CRAFT TECH

Vocational School

MSC04, group 20, May 2023
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INTRODUCTION

The aspiration of this thesis proposal is the design of a multi-functional educational building in Aarhus' city center that showcases craftsmanship and artisanal education, as a creative, dynamic, and modern pursuit. The origin of this goal is that fewer and fewer Danish students choose vocational education over traditional education every year. This is a multi-faceted problem whose origins are explored in the opening chapters of this report.

Through an analysis of the current situation, it is then possible to design a building that can address the issue at hand through its program and design. Although vocational education covers a broad spectrum of fields and careers this thesis will design a school at a specific location with a targeted program as a case study whose principles can be applied to other types of vocational developments or renovations.

“How can artisanal education be promoted by revitalizing and redefining craftsmanship in modern society, through the use of socially and environmentally sustainable tectonic architecture?”

PROBLEM STATEMENT

PROGRAM

METHODOLOGY

Evidence Based Design Method

Evidence Based Design (EBD) can be defined as **"the integration of professional wisdom with the best available empirical evidence in making decisions about how to deliver [a product]"** (Whitehurst. 2002). In the definition above professional wisdom is needed to be able to realistically propose something new. For example, int the case of this thesis in order to develop a more effective new type of artisan school it's useful to know how current such schools operate and the issues they have. Evidence allows for more unbiased, informed decisions (Whitehurst, 2002). That being said, the nature of the considered evidence can vary widely from quantitative experiments to quantitative anecdotes (Lippman, 2010). The basic structure is as follows:

- Examining the existing research literature to determine findings and recommendations
- Evaluating these findings together with data gathered from site visits and dialogues with experts and stakeholders
- Hypothesizing the potential outcomes and implications (Looker, 2009)

EBD should be viewed as a process, as the continuous accumulation of new knowledge over time means that solutions of complex problems also change as they are refined over time. This is especially true in brand new fields of research. One important thing to note is that although architects have always used broad knowledge base to inform their designs (such as site analysis) EBD differs in its emphasis on research and observations which allows a broader view beyond the site specific (Hamilton, 2009). This is important in this case in particular as the vocational school being designed is simultaneously site specific while also serving as a broader socio-economic case study.

It's useful to break down the general EDP process in smaller steps. To do this we used a model called the WHR nine-step process as a reference on how to do this (Hamilton, 2009). The steps we defined are as follows:

1.**COMPILE** RESEARCH AND INFORMATION RELATED TO PROBLEM BEING EXAMINED

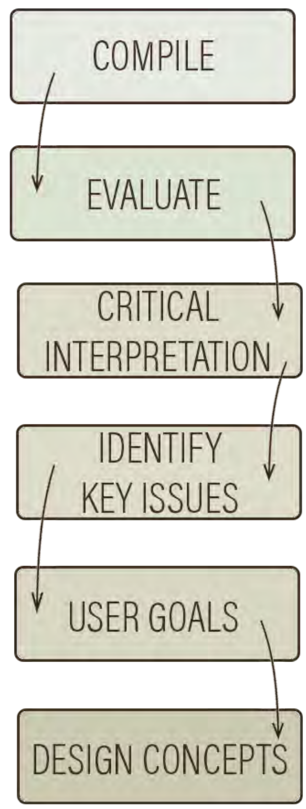
2.**EVALUATE** WHICH SOURCES ARE RELEVANT OR USEFUL

3.**CRITICAL INTERPRETATION** OF THE EVIDENCE

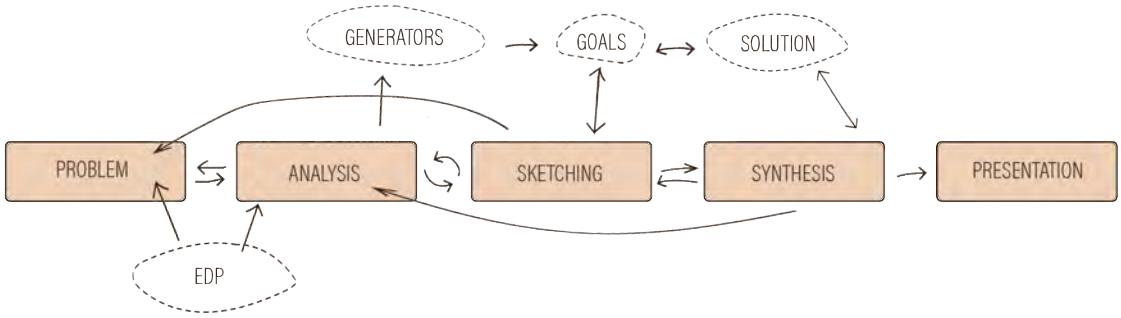
4.**IDENTIFY** THE **KEY ISSUES** AND OPPORTUNITIES AND CONVERT THEM INTO RESEARCH QUESTIONS

5.IDENTIFY THE **USER'S GOALS**, WISHES AND NEEDS

6.CREATE EVIDENCE-BASED **DESIGN CONCEPTS**



Integrated Design Process



Architects and engineers, work on interacting with complex problems in the endeavor to create solutions in an interdisciplinary field, with an end goal of a holistic work that meets both the requirements of the site, user, client, and designer. The Integrated Design Process(IDP) by Mary-Ann Knudstrup is an iterative methodology, that was created to achieve a holistic design with a clear connection between aesthetics, functions, and techniques.

The methodology is divided into 5 non-linear phases, that cover the design process from initial problem to the final presentation (Knudstrup, 2005):

1. PROBLEM: The formulation of a problem, in this case the design of an artisan school that changes the perception of vocational education.

2. ANALYSIS: Gathers all the knowledge needed before the sketching can start. This includes everything from site analysis to research. It is here that the first five phases of EBD will be used.

3. SKETCHING: the information from the analysis is used to create preliminary designs through mediums such as sketching and modeling.

4. SYNTHESIS: combines individual ideas and considerations from the sketching phase and details them to achieve the final form of the building at a greater level of detail. Here there are in depth qualitative and quantitative decisions.

