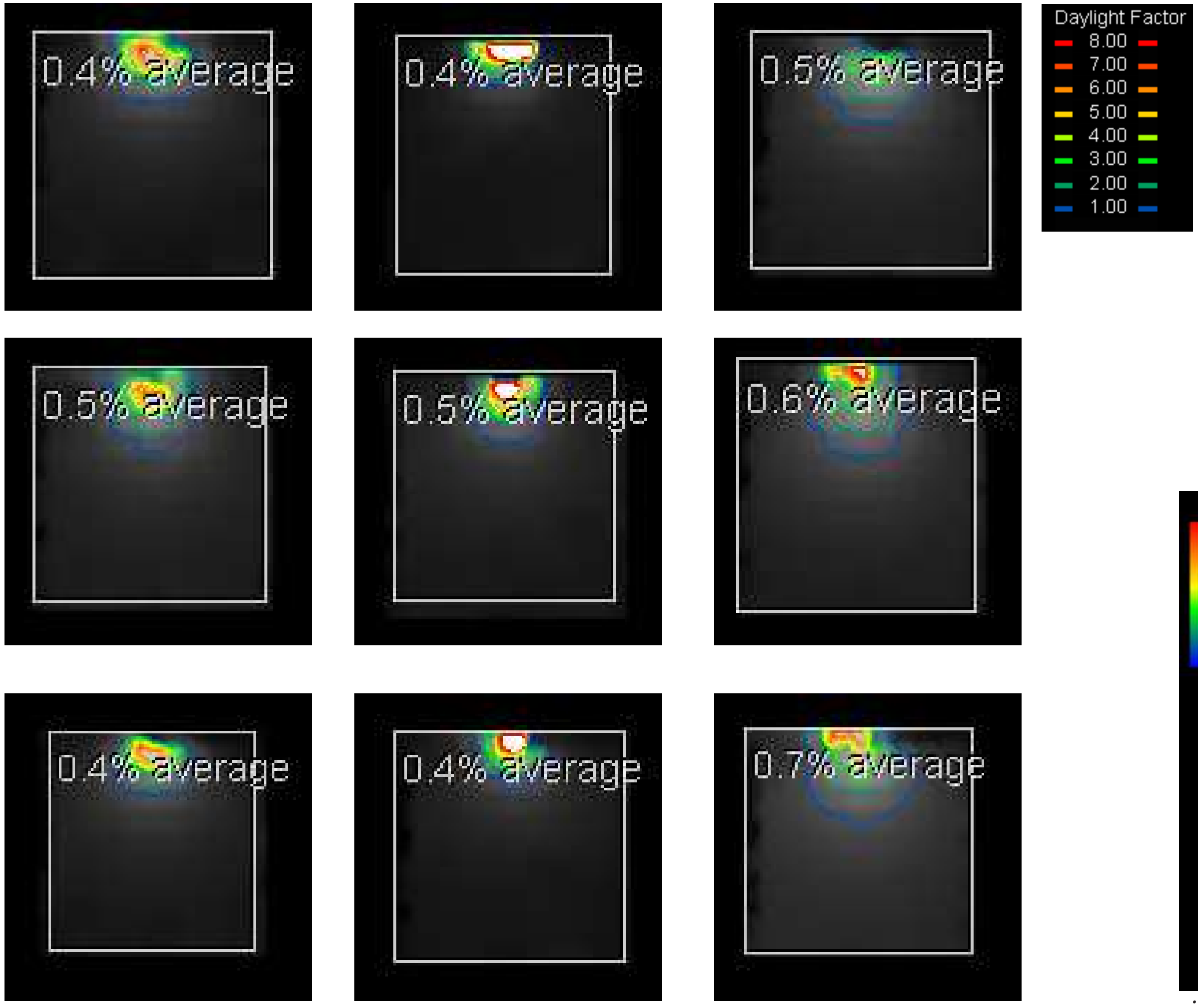
In conclusion, the project succeeded in selecting and fulfilling a variety of design and technical criteria relevant to the concept, from different standards and collating them into a feasible solution. More so, the standards were deeply integrated with the concept of stress alleviation with aspects of natural material usage, patterns and colors. Thus, the project quantified the stress alleviation measures as well.

# 10| ANNEX

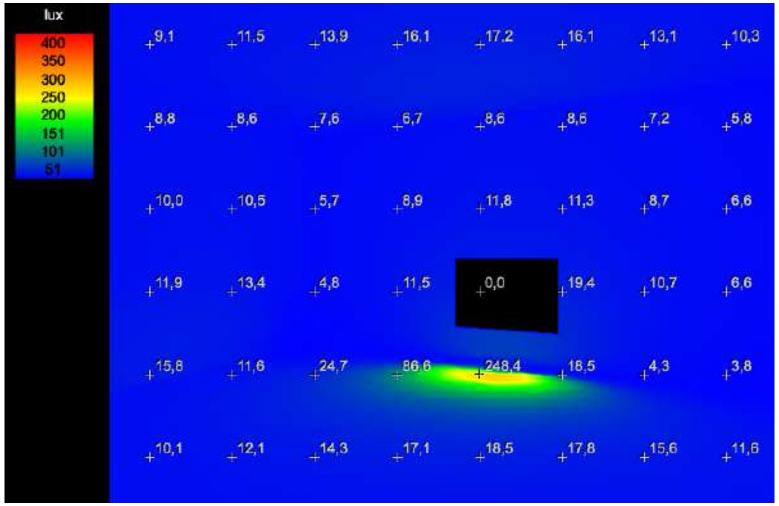
# 10.1 ANNEX 1

## VELUX:

### Window height and orientation



ill. 162 - Horizontal (first row), vertical (second row) and square (third row) window's orientation -

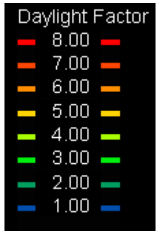


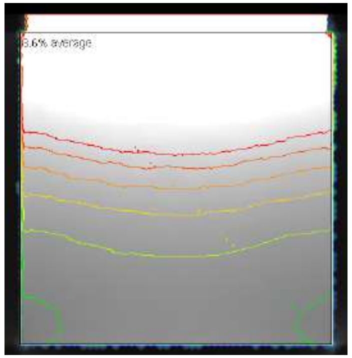
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9,1 | 11,5 | 13,9 | 16,1 | 17,2 | 16,1 | 13,1 | 10,3 |
| 8,8 | 8,6 | 7,6 | 6,7 | 8,6 | 8,6 | 7,2 | 5,8 |
| 10,0 | 10,5 | 5,7 | 8,9 | 11,8 | 11,3 | 8,7 | 6,6 |
| 11,9 | 13,4 | 4,8 | 11,5 | 0,0 | 19,4 | 10,7 | 6,6 |
| 15,8 | 11,6 | 24,7 | 86,6 | 248,4 | 18,5 | 4,3 | 3,8 |
| 10,1 | 12,1 | 14,3 | 17,1 | 18,5 | 17,8 | 15,6 | 11,6 |

ill. 163 - Lux values for the horizontal window at 0,5 m height -

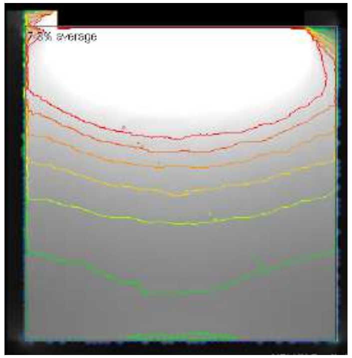
## The 7x7 grid

The process of finding the appropriate opening area started from a big opening of 15 sqm. The dimension has been reduced until 7,5 sqm, which showed to be not sufficient for the 5% daylight aim. Same system for the other opening options.

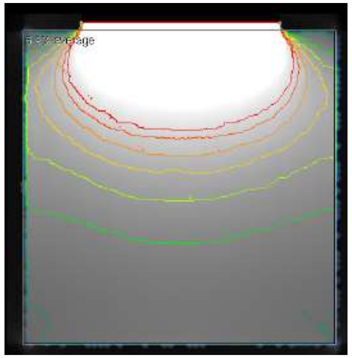




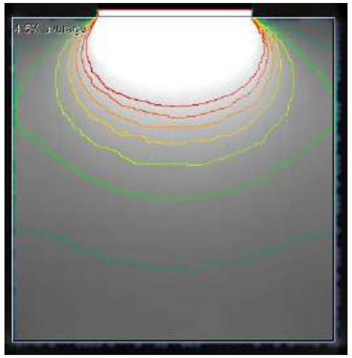
ill. 164 - 1 opening of 15 sqm -



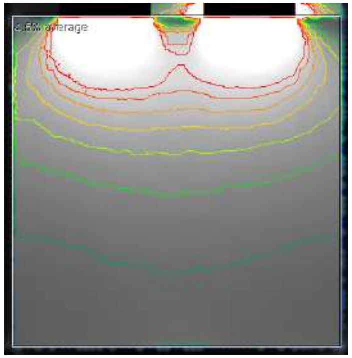
ill. 165 - 1 opening of 12,5 sq



ill. 166 - 1 opening of 10 sqm -

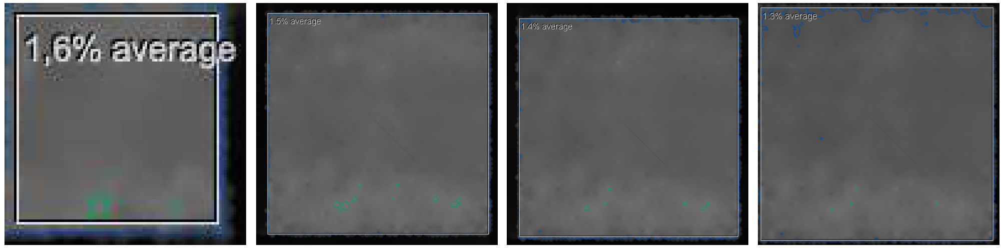


ill. 167 - 1 opening of 7,5 sqm -

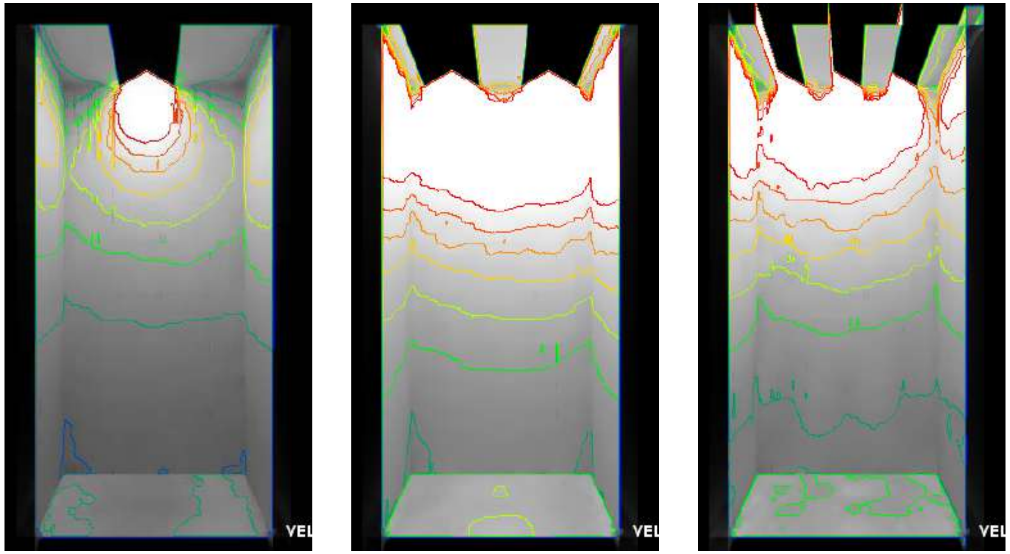


ill. 168 - 2 opening of 8,75 sqm -

## Atrium



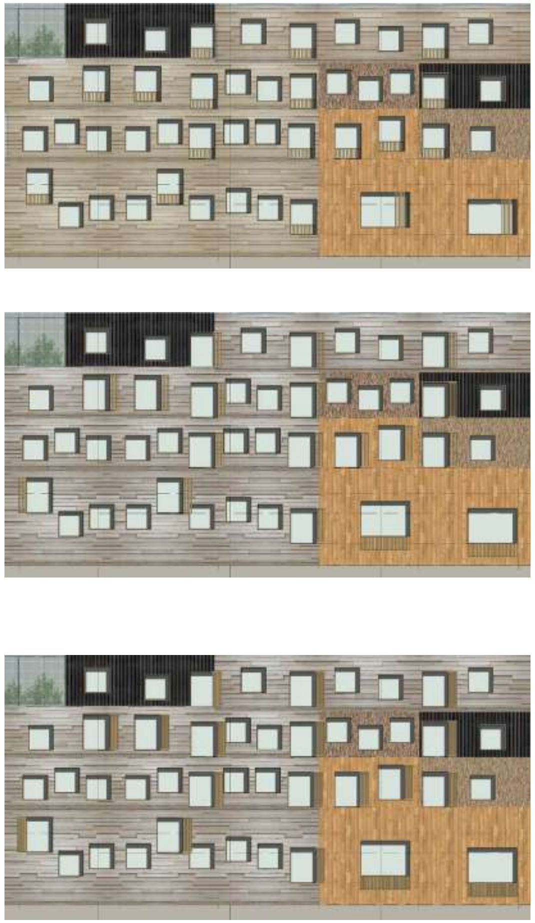
ill. 169 - Daylight percentege of one skylight of 0°, 30°, 45° and 60° respectively -