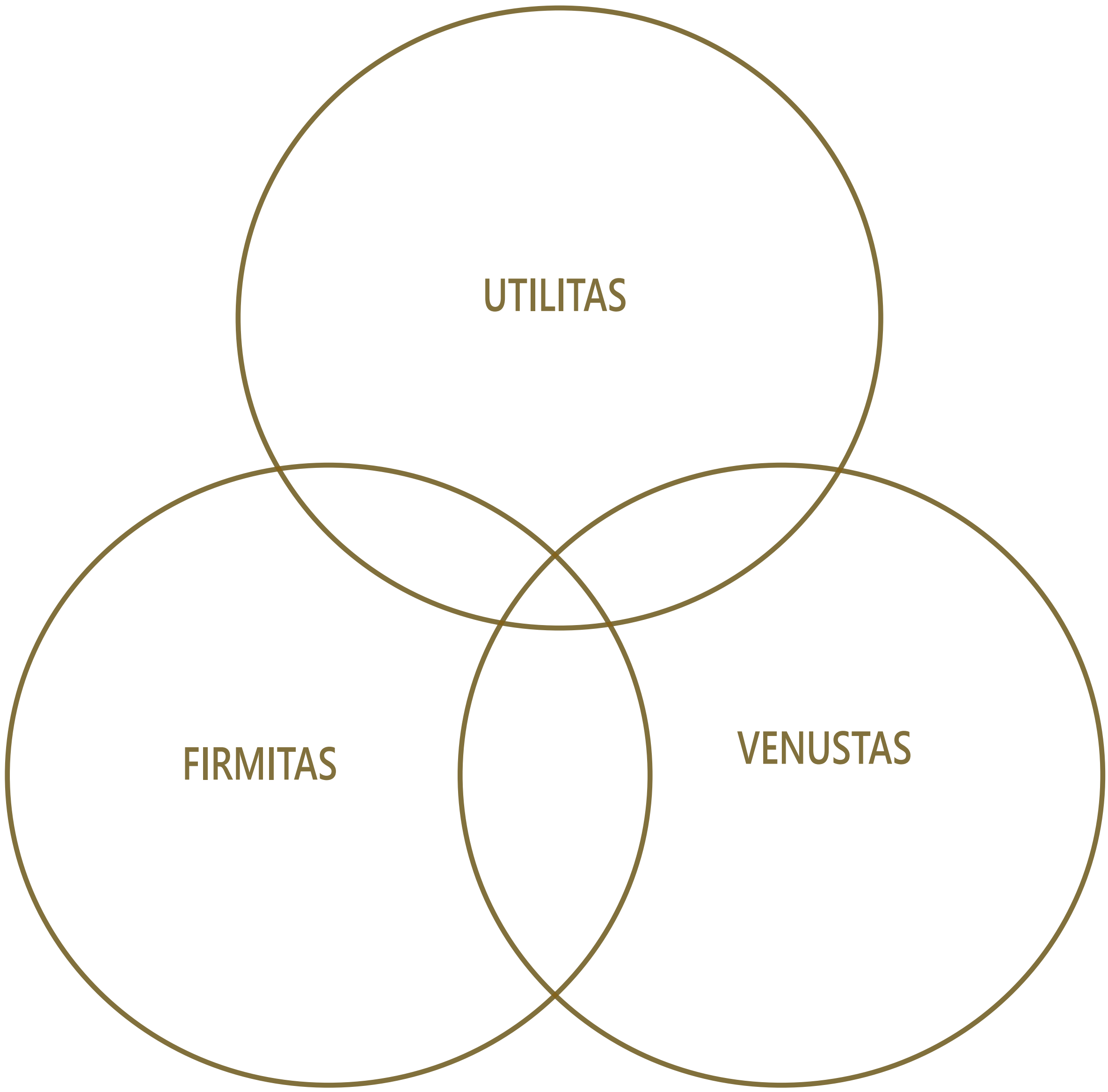
5. PRESENTATION: The effective communication of the ideas and the project overall through the use of graphics that show how the goals of the project have been met.

IDP is an iterative process, where each phase can affect and redefine other phases. When moving between phases, it is important to reflect upon former stages and if necessary, go back and redefine them. IDP can also be understood as navigating between a “Problem-Space” (pertaining to problem and analysis phases) and a “Solution-Space” (related to sketching and synthesis). These spaces represent two distinct approaches to problem-solving, termed “co-evolution.” During the Problem-Space phase, data is collected and analyzed through research, case studies, and testing. As understanding of the problem deepens, the design transitions to the Solution-Space, where sketching or modeling based on these findings occurs, further allowing for testing and refinement. This iterative process results in increasingly informed designs that better respond to the initial problem.

Each of the phases above lend themselves to certain tools. The research phase is suited to literature review, the sketching phase is suited to basic design explorations. Gradually more in depth tools such as drafting and building simulation software such as Revit and BSIM will be introduced along with LCAbyg and 3D modeling software.

While co-evolution illustrates the iterative nature of the process, it does not address the practicalities of creativity and design. To fill this gap, Lawson introduces the concept of primary generators. These generators stem from requirements or objectives set by the goals of the project such as addressing user needs or sustainability goals. Ideas generated from an understanding of these requirements can be synthesized into a cohesive design solution, with a group of generators often shaping the identity of a design.

INTEGRATED DESIGN PROCESS	TOOLS
PROBLEM	EPD
ANALYSIS	EPD SITE VISIT PHOTOS MAPPING DIAGRAMS
SKETCHING	VOLUME STUDIES SHADOW ANALYSIS MOODBOARD (CASE STUDIES) PHOTOS PASSIVE STRATEGIES DIAGRAMS RHINO HAND DRAWING
SYNTHESIS	DIAGRAMS SKETCHES B18 GRASSHOPER BSIM LCA REVIT AUTOCAD PHOTOSHOP MATERIAL STUDIES SKETCHES PASSIVE STRATEGIES
PRESENTATION	INDESIGN PHOTOSHOP REVIT ILLUSTRATOR PHYSICAL MODELS SKETCHES


UTILITAS
FIRMITAS
VENUSTAS

The Vitruvian Triad

When designing it is important to have well-established idea of what main considerations should be addressed in the resulting product. Architecture is often conceptualized as having three main aspects, an idea that goes back to Roman times. The Vitruvian Triad created by Marcus Vitruvius Pollio, advocates that exceptional buildings should embody Utilitas, Firmitas, and Venustas which can be roughly interpreted as functional, technical, and aesthetic considerations, whose interplay results in architecture that has depth and meaning (Pollio, 2019). They can be more specifically defined as follows (Pollio, 2019);

UTILITAS: A broad term that is related to the idea of usability and utility, in both a functional and experiential sense.

FIRMITAS: The technical performance of a building structurally, environmentally, and performance wise.

VENUSTAS: Relating to "delight and firmness" (Pollio, 2019) Venustas relates to the aesthetical qualities of a project. This can include aspects such as materiality or how a building relates to its surroundings.

Despite it's age the Vitruvian Triad has remained relevant as a framework for understanding and assessing architectural excellence. Architects often strive to balance Utilitas, Firmitas, and Venustas in their designs. That being said interpretations of these principles vary, from architect to architect or even project to project. One slightly more universal method of interpretation of the triad is as something that provides an excellent starting point for defining the aspects which are fundamental to a project. After all every architecture project is unique and requires its own targeted approach. In other words, creating a unique architectural triad is useful way of slightly re-prioritizing Vitruvius' general framework.

In order to create a new framework, it is first necessary to have a good understanding of the conditions and requirements which underlay the architectural task. Informed adjustments based on research findings are more useful than ungrounded assumptions. This fundamental research context is detailed in the following section, providing the background needed to create a project specific triad.