ill. 170 - Lux values for one, two and three skylights of 30° -

# 10.2 ANNEX 2

## Window and facade study

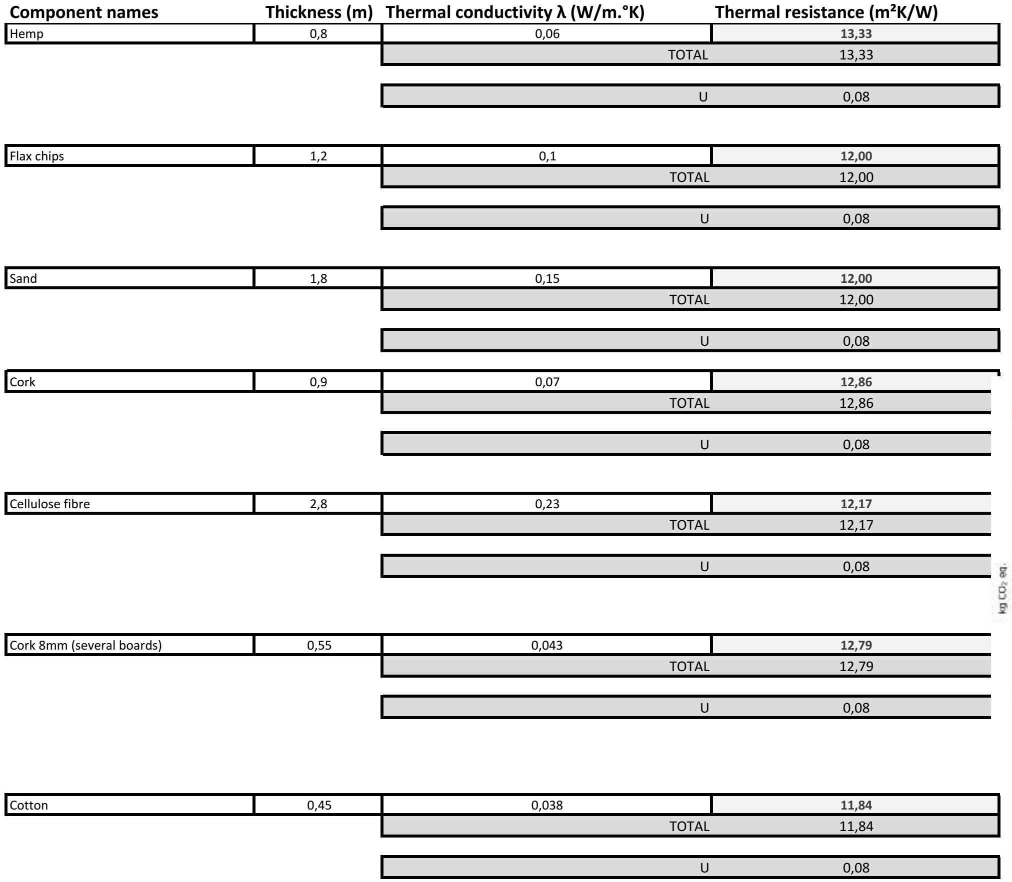


ill. 171 - Wooden lamellas option 1,2 and 3 -

ill. 172 - Material cladding iterations -

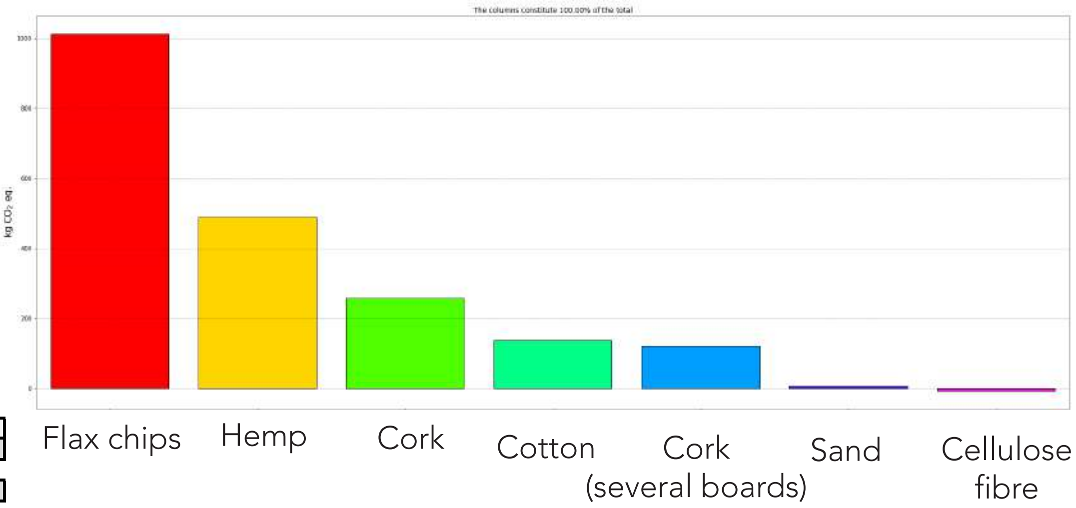
# 10.3 ANNEX 3

## LCA and U-values

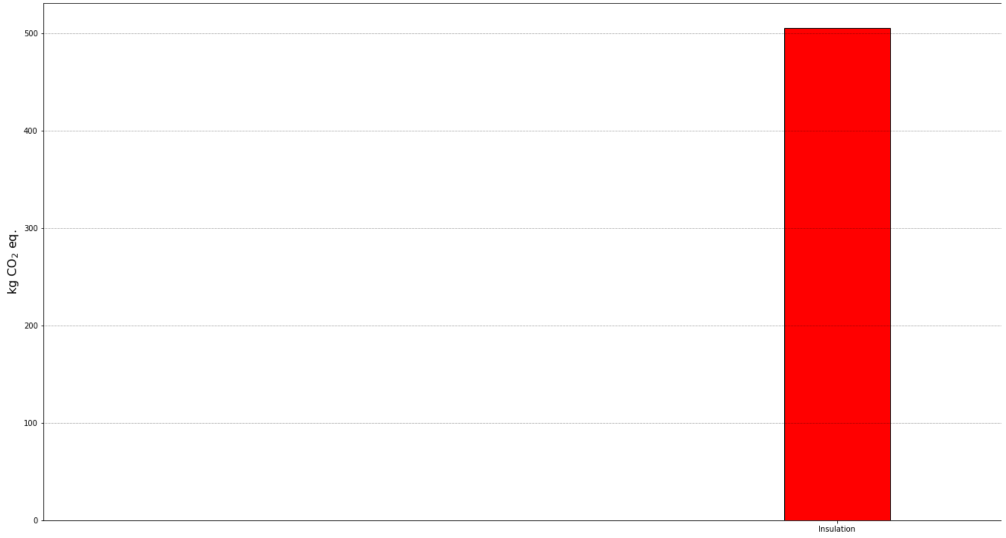


| Component names | Thickness (m) | Thermal conductivity λ (W/m.°K) | Thermal resistance (m²K/W) |
|---|---|---|---|
| Hemp | 0,8 | 0,06 | 13,33 |
| | | TOTAL | 13,33 |
| | | U | 0,08 |
| Flax chips | 1,2 | 0,1 | 12,00 |
| | | TOTAL | 12,00 |
| | | U | 0,08 |
| Sand | 1,8 | 0,15 | 12,00 |
| | | TOTAL | 12,00 |
| | | U | 0,08 |
| Cork | 0,9 | 0,07 | 12,86 |
| | | TOTAL | 12,86 |
| | | U | 0,08 |
| Cellulose fibre | 2,8 | 0,23 | 12,17 |
| | | TOTAL | 12,17 |
| | | U | 0,08 |
| Cork 8mm (several boards) | 0,55 | 0,043 | 12,79 |
| | | TOTAL | 12,79 |
| | | U | 0,08 |
| Cotton | 0,45 | 0,038 | 11,84 |
| | | TOTAL | 11,84 |
| | | U | 0,08 |

*ill. 173 - U-values for insulations -*

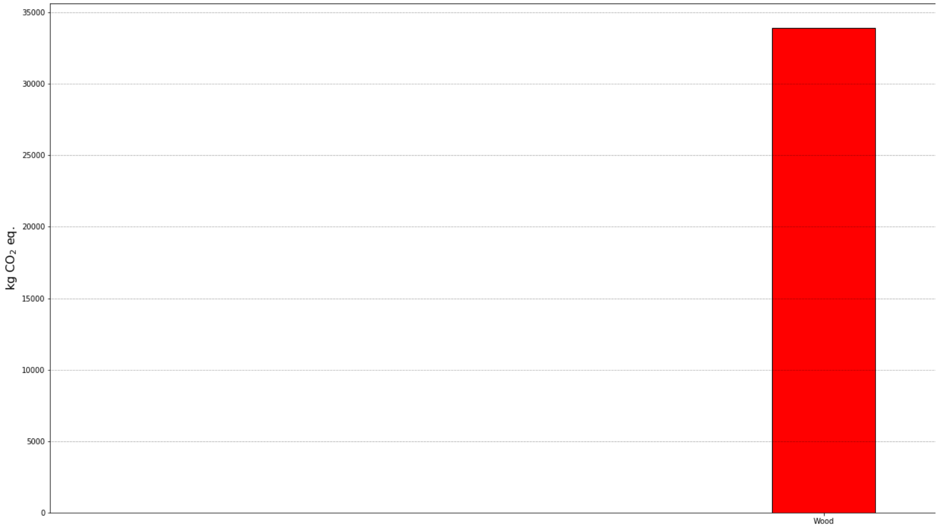


*ill. 174 - LCA for insulations -*

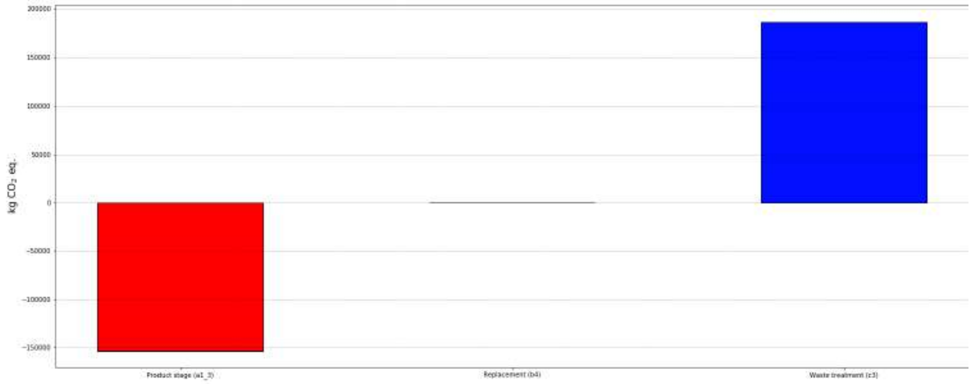


ill. 175 - Cotton CO2 -

ill. 176 - Cotton life cycle stages -



ill. 177 - Cork CO2 -



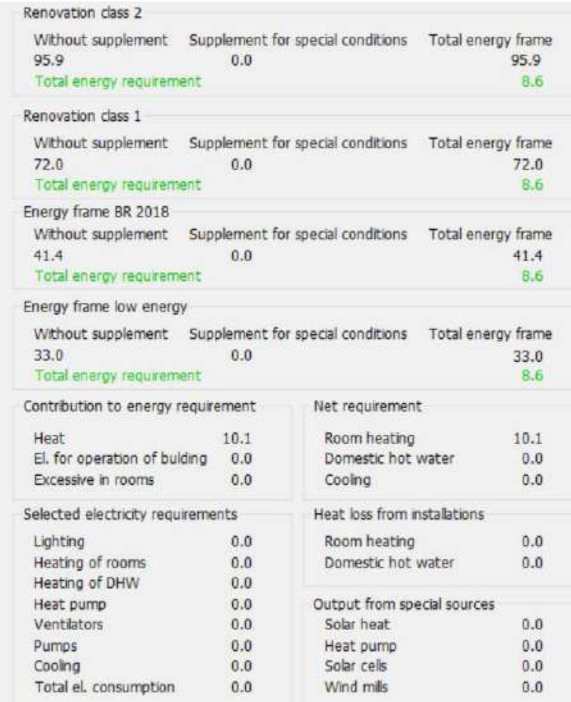
ill. 178 - Cork life cycle stages -

# 10.4 ANNEX 4

## Energy consumption: Be18

```
Key numbers, kWh/m² year
  Renovation class 2
    Without supplement   Supplement for special conditions   Total energy frame
    95.9                 0.0                                 95.9
    Total energy requirement                                 7.8
  Renovation class 1
    Without supplement   Supplement for special conditions   Total energy frame
    72.0                 0.0                                 72.0
    Total energy requirement                                 7.8
  Energy frame BR 2018
    Without supplement   Supplement for special conditions   Total energy frame
    41.4                 0.0                                 41.4
    Total energy requirement                                 7.8
  Energy frame low energy
    Without supplement   Supplement for special conditions   Total energy frame
    33.0                 0.0                                 33.0
    Total energy requirement                                 7.8
  Contribution to energy requirement      Net requirement
    Heat                          9.2       Room heating            9.2
    El. for operation of bulding  0.0       Domestic hot water      0.0
    Excessive in rooms            0.0       Cooling                 0.0
  Selected electricity requirements       Heat loss from installations
    Lighting                      0.0       Room heating            0.0
    Heating of rooms              0.0       Domestic hot water      0.0
    Heating of DHW                0.0
    Heat pump                     0.0     Output from special sources
    Ventilators                   0.0       Solar heat              0.0
    Pumps                         0.0       Heat pump               0.0
    Cooling                       0.0       Solar cells             0.0
    Total el. consumption         0.0       Wind mills              0.0
```

ill. 179 - Volume study 1 -

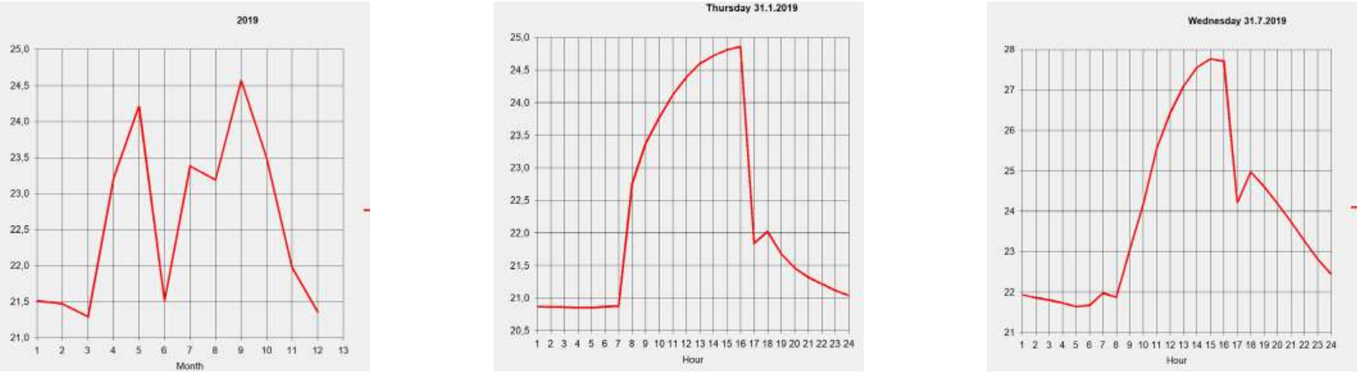


```
Renovation class 2
  Without supplement   Supplement for special conditions   Total energy frame
  95.9                 0.0                                 95.9
  Total energy requirement                                 8.6
Renovation class 1
  Without supplement   Supplement for special conditions   Total energy frame
  72.0                 0.0                                 72.0
  Total energy requirement                                 8.6
Energy frame BR 2018
  Without supplement   Supplement for special conditions   Total energy frame
  41.4                 0.0                                 41.4
  Total energy requirement                                 8.6
Energy frame low energy
  Without supplement   Supplement for special conditions   Total energy frame
  33.0                 0.0                                 33.0
  Total energy requirement                                 8.6
Contribution to energy requirement      Net requirement
  Heat                          10.1      Room heating            10.1
  El. for operation of bulding  0.0       Domestic hot water      0.0
  Excessive in rooms            0.0       Cooling                 0.0
Selected electricity requirements       Heat loss from installations
  Lighting                      0.0       Room heating            0.0
  Heating of rooms              0.0       Domestic hot water      0.0
  Heating of DHW                0.0
  Heat pump                     0.0     Output from special sources
  Ventilators                   0.0       Solar heat              0.0
  Pumps                         0.0       Heat pump               0.0
  Cooling                       0.0       Solar cells             0.0
  Total el. consumption         0.0       Wind mills              0.0
```