DANISH EDUCATION SYSTEM: VOCATIONAL EDUCATION

After 9th Grade

According to the Danish education system the students in 9th grade, after finishing the compulsory education, can choose their next path which can be:

a) General upper secondary education (Gymnasium)
b) Vocational education

A third option after the 9th and before choosing the next path could also be to attend the non-compulsory 10th grade or efterskole. This offers a transitional period where students can explore their interests and talents. This transition year helps students to develop greater maturity and make more informed choices about their future education.

Gymnasium

Gymnasium is divided into four categories: STX, HHX, and HTX (3 years), and HF (2 years). STX and HF programs consist of a broad range of subjects in the humanities, natural science, and social science fields. The HHX program focuses on business and socio-economic disciplines in combination with foreign languages and other general subjects. Lastly, the HTX program focuses on technological and scientific subjects in combination with general subjects.The three-year programs and HF with superstructure give access to all types of higher education. HF without superstructure gives access to vocational academies and professional bachelor's programs. **(Overblik over gymnasiale uddannelser , 2023)**

Vocational education

Danish vocational education consists of three programs: EUD, which is vocational education for young people, EUX, a combination of vocational education and general upper secondary education, and EUV, vocational education for adults. **(Vocational Education and Training in Denmark, 2023)**

The Danish vocational education and training system (VET) is divided into a basic program, which is normally school-based, and a main program, which consists of long internships and shorter periods of school-based learning. The length of internship and school periods varies for the different VET programs. Completing a full VET program typically takes four years, but this may vary in length from two to five and a half years. A completed vocational education gives access to the labor market as a skilled worker.

The first part of the basic program is available in three forms:

GF1: This form is an option for students that have finished 9th or 10th grade no more than 2 years before. This course provides a broad scope of vocational skills, and the students can get an insight into various fields. At the end of GF1, the attendant needs to choose between four main areas:

- Care, health, and pedagogy
- Office, trade, and business services
- Food, agriculture, and experiences
- Technology, construction, and transport.

GF+: This program has a duration of 10 weeks and it is suitable for those who have trouble deciding a vocational training.

GF2: In this second part of the basic program students receive all the practical and theoretical knowledge that they need to be able to get an apprenticeship.

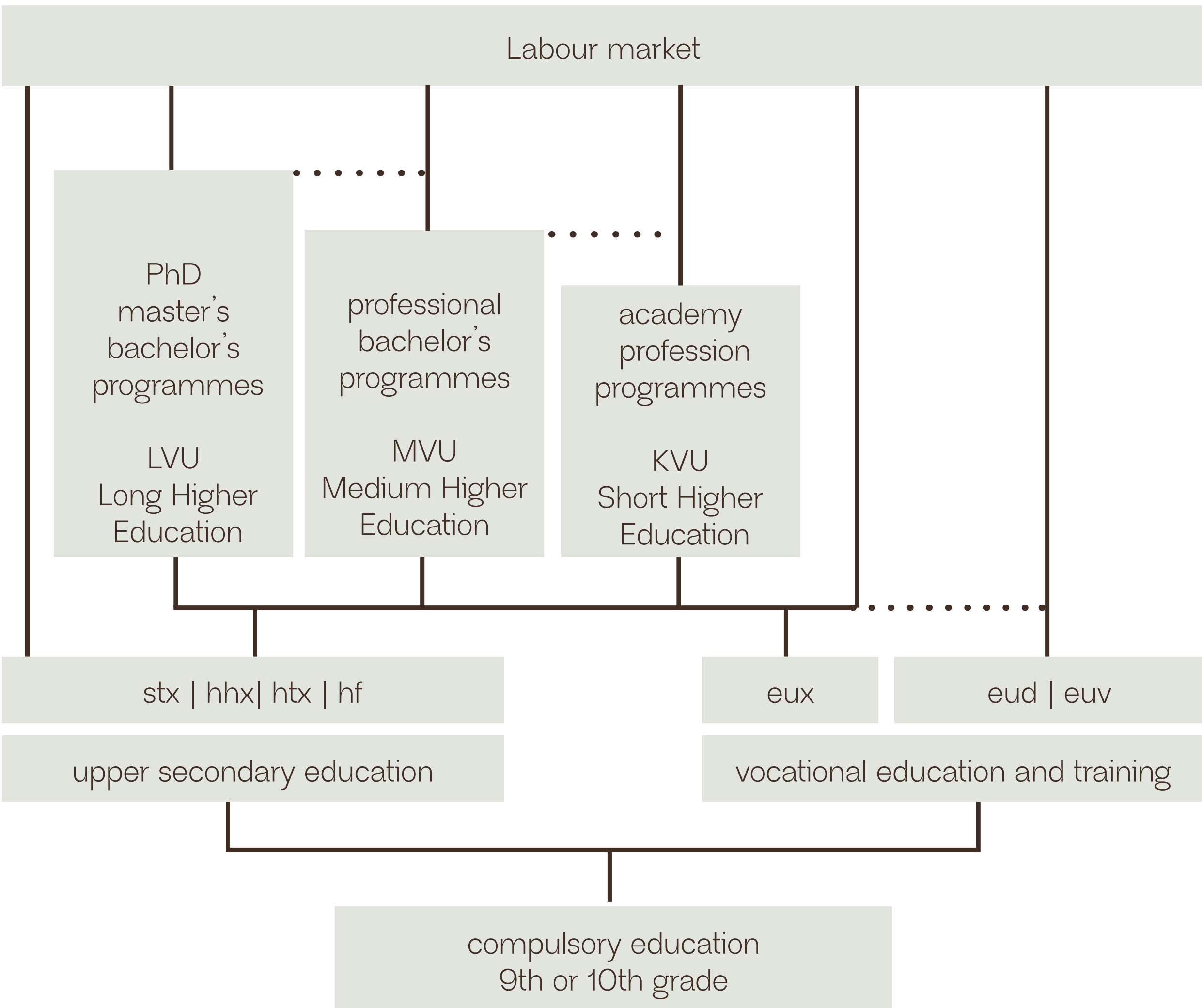
GF1 and GF2 each span half a year, making a total duration of one year. Students who finished 9th grade more than two years ago and adults over 25 years old can go directly to GF2. **(Grundforløbets to dele, 2023)**

The main program varies greatly in duration depending on the choice of the degree. A typical main course includes training, with shorter periods of classroom attendance, and ends with an exam after three years. The training periods take place in a company that the student has an agreement with. The apprentices receive wages paid by the employer. Considering that the internship covers two-thirds of the program, the employers are strongly involved. If the student cannot find a company internship it is also possible to complete the training inside of the school providing a guarantee that a student can finish their education. The short periods of classroom teaching ensures students achieve the competence goals set for their education.