ill. 180 - Volume study 2 -

# 10.5 ANNEX 5

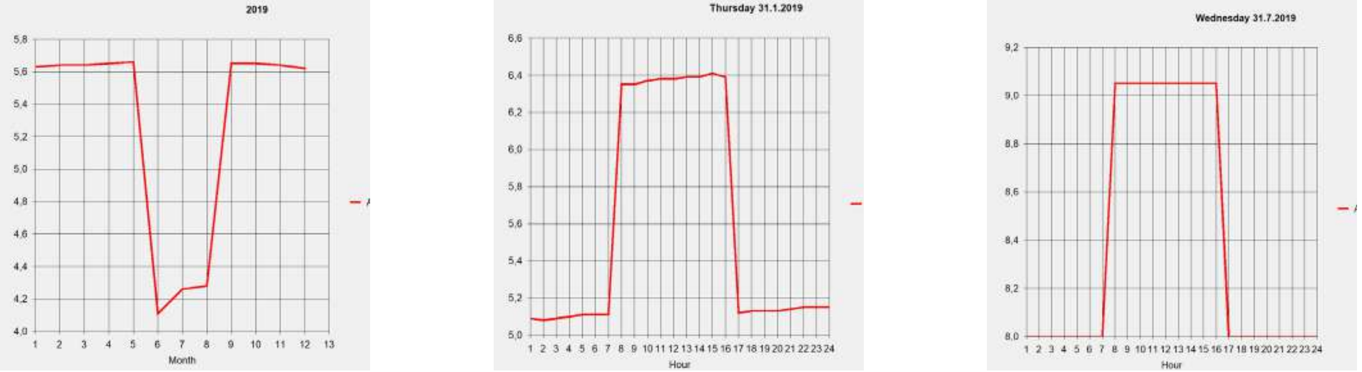
## Indoor environment: BSim



Total (annual) temperature

Temperature on 31st of January

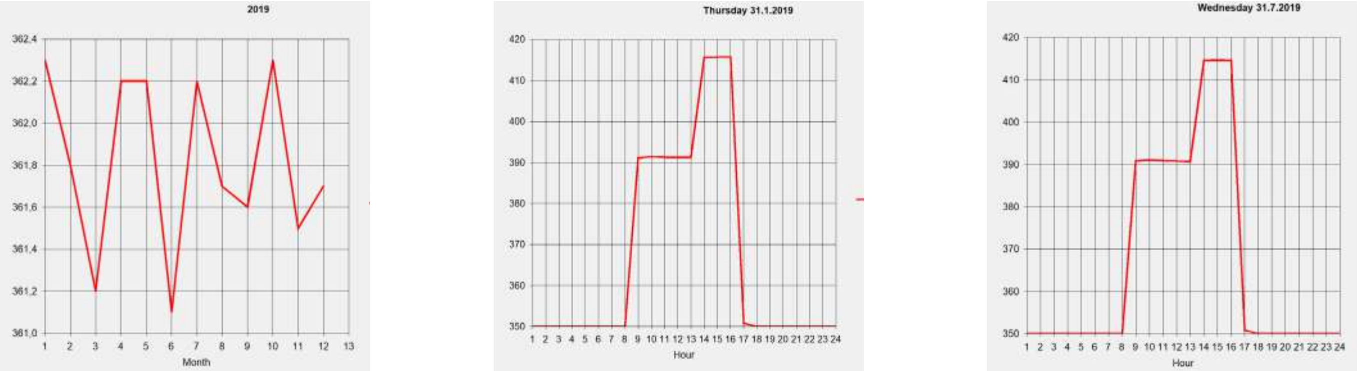
Temperature on 31st of July



Total (annual) air change

Air change on 31st of January

Air change on 31st of July



Total (annual) CO2

CO2 on 31st of January

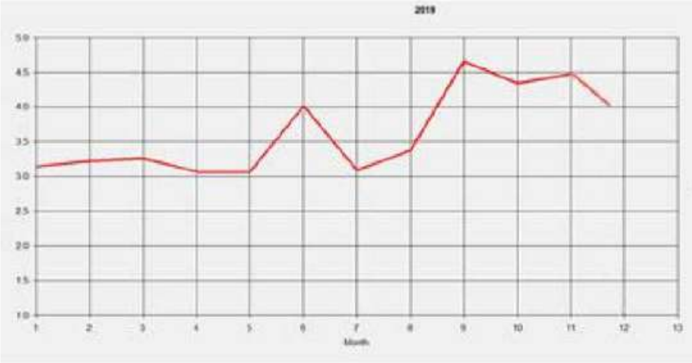
CO2 on 31st of July

*ill. 181 - Indoor environment results before the implementation of the design with shadings and optimal window's opening area -*

Total (annual) temperature

Temperature on 31st of January

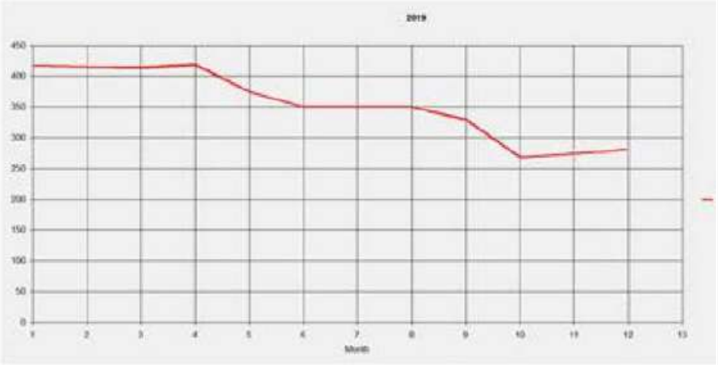
Temperature on 31st of July



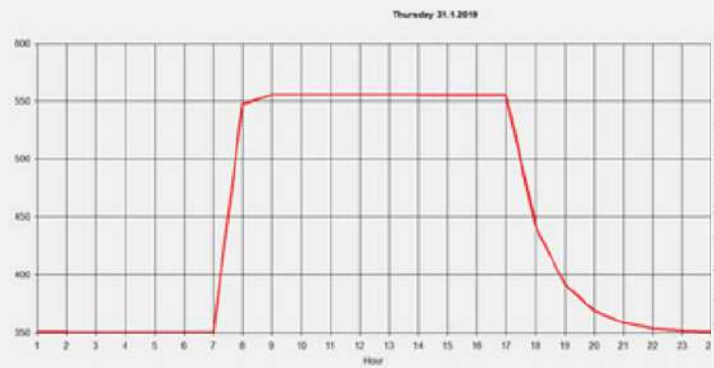
Total (annual) air change

Air change on 31st of January

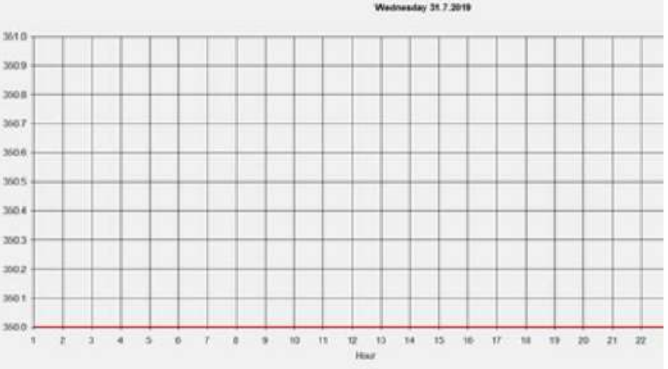
Air change on 31st of July



Total (annual) CO2



CO2 on 31st of January

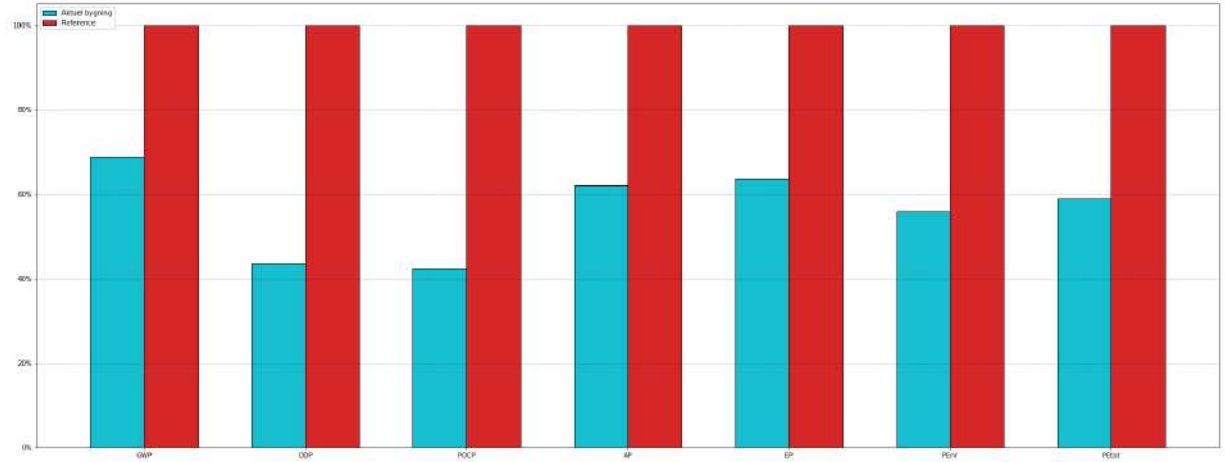


CO2 on 31st of July

*ill. 182 - Indoor environment results after the implementation of the design with shadings and improved window's opening area -*

# 10.6 ANNEX 6

## LCA



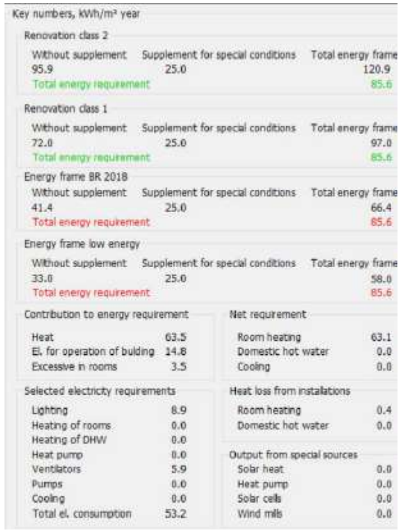
*ill. 183 - LCA comparison of project with DGNB -*