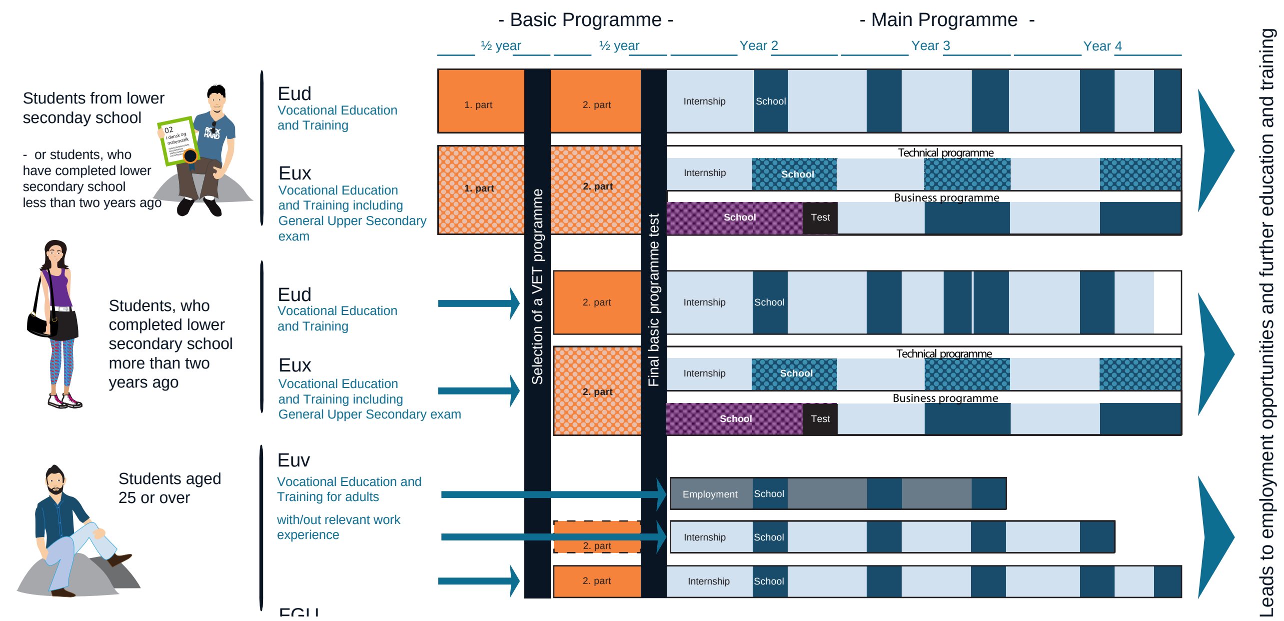
As mentioned above, vocational education typically starts with the first or second part of the basic course, but in special cases, you can also start direc directly on a main course,e.g. in a new master's degree, vocational training for adults, with relevant prior work experience, or if you already have vocational training in the same subject area. **(Grundforløbets to dele, 2023)**

Higher education

With a completed vocational education someone, under specific circumstances, has the opportunity to attend higher education programs. First of all, since EUX gives a general study competence the students have the same rights for higher education as the gymnasium graduates. But also, in traditional vocational education, a student can continue to a professional academy program or professional bachelor as long as they meet the admission requirements for that specific program. Finally, there is also the path of taking some supplementary courses or the Hf program mentioned above. **(Muligheder for videregående uddannelse, 2023)**



ill. 1: The danish education system
source: Ministry of Children and Education



ill. 2: Vocational education system
source: Ministry of Children and Education

The 4 Goals of the Ministry of Children & Education: What are the Revealing Problems?

The Ministry of Children and Education **(Klare mål, 2023)** has set four main goals for the development of vocational education. These goals set a clear framework and direction for the work at the educational institutions. They will also ensure a well-defined follow-up basis, where measurements are made at both sector level and institutional level. From the ministry goals, it is clear to conclude the main problems dictated by the ministry.

Goal 1: "The proportion of students who choose a vocational education directly after the 9th or 10th grade must reach 25 percent in 2020, and the proportion must increase to at least 30 percent in 2025. In 2013, 19 percent of students chose a vocational education directly after 9/10 class."

- The percentage of students who choose vocational education is low.

Goal 2: "The proportion of students who complete a vocational education must increase from 52 percent in 2012 to at least 60 percent in 2020 and at least 67 percent in 2025. "

- The dropout rate in vocational education is high.

Goal 3: "The proportion of the most talented students must increase year by year.

Part 1: The proportion of the best pupils – measured by the proportion of pupils with the total number of subjects who complete at a higher level than the compulsory level set by the subject committees – must be increased year by year. A baseline is prepared starting from the 2013/2014 school year."

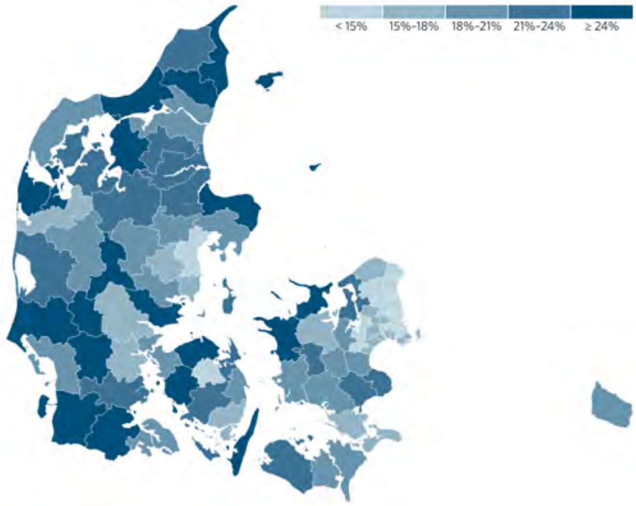
- Most of the students complete the courses at the compulsory level.

"**Part 2:** The high level of employment for new graduates must be maintained"

- The level of employment after school is a priority.

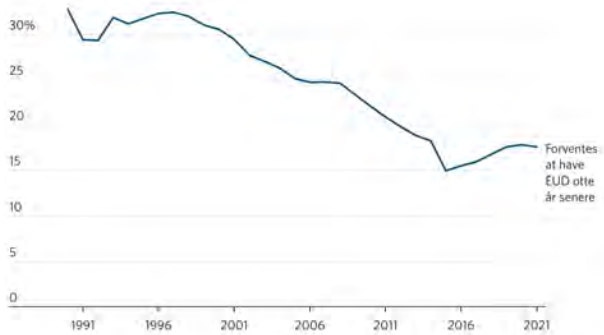
Goal 4: "Pupils' well-being and customer companies' satisfaction must be increased towards 2020."

- The pupils and the companies are not completely satisfied with the system.



ill. 3: Jutland municipalities train many skilled workers – fewer in North Zealand
Map: Arbejderbevægelsens Erhvervsråd, Source AE pba. The profile model published by UVM.

Note: the figure shows the proportion of young people who finished 9th grade in 2021 who are expected to get vocational training within eight years after, distributed by the municipality of residence in 9th grade.



ill. 4: Only one in six young people is expected to receive vocational training
grafic: Arbejderbevægelsens Erhvervsråd, Source AE pba. The profile model published by UVM.

Note: The figure shows the proportion of a youth cohort who are expected to have received a vocational education eight years after 9th grade. The numbers on the x-axis indicate the time of completion of 9th grade.

Low Percentages of Students Choosing & Finishing Vocational Education

As mentioned in the ministry goals the percentage of young students choosing vocational education is very low. This is a complex multifaceted problem and for that reason, many non-profit organizations, think tanks, research institutions, associations, etc. are making various analyses and reports trying to light up the current situation and its socio-economic aspects.

According to research conducted by Arbejderbevægelsens Erhvervsråd (The Workers' Business Council), the ministry's goals for higher percentages in vocational education are far from being met. **(Klarskov & Jensen, 2023)**. Only 17.6% of the young students who finished 9th grade in 2021 are expected to have a vocational education in 2029. The level is approximately the same low as the past five years. The percentage is significantly lower than in the 1990s and the period leading up to the financial crisis.

Current educators and participants of vocational education have also expressed their frustration about the out-of-date equipment, poor physical conditions, and poor quality of teaching in vocational schools. On the Danish Parliament web page for citizens' proposals, there is a protest named "The apprentice uprising: invest in vocational education", with 25,642 supporters. **(Lærlingeoprøret, 2022)**

However, there are large geographical differences in the extent to which young people receive vocational training. According to the figure, there are municipalities in Jutland which are expected almost one in four students to receive vocational education, while on the other hand in the greater Copenhagen area, there are municipalities with percentages lower than 15%.

Choosing a Path in 9th Grade

Presented below some very interesting parts of a survey among 2,109 students in 9th grade about the choice of youth education. **(Klöcker-Gatzwiller & Krog, 2018)** The survey is held by DEA think tank and is part of the project: "What drives young people's educational choices?". The goal is to shed light on this question, focusing on understanding the opt-out of vocational education.

Parents influence

A big part of the survey was researching to what degree parents affect their children's choice.

In the question: "What are your parents' expectations for your choice of youth education?", 38% of the students answered that their parents expect them to have upper secondary education while for another 38%, their parents have no specific expectations about their choice. For vocational education, the percentage was only 8%.

These parent expectations can have a big impact on students' final choices if we take into consideration the results from the question: "To what extent is important that your parents support your choice of education?" The answer "greatly" gathered the bigger percentage of 42% and "to some extent" 33%. Furthermore, in the query "Who are you inspired by concerning choosing youth education?", half of the students add their parents in one of their choices. On the other hand though, for the phrase:" I feel pressured to choose upper secondary school over vocational training" 80% of the students answered "disagree".

Gymnasium: the Choice that Keeps the Doors Open

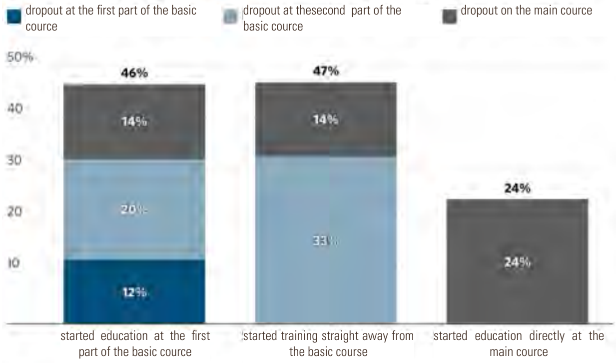
According to the study, 64% of the students believe that graduating from the gymnasium gives them more education opportunities. Furthermore, the gymnasium is to a large extent a postponement of later choices that have a decisive impact on working life. More specifically 41% of the students agree that the gymnasium is the best choice if you don't know what you want, while another 33% were neutral.

In Favor of Choosing Vocational
Education

Another big part of the survey is around questions that investigate parameters that could affect the choice of young people towards vocational school. According to the research, more practical subjects could have led half of the young people to choose a vocational education. More specifically in the question "To what extent could more practical subjects in 8th and 9th grade make you choose a vocational education?" 16% answered "greatly" while another 33% answered, "to some extent". In the same way, at the query, if the students would lean towards vocational education if they had better knowledge about vocational training, 12% answered greatly while 33% answered: "to some extent".

Another intriguing part of the research is the attitude of the students towards the structure of vocational education. The students were asked whether they would choose vocational education if they didn't have to go for an internship at a company. 55% answered that this would affect their choice at all, while 31% answered to a lesser degree. However, to the query: "To what extent could a guarantee for an internship make you choose vocational education" 23% answered "greatly" and 30% answered "to some extent". According to this result, an internship is not a deterrent factor for the students, but the uncertainty of whether they could find one or not is.

Lastly, when the students were asked if they think that the EUD education level is too low, 42% were neutral, and 40% disagreed with that statement.



ill. 5: The dropout is greatest in connection with the second part of the basic course
graphic: Arbejderbevægelsens Erhvervsråd, Source AE based on Statistics Denmark's registers.

Note: the figure shows dropouts from vocational training started in the 2018/2019 school year grouped by the first part of the education (bars) and the last part of education before dropping out (percentage).

Extremely High Dropout Rates

The extremely high dropout rates are another big problem in vocational education. According to an analysis conducted by Arbejderbevægelsens Erhvervsråd, **(Jensen, 2023)**, almost half of the students in vocational school drop out. As mentioned above, the number of students choosing a vocational school is already low, this fact in conjunction with the dropout rate can lead to a significant lack of skilled workers.

The dropout rate has decreased slightly in the last years, from 46% for the year 2015/2016 to 43% for the year 2018/2019, however is still very high. It is interesting to investigate in which part of their vocational education most of the students drop out.

As previously noted a student can start the education either from the first part of the basic course, GF1, or go directly to GF2, even in some cases starting with the main course immediately, always according to the background of each student.

The figure analyzes the students who started their education in the year 2018/2019. As can be seen from the diagram most of the students who drop out are the ones who start from the basic course 46% for GF1 and 47% for GF2, while the dropout rate for those who start directly at the main course is much lower 24%. The majority of the students withdraw either during the second part of the basic course or during the transition between the basic and the main course.

A student typically enters into an agreement with a company during the second part of the training course or the transition to the main course. The fact that the dropout rate is particularly high at this period can therefore be partly because in some places and some industries it can be difficult to get an internship. Additionally, the dropout rates of those who had a school internship instead of a commercial one are even bigger. Developments in recent years, with an increasing number of training agreements, appear to have a positive effect on dropouts. More specifically the dropout rate of those who passed from the GF2 to the main course was 23% for the year 2015/2016 and has dropped to 18% for the year 2021/2022.