# 10.7 ANNEX 7

## Energy consumption: Be18 and photovoltaic panels

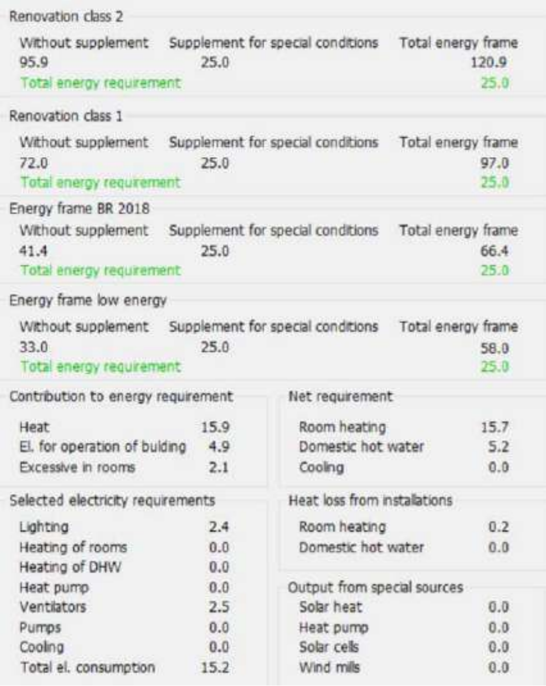
```
Key numbers, kWh/m² year
  Renovation class 2
    Without supplement   Supplement for special conditions   Total energy frame
    95.9                        25.0                                      120.9
    Total energy requirement                                               93.7
  Renovation class 1
    Without supplement   Supplement for special conditions   Total energy frame
    72.0                        25.0                                       97.0
    Total energy requirement                                               93.7
  Energy frame BR 2018
    Without supplement   Supplement for special conditions   Total energy frame
    41.4                        25.0                                       66.4
    Total energy requirement                                               93.7
  Energy frame low energy
    Without supplement   Supplement for special conditions   Total energy frame
    33.0                        25.0                                       58.0
    Total energy requirement                                               93.7
  Contribution to energy requirement      Net requirement
    Heat                          56.3      Room heating              55.9
    El. for operation of bulding  18.1      Domestic hot water         0.0
    Excessive in rooms            11.5      Cooling                    0.0
  Selected electricity requirements       Heat loss from installations
    Lighting                      10.5      Room heating               0.4
    Heating of rooms               0.0      Domestic hot water         0.0
    Heating of DHW                 0.0
    Heat pump                      0.0    Output from special sources
    Ventilators                    7.6      Solar heat                 0.0
    Pumps                          0.0      Heat pump                  0.0
    Cooling                        0.0      Solar cells                0.0
    Total el. consumption         56.5      Wind mills                 0.0
```

*ill. 184 - Result before ventilation system runtime was reduced to working hours -*



```
Key numbers, kWh/m² year
  Renovation class 2
    Without supplement   Supplement for special conditions   Total energy frame
    95.9                        25.0                                      120.9
    Total energy requirement                                               85.6
  Renovation class 1
    Without supplement   Supplement for special conditions   Total energy frame
    72.0                        25.0                                       97.0
    Total energy requirement                                               85.6
  Energy frame BR 2018
    Without supplement   Supplement for special conditions   Total energy frame
    41.4                        25.0                                       66.4
    Total energy requirement                                               85.6
  Energy frame low energy
    Without supplement   Supplement for special conditions   Total energy frame
    33.0                        25.0                                       58.0
    Total energy requirement                                               85.6
  Contribution to energy requirement      Net requirement
    Heat                          63.5      Room heating              63.1
    El. for operation of bulding  14.8      Domestic hot water         0.0
    Excessive in rooms             3.5      Cooling                    0.0
  Selected electricity requirements       Heat loss from installations
    Lighting                       8.9      Room heating               0.4
    Heating of rooms               0.0      Domestic hot water         0.0
    Heating of DHW                 0.0
    Heat pump                      0.0    Output from special sources
    Ventilators                    5.9      Solar heat                 0.0
    Pumps                          0.0      Heat pump                  0.0
    Cooling                        0.0      Solar cells                0.0
    Total el. consumption         53.2      Wind mills                 0.0
```

*ill. 185 - Result before lighting system was changed from automatic to continuous automatic control according to daylight level -*



```
Renovation class 2
  Without supplement   Supplement for special conditions   Total energy frame
  95.9                        25.0                                      120.9
  Total energy requirement                                               25.0
Renovation class 1
  Without supplement   Supplement for special conditions   Total energy frame
  72.0                        25.0                                       97.0
  Total energy requirement                                               25.0
Energy frame BR 2018
  Without supplement   Supplement for special conditions   Total energy frame
  41.4                        25.0                                       66.4
  Total energy requirement                                               25.0
Energy frame low energy
  Without supplement   Supplement for special conditions   Total energy frame
  33.0                        25.0                                       58.0
  Total energy requirement                                               25.0
Contribution to energy requirement      Net requirement
  Heat                          15.9      Room heating              15.7
  El. for operation of bulding   4.9      Domestic hot water         5.2
  Excessive in rooms             2.1      Cooling                    0.0
Selected electricity requirements       Heat loss from installations
  Lighting                       2.4      Room heating               0.2
  Heating of rooms               0.0      Domestic hot water         0.0
  Heating of DHW                 0.0
  Heat pump                      0.0    Output from special sources
  Ventilators                    2.5      Solar heat                 0.0
  Pumps                          0.0      Heat pump                  0.0
  Cooling                        0.0      Solar cells                0.0
  Total el. consumption         15.2      Wind mills                 0.0
```

*ill. 186 - Fulfillement of enery f rame BR 2018 -*

```
Renovation class 2
  Without supplement   Supplement for special conditions   Total energy frame
  95.9                        25.0                                      120.9
  Total energy requirement                                                0.0
Renovation class 1
  Without supplement   Supplement for special conditions   Total energy frame
  72.0                        25.0                                       97.0
  Total energy requirement                                                0.0
Energy frame BR 2018
  Without supplement   Supplement for special conditions   Total energy frame
  41.4                        25.0                                       66.4
  Total energy requirement                                                0.0
Energy frame low energy
  Without supplement   Supplement for special conditions   Total energy frame
  33.0                        25.0                                       58.0
  Total energy requirement                                                0.0
Contribution to energy requirement      Net requirement
  Heat                          15.9      Room heating              15.7
  El. for operation of bulding  -8.2      Domestic hot water         5.2
  Excessive in rooms             2.1      Cooling                    0.0
Selected electricity requirements       Heat loss from installations
  Lighting                       2.4      Room heating               0.2
  Heating of rooms               0.0      Domestic hot water         0.0
  Heating of DHW                 0.0
  Heat pump                      0.0    Output from special sources
  Ventilators                    2.5      Solar heat                 0.0
  Pumps                          0.0      Heat pump                  0.0
  Cooling                        0.0      Solar cells               33.6
  Total el. consumption         15.2      Wind mills                 0.0
```

*ill. 187 - Addition of photovoltaic energy -*

## Photovoltaic panels:

The energy demand of the project building derived from Be18 is 25 kWh/m2 per year. Thus, the- annual energy demand is- (25 kWh/m2/1.8)*2678.88= 37206.66 kWh/year

Since the energy demand does not include the electric consumption of the premise, the electricity is calculated by the consumption of one employee in an office in Denmark per year (Odyssee-Mure.eu.) multiplied by the number of employees. Thus, the electricity consumed in office- 2537*70 employees= 177590 kWh/year

The total energy demand in the office building= 37206.66 kWh/year
+ 177590 kWh/year
=214796.66 kWh/year

The energy produced by solar cells are calculated separately based on the alignment and the orientation.

Thus, for Southern facade vertical PVs-
362.7 x 0.8x 0.18 x 867= 55139.11
Southern facade 30 degree aligned PVs produce-
143.29 x 0.8 x 0.18 x 1124= 23192.34
Eastern facade vertical PVs produce-
198.22 x 0.18 x 0.8 x 738= 21065.23
Eastern facade aligned PVs produce-
81.33 x 0.18 x 0.8 x 1012= 11852.05
Western facade vertical PVs produce-
152.67 x 0.18 x 0.8 x 726= 15960.73

Thus, the total energy produced by facade panels- 127209.46 kWh/year
To find out the area of PVs required to generate the balance energy, the following formula is used-
Ax0.18x0.85x1163= 87587.2 kWh/year

Hence, 674.134 m2 PVs are needed to produce the balance energy at an angle of 45 degree facing south. However, to maintain the concept of a roof garden, we take 500 sq m from roof and the railings on the roof toward west, east and south facade with the same efficiency which produces-
88969.5 kWh/year.

# 10.8 ANNEX 8

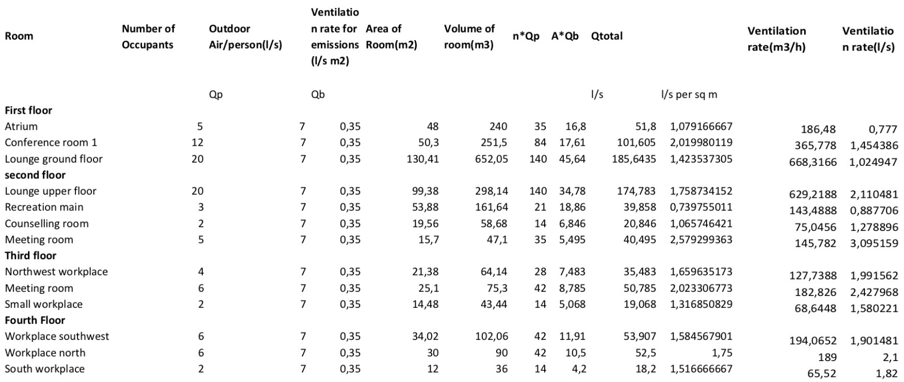
## Indoor environment: BSim

### Ventilation

The indoor environment standard was referred for determining the design ventilation rate based on the pollution from the occupants and the building components. The formula used for calculating ventilation was thus-

Total ventilation rate for a room tot p B q = n × q + A× q (B1)
where
qtot= total ventilation rate of the room, l/s
n = design value for the number of the persons in the room,-
qp = ventilation rate for occupancy per person, l/s, pers
A= room floor area, m2
qB = ventilation rate for emissions from building, l/s,m2

Since Category II was chosen for the project, airflow per person was 7 l/s while the ventilation rate for building emission for a very low polluting building is 0.35 l/s per sq m. Thus, the total ventilation in l/s per sq m and the ventilation rate in cubic m per hour is derived. Since two rooms from the project- workplace and recreation; are simulated, the values for ventilation rate for the rooms will be aimed for as a result of the simulations.



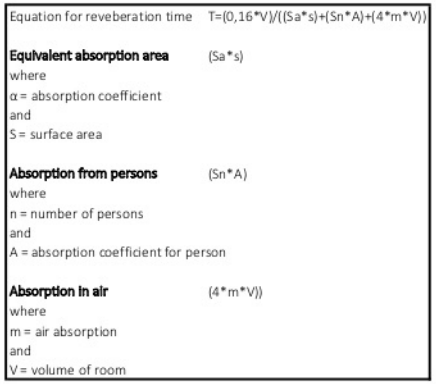
| **Room** | **Number of Occupants** | **Outdoor Air/person(l/s)** | **Ventilation rate for emissions (l/s m2)** | **Area of Room(m2)** | **Volume of room(m3)** | **n*Qp** | **A*Qb** | **Qtotal** | | **Ventilation rate(m3/h)** | **Ventilation rate(l/s)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Qp | Qb | | | | | l/s | l/s per sq m | | |
| **First floor** | | | | | | | | | | | |
| Atrium | 5 | 7 | 0,35 | 48 | 240 | 35 | 16,8 | 51,8 | 1,079166667 | 186,48 | 0,777 |
| Conference room 1 | 12 | 7 | 0,35 | 50,3 | 251,5 | 84 | 17,61 | 101,605 | 2,019980119 | 365,778 | 1,454386 |
| Lounge ground floor | 20 | 7 | 0,35 | 130,41 | 652,05 | 140 | 45,64 | 185,6435 | 1,423537305 | 668,3166 | 1,024947 |
| **second floor** | | | | | | | | | | | |
| Lounge upper floor | 20 | 7 | 0,35 | 99,38 | 298,14 | 140 | 34,78 | 174,783 | 1,758734152 | 629,2188 | 2,110481 |
| Recreation main | 3 | 7 | 0,35 | 53,88 | 161,64 | 21 | 18,86 | 39,858 | 0,739755011 | 143,4888 | 0,887706 |
| Counselling room | 2 | 7 | 0,35 | 19,56 | 58,68 | 14 | 6,846 | 20,846 | 1,065746421 | 75,0456 | 1,278896 |
| Meeting room | 5 | 7 | 0,35 | 15,7 | 47,1 | 35 | 5,495 | 40,495 | 2,579299363 | 145,782 | 3,095159 |
| **Third floor** | | | | | | | | | | | |
| Northwest workplace | 4 | 7 | 0,35 | 21,38 | 64,14 | 28 | 7,483 | 35,483 | 1,659635173 | 127,7388 | 1,991562 |
| Meeting room | 6 | 7 | 0,35 | 25,1 | 75,3 | 42 | 8,785 | 50,785 | 2,023306773 | 182,826 | 2,427968 |
| Small workplace | 2 | 7 | 0,35 | 14,48 | 43,44 | 14 | 5,068 | 19,068 | 1,316850829 | 68,6448 | 1,580221 |
| **Fourth Floor** | | | | | | | | | | | |
| Workplace southwest | 6 | 7 | 0,35 | 34,02 | 102,06 | 42 | 11,91 | 53,907 | 1,584567901 | 194,0652 | 1,901481 |
| Workplace north | 6 | 7 | 0,35 | 30 | 90 | 42 | 10,5 | 52,5 | 1,75 | 189 | 2,1 |
| South workplace | 2 | 7 | 0,35 | 12 | 36 | 14 | 4,2 | 18,2 | 1,516666667 | 65,52 | 1,82 |