From Where Dropout Students Come & Where They Go After

A research held by Danske Erhvervsskoler og -Gymnasier (DEG), is trying to shed light to the question: from where dropout students come from and where do they go after. **(Ilsøe, 2023)**. People in vocational education are a diverse group that consists of both young people coming directly from primary school but also slightly older people and adults. The average age of the students who start GF2 is 25 years old, this means that most of them have done different things before, compared to for example gymnasium students. This is also evident in the diagram. Almost half of the students that later dropped out were engaged in education before while a quarter came from employment or unemployment. 29% represents the group "others", which consists of self-employed, young people who still live at home, pregnant women, retirees, early retirees, and others.

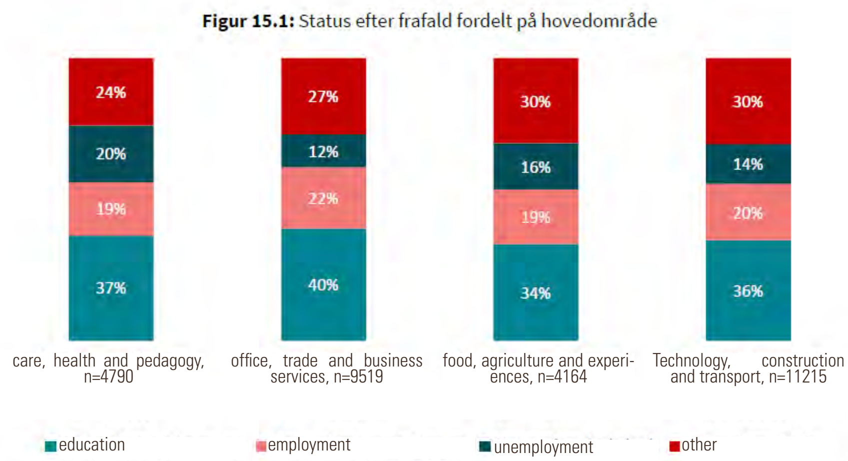
According to the diagram describing the post-dropout status, fewer are starting an education, and more are going to employment in comparison with the pre-accession status. More specifically, 9 percentage points fewer students are starting a degree, and 8 percentage points more are moving towards employment. If the education percentage after dropout is further analyzed, almost half of the students choose vocational education again.

ill. 6: Status after dropout
graphic: Danske Erhvervsskoler og -Gymnasier, Source: Statistics Denmark and DEG's calculations

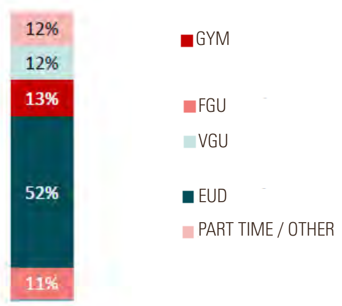
ill. 7: Status before access
graphic: Danske Erhvervsskoler og -Gymnasier, Source: Statistics Denmark and DEG's calculations

Considering the age status of the dropout pupils, according to the data, the older the students the more drop out for employment and unemployment, while on the other hand the younger the students the more choose again education.

Focusing more on the technical education sector, it has one of the highest percentages of students that after dropping out of education chose EUD education again. Focusing even more on just the construction sector 33% are choosing to stay in education and 52% at EUD.



ill. 8: Status after dropout divited by main area
graphic: Danske Erhvervsskoler og -Gymnasier, Source: Statistics Denmark and DEG's calculations



ill. 9: Education status after dropout for the constuction sector
graphic: Danske Erhvervsskoler og -Gymnasier, Source: Statistics Denmark and DEG's calculations

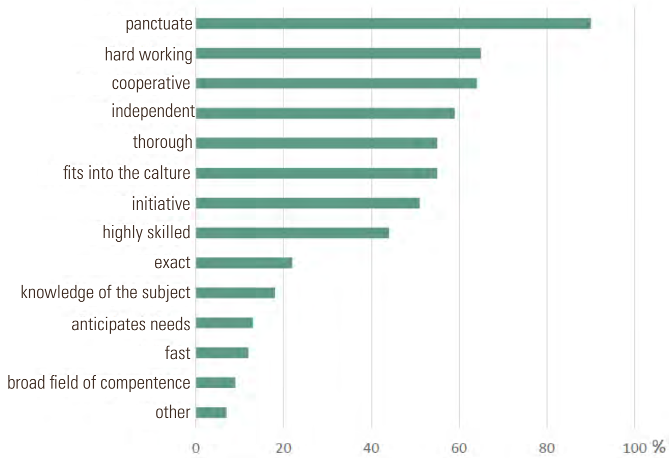
Apprenticeships in Vocational Education

Vocational education is a practical education where most of the time is taken by internship, for that reason companies have a big influence on a student's education. A survey was conducted by the association of Danske Erhvervsskoler og -Gymnasier aiming to present internships from a company perspective and a student perspective. (Schultz, 2020) Through a sociological behavioral analysis, it was tried to achieve a basic understanding of what motivatescompanies to take on apprentices, what keeps them from doing so, and how they experience the internship system.

Furthermore, insight is given into the students' expectations from an internship, and how much they value the commercial internship, the school internship, and the school teaching. In total, the study contains data from 4,095 companies and 3,395 students who started directly from the second part of the basic course.

From the Company's Perspective

The study outlines that companies expect from their apprentices the same things that they would from any employer: to have a strong work ethic and desire to work and learn. We can see from the figure that characteristics such as reliability, hard work, collaboration skills, and independence are considered much more important than the knowledge of the subject or the work speed. These work values such as punctuality, diligence, and cooperation according to the companies must be taught from primary school and students' families, but either way, they should be enforced by the vocational schools.



ill. 10: characteristics of an apprentice/student who is most important to the company.
source: Danske Erhvervsskoler og -Gymnasier

The companies expect from the school to prepare the students for the work life. Besides the values mentioned above, companies expect the school to enforce the same rules that are expected to apply in a company, so students can be prepared for what kind of everyday life awaits them. In other words, the companies need the schools to be much more company-oriented than they are and introduce students more to the real working hours and working conditions.

Furthermore, 27% of the companies find it important that the school helps to much the right student/ intern to the right position. A common characteristic of those companies is that they also have good cooperation with vocational schools. Since the teacher has a better knowledge of the students' competencies but also the industry and the subject, they could play a pivotal role in facilitating the internship placementprocess. Through this collaboration between companies and schools, there is an increased likelihood for companies without interns to be more motivated to engage in such partnerships. Additionally, the schools help with administrative matters, could also act positively for the companies. Finally, a close collaboration between schools and companies can also help in a better individualized adaptation of the internship and school teaching hours.

Internships From a Student Perspective

The vast majority of the students consider job security and opportunities along with internship opportunities as the most important decisive factors while the school's reputation is much lower on the list of criteria. The data support that the students do not choose a school but rather simply end up with what meets the practical criteria they set. Another usual criterion for choosing a school is the company that the individual already works for, which encourages them to go to a specific school. Many of the students have an internship agreement before they start their education and choose their school in close collaboration with the company.

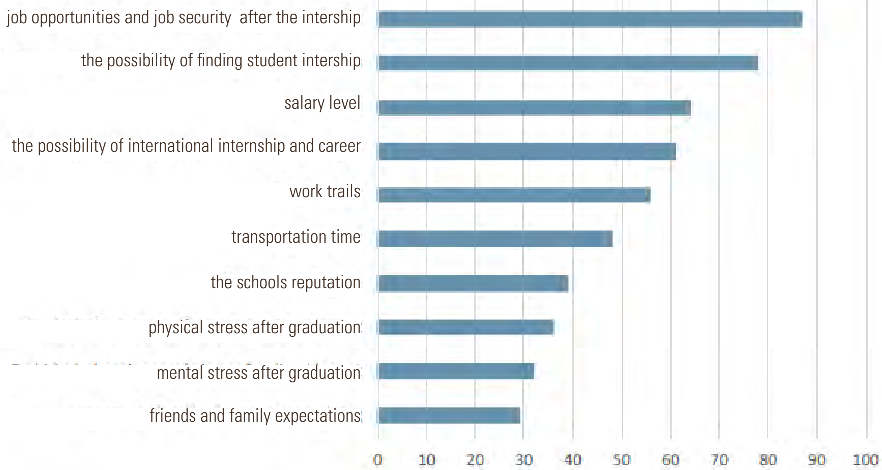
Generally speaking, the students are using a wide range of application methods when it comes to securing an internship. The most popular ones are active ways like visiting the company, using their network, and searching unsolicited. But when it comes to women and adults over 25 years old, they tend to use more passive ways like social media and websites (**Praktikpladsen.dk)**. More specifically 58% of women and 57% of adults over 25 years old expect to use social media while this percentage for men is 44%.

72% of the students still have to make an effort to find an internship, after the start of their education. Some specific characteristics can be identified among those who find an internship relatively early in the education process. 34% of men have an internship agreement, while this percentage for women is 19%. At the same time, 58% of young people under the age of 18 have an internship almost from the beginning of their education, in this situation, parents also play a significant role since 64% of them live at home. According to the research, this percentage is not an indication that companies have a gender or age preference, but it is more up to the application strategies that each social group uses. Companies' behavior and expectations are oriented toward active and targeted application strategies. This could explain why fewer women and young adults over 25 have an internship.

Data indicate that the students are mainly interested in being part of a professional community that is linked to a company or a specific department. On the other hand, they have low interest in the class or school community. In addition, most of the students measure their success by the company's recognition. Only when a student finds an internship, in which they will be recognized as a contributing member who performs tasks in the company, their education is considered successful and worthy.

The students participating in the survey from the very beginning of GF2 have a biased attitude towards school internships. They expect that school internships contribute to poor learning of the subject and can't teach the students the cultural codes of the profession. It is also believed that working tasks in a school internship are hypothetical and unrelated to real-world scenarios. For that reason, the students who end up in school internships are considered to have poor learning competencies and a lack of interest. Additionally, a school internship provides a lower income than a commercial one. The bad learning, the low income, and the lack of real-life experience lead the student to consider school internships as a dead end.

As mentioned above internships play a significant role in the dropout rates since most of the students will not continue their education if they can't find a commercial internship. And since for most students school internship is not a valid option, it is obvious the importance of updating this internship searching system to reduce the withdrawal percentages.



ill. 11: Criteria choosing an education
source: Danske Erhvervsskoler og -Gymnasier

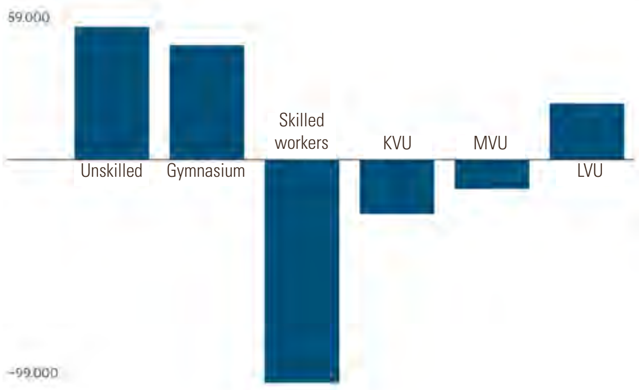
Lack of Skilled Workers

The low percentages of students choosing vocational education along with the significantly high percentages of pupils that are dropping out can lead to various social-economic problems.

A projection made by Arbejderbevægelsens Erhvervsråd (AE) **(Klarskov et al., 2021)** highlights the imbalances that will occur in the Danish labor market in 2030. More specifically, Denmark will lack 99.000 skilled workers. At the same time, there will be a surplus of unskilled labor of 59.000 people and a surplus of academics of 25,000 people. There will also be a shortage of people with short and medium-term higher education.

This lack and surplus projection is very much affected by the number of people entering the labor market and the ones who leave the market (retirement) but is also determined by the market supply in employment positions. The demand for unskilled labor is expected to have a drop of 63% from 1990 to 2030. For that reason, even though the number of unskilled workers is also dropping (18,6% from 2020-2023), there is still a big surplus. This means that the number of unskilled jobs falls faster than the number of unskilled workers in the workforce. On the other hand, the demand for skilled workers remains more or less the same throughout the period 1990-2030, but the supply of skilled workers is lower (-9,6 % from 2020-2030) leading to the expected shortage.

If those labor market imbalances are not resolved, they will have negative consequences for the economy and will also exacerbate social inequalities. Companies need skilled workers to grow and flourish, and their prosperity affects the whole economy. At the same time, unskilled workers will face downward pressure on their wages and higher unemployment. This can lead to a big social imbalance. **(Klarskov, 2021)**



ill. 12: Imbalances in the labour market
graphic: Arbejderbevægelsens Erhvervsråd, Source AE based on Statistics Denmark's registers and the Ministry of Finances 2025 course

Note: the figure shows wich groups will have a superplus or deficit in the labour market in 2030.

Vocational Education: Fostering Innovation and Entrepreneurship

A skilled education is a strong access card to the labor market. In addition to that vocational education can also foster innovation and entrepreneurship. Many skilled tradespeople often have great ideas, start sustainable businesses, and create job openings. An analysis from AE **(Glavind, 2023)** shows that is far from only academics who are entrepreneurs. 1 in 15 skilled workers have their own business (the respective number for academics is 1 in 12), and according to another analysis those companies often turn out to be more viable than the ones from other educational groups. This is important to highlight because a part of society often talks down skilled worker career paths. Like it was mentioned in previous chapters there is a prevailing narrative in both parents and students prevailing narrative in both parents and students that the gymnasium is better for opportunities. Young people need to learn that innovation and entrepreneurship are not only cultivated at the universities but are equally promoted by vocational schools.