*ill. 188 - Ventilation chart -*

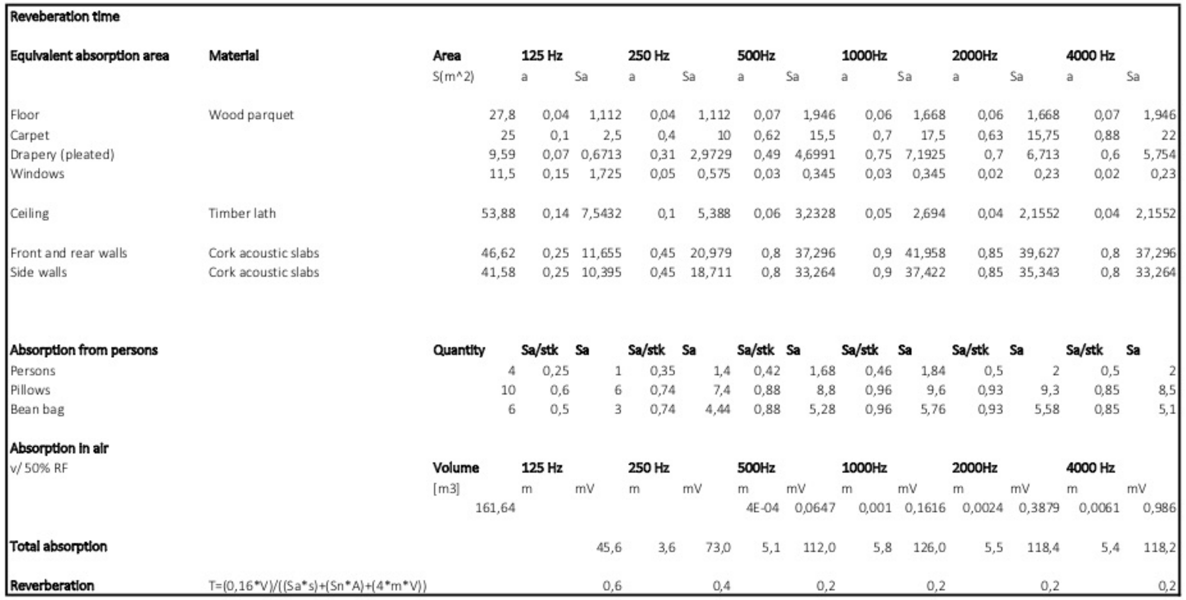
# 10.9 ANNEX 9

## Acoustics

**Reverberation**

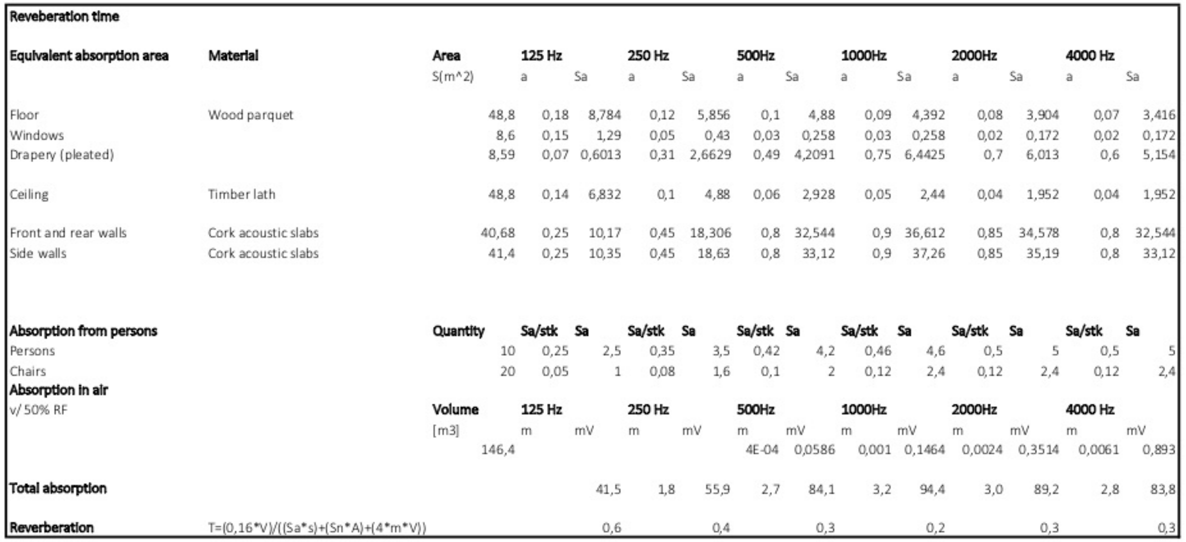


| | |
|---|---|
| Equation for reveberation time | T=(0,16*V)/((Sa*s)+(Sn*A)+(4*m*V)) |
| | |
| **Equivalent absorption area** | (Sa*s) |
| where | |
| α = absorption coefficient | |
| and | |
| S = surface area | |
| | |
| **Absorption from persons** | (Sn*A) |
| where | |
| n = number of persons | |
| and | |
| A = absorption coefficient for person | |
| | |
| **Absorption in air** | (4*m*V)) |
| where | |
| m = air absorption | |
| and | |
| V = volume of room | |



| **Reveberation time** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Equivalent absorption area** | **Material** | **Area** | **125 Hz** | | **250 Hz** | | **500Hz** | | **1000Hz** | | **2000Hz** | | **4000 Hz** | |
| | | S(m^2) | a | Sa | a | Sa | a | Sa | a | Sa | a | Sa | a | Sa |
| Floor | Wood parquet | 27,8 | 0,04 | 1,112 | 0,04 | 1,112 | 0,07 | 1,946 | 0,06 | 1,668 | 0,06 | 1,668 | 0,07 | 1,946 |
| Carpet | | 25 | 0,1 | 2,5 | 0,4 | 10 | 0,62 | 15,5 | 0,7 | 17,5 | 0,63 | 15,75 | 0,88 | 22 |
| Drapery (pleated) | | 9,59 | 0,07 | 0,6713 | 0,31 | 2,9729 | 0,49 | 4,6991 | 0,75 | 7,1925 | 0,7 | 6,713 | 0,6 | 5,754 |
| Windows | | 11,5 | 0,15 | 1,725 | 0,05 | 0,575 | 0,03 | 0,345 | 0,03 | 0,345 | 0,02 | 0,23 | 0,02 | 0,23 |
| Ceiling | Timber lath | 53,88 | 0,14 | 7,5432 | 0,1 | 5,388 | 0,06 | 3,2328 | 0,05 | 2,694 | 0,04 | 2,1552 | 0,04 | 2,1552 |
| Front and rear walls | Cork acoustic slabs | 46,62 | 0,25 | 11,655 | 0,45 | 20,979 | 0,8 | 37,296 | 0,9 | 41,958 | 0,85 | 39,627 | 0,8 | 37,296 |
| Side walls | Cork acoustic slabs | 41,58 | 0,25 | 10,395 | 0,45 | 18,711 | 0,8 | 33,264 | 0,9 | 37,422 | 0,85 | 35,343 | 0,8 | 33,264 |
| **Absorption from persons** | | **Quantity** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** |
| Persons | | 4 | 0,25 | 1 | 0,35 | 1,4 | 0,42 | 1,68 | 0,46 | 1,84 | 0,5 | 2 | 0,5 | 2 |
| Pillows | | 10 | 0,6 | 6 | 0,74 | 7,4 | 0,88 | 8,8 | 0,96 | 9,6 | 0,93 | 9,3 | 0,85 | 8,5 |
| Bean bag | | 6 | 0,5 | 3 | 0,74 | 4,44 | 0,88 | 5,28 | 0,96 | 5,76 | 0,93 | 5,58 | 0,85 | 5,1 |
| **Absorption in air** | | | | | | | | | | | | | | |
| v/ 50% RF | | **Volume** | **125 Hz** | | **250 Hz** | | **500Hz** | | **1000Hz** | | **2000Hz** | | **4000 Hz** | |
| | | [m3] | m | mV | m | mV | m | mV | m | mV | m | mV | m | mV |
| | | 161,64 | | | | | 4E-04 | 0,0647 | 0,001 | 0,1616 | 0,0024 | 0,3879 | 0,0061 | 0,986 |
| **Total absorption** | | | | 45,6 | 3,6 | 73,0 | 5,1 | 112,0 | 5,8 | 126,0 | 5,5 | 118,4 | 5,4 | 118,2 |
| **Reverberation** | T=(0,16*V)/((Sa*s)+(Sn*A)+(4*m*V)) | | | 0,6 | | 0,4 | | 0,2 | | 0,2 | | 0,2 | | 0,2 |

*ill. 189 - Reverberation time chart for restorative room -*



| **Reveberation time** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Equivalent absorption area** | **Material** | **Area** | **125 Hz** | | **250 Hz** | | **500Hz** | | **1000Hz** | | **2000Hz** | | **4000 Hz** | |
| | | S(m^2) | a | Sa | a | Sa | a | Sa | a | Sa | a | Sa | a | Sa |
| Floor | Wood parquet | 48,8 | 0,18 | 8,784 | 0,12 | 5,856 | 0,1 | 4,88 | 0,09 | 4,392 | 0,08 | 3,904 | 0,07 | 3,416 |
| Windows | | 8,6 | 0,15 | 1,29 | 0,05 | 0,43 | 0,03 | 0,258 | 0,03 | 0,258 | 0,02 | 0,172 | 0,02 | 0,172 |
| Drapery (pleated) | | 8,59 | 0,07 | 0,6013 | 0,31 | 2,6629 | 0,49 | 4,2091 | 0,75 | 6,4425 | 0,7 | 6,013 | 0,6 | 5,154 |
| Ceiling | Timber lath | 48,8 | 0,14 | 6,832 | 0,1 | 4,88 | 0,06 | 2,928 | 0,05 | 2,44 | 0,04 | 1,952 | 0,04 | 1,952 |
| Front and rear walls | Cork acoustic slabs | 40,68 | 0,25 | 10,17 | 0,45 | 18,306 | 0,8 | 32,544 | 0,9 | 36,612 | 0,85 | 34,578 | 0,8 | 32,544 |
| Side walls | Cork acoustic slabs | 41,4 | 0,25 | 10,35 | 0,45 | 18,63 | 0,8 | 33,12 | 0,9 | 37,26 | 0,85 | 35,19 | 0,8 | 33,12 |
| **Absorption from persons** | | **Quantity** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** | **Sa/stk** | **Sa** |
| Persons | | 10 | 0,25 | 2,5 | 0,35 | 3,5 | 0,42 | 4,2 | 0,46 | 4,6 | 0,5 | 5 | 0,5 | 5 |
| Chairs | | 20 | 0,05 | 1 | 0,08 | 1,6 | 0,1 | 2 | 0,12 | 2,4 | 0,12 | 2,4 | 0,12 | 2,4 |
| **Absorption in air** | | | | | | | | | | | | | | |
| v/ 50% RF | | **Volume** | **125 Hz** | | **250 Hz** | | **500Hz** | | **1000Hz** | | **2000Hz** | | **4000 Hz** | |
| | | [m3] | m | mV | m | mV | m | mV | m | mV | m | mV | m | mV |
| | | 146,4 | | | | | 4E-04 | 0,0586 | 0,001 | 0,1464 | 0,0024 | 0,3514 | 0,0061 | 0,893 |
| **Total absorption** | | | | 41,5 | 1,8 | 55,9 | 2,7 | 84,1 | 3,2 | 94,4 | 3,0 | 89,2 | 2,8 | 83,8 |
| **Reverberation** | T=(0,16*V)/((Sa*s)+(Sn*A)+(4*m*V)) | | | 0,6 | | 0,4 | | 0,3 | | 0,2 | | 0,3 | | 0,3 |

*ill. 190 - Reverberation time chart for meeting room -*

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