A great example of how to show the outside world and especially primary school students, the varied and exciting possibilities of vocational education, is DM I Skills. An annual Danish championship for young people from vocational education. Around 300 participants compete in various categories, having the chance to show their talents. **("DM i Skills," n.d.)**

Adult Education

Adult vocational education (EUV) is also very important to be promoted to increase the number of skilled workers in the labor market. Unskilled workers or skilled workers who want to update their knowledge have a chance to do so through EUV.

Historically, adult education held a prominent place in Danish society, valued for its role in personal enlightenment, leisure, and vocational competence. However, recent years have seen a decline in public and political engagement with adult education. This shift can be attributed to changes in policy-making dynamics.

To understand these shifts, three theoretical frameworks provide valuable insights: the competition state, policy networks and corporatism, and the influence of policy entrepreneurs. Denmark, like many nations, has embraced the competition state paradigm, focusing on enhancing institutional competitiveness in a globalized world. Policy makers, whether private or governmental, exert influence on adult education policies, shaping priorities within the evolving political and economic landscape. The character of Danish adult education reflects a balance between vocational and general elements, emphasizing equal learning oppertunities. Recent reforms have led to a shift in focus, with greater attention placed on enterprise needs and lifelong competence development tailored to labor market demands. This also reflects future demand.

The Danish Government would like to increase engagement and satisfaction with adult vocational education. From 2006 to 2014 twenty-two adult guidance networks were established aimed at strengthening guidance for low-skilled workers and small and medium-sized companies, with a focus on employment and competence development.

There is still however a lack of emphasis on popularizing adult education and engagement isn't high. Currently there is a negotiated 'growth plan' for the Danish economy, including a grant of one billion DKK to increase adult education and training activity over the following six years. This plan aimed to increase participation in vocational training courses and improve continuing education to higher levels of education. This means a reduction of fees for vocational training courses, a reform of part-time vocational education, and new agreements on labor market integration of immigrants and refugees.

The Institutes

All the research information and graphs mentioned on this chapter are extracted from various think tank surveys that are trying to shed light in the different aspects of the problem. A short description of those institutes is following:

Arbejderbevægelsens Erhvervsråd (The Workers' Business Council): Is a Danish economic-political think tank and socio-economic analysis institute dedicated to promoting social justice. They focus on important themes such as the labor market, education, inequality, public finances, social prosperity, and economic opportunities in the green transition. Through collaborative efforts, they provide analyses, reports, and economic forecasts to address societal and economic issues, aiming to contribute to informed decision-making and policy proposals. **(Om Arbejderbevægelsens Erhvervsråd, n.d.)**

Danske Erhvervsskoler og -Gymnasier (DEG): is the association for vocational education, hhx, htx, eud, eux, and amu. DEG works to create the best possible conditions for vocational education and its students. DEG represents member schools' education policy interests to social partners, stakeholders, and politicians. The secretariat provides legal, operational, financial, and HR-related advice to members. **(Om DEG, n.d.)**

DEA: is an independent, non-profit Think Tank that focuses on intelligent investments in education, research, and innovation to foster value creation and growth in Denmark. DEA is conducting high-quality research, analyses, and policy advice, engaging in constructive dialogue with political and key stakeholders, and collaborating with public and private companies to ensure industry insights inform policy development. Their activities include state-of-the-art research, organizing events to stimulate informed debates, participating in public discourse, engaging in collaborative projects, and addressing key societal challenges through a holistic approach to research, education, and innovation systems. **(About DEA, n.d.)**

Danish Evaluation Institute(EVA): "Explores and develops the quality of daycare centers, schools, and educational programs. We provide usable knowledge at all levels and of interest to both local governments, ministries, and practitioners in all educational institutions. Is an independent state institution established under the Ministry of Education in 1999." **(EVA Evaluates and Develops the Danish Educational System, n.d.)**

Social status and regional economy: According to the statistics, the rates of students choosing vocational education differ a lot between the municipalities. The numbers could be affected by the economic and social status differences between the municipalities, but also the type of regional economy and where it depends.

Adult Education programs aren't well known/popularized: Many adults don't know or seriously consider adult education programs. There is a perception that after a certain age education is done.

Weak path for unskilled workers who are unsure: It is difficult to choose how to continue education as an adult, the person in question is unsure of what they would like to do. As a rule, adult education is specialized without the chance to try out a variety of options.

Male bias?: Vocational training especially artisan is a male-dominated field. However, in no part of this research, during which a lot of reports and surveys have been read, there was an indication that women are left out because of their gender. The only gender difference mentioned was on the DEGs internship survey. According to the data women at the beginning of their vocational education have fewer internship contracts than men, but companies argue that this is a matter of application strategies and not gender discrimination.

Design goals

• Facilitate an intriguing education program that corresponds to market needs and gives work opportunities.

• Accessible location that promotes interaction with the rest of the city.

• High-quality architecture space both for learning and socializing activities. An inviting building where students are happy to be there.

• A building that works itself as an educative resource of architecture quality, aesthetics, sustainable techniques, and functionality.

• Well-functioning workshop areas with up-to-date equipment.

• Lecture rooms for providing also valuable theoretical knowledge.

• Socializing spaces where the students can spend their time with their co-students and feel part of the school community.

• Leisure activities, which allow the students to visit the building besides learning, for other fun activities.

• Facilities for the teaching staff, to ensure they have everything necessary to teach students without any disruptions.

• A multifunction space, for exhibitions and other events accessible also to visitors.

•Sex equality in all the facilities and accessibility for all.

Conclusions

Vocational education is an important part of the Danish educational system. It prepares skilled workers for the labor market, where they play an essential role in both companies and the overall economy. However, it is a fact that fewer and fewer students choose this type of education, and among those who do so, the dropout rate is very high. Various think tanks and organizations have conducted multiple surveys, trying to shed light on the different aspects of the situation.

This thesis project aims to create an artisan school, working as a case study proposal. A vocational school for most of the students is just an obligatory means to get to their goal. Instead, the school should be the starting point, a milestone in the life of students where young teenagers are being prepared for the labor market field.

Design Generators

• **Lack of Respect and/or Prestige for the Tades in Modern Society** A big part of society does not recognize the perspective of vocational training in professional growth, innovation, and entrepreneurship. A high percentage of students and parents believe that gymnasium and then higher education give you the best opportunities.

• **Lack of Knowledge About Trades and Vocational Education** The majority of the students in 9th grade declared that they could have chosen vocational school if they had more information about this type of education and more practical courses in primary school. In addition, craftsmanship professions are not that much projected to kids and young people.

• **Vocational Education Quality** Members of society are complaining about the out-of-date equipment, poor physical conditions, and poor quality of teaching in vocational schools. In addition, one of the ministry's goals revealed that the majority of the students pass the courses at the compulsory level.

• **Lack of Respect from the Vocational Students to the Education System**

• Most students choose schools not based on quality but based on more practical criteria like proximity. In other cases, they just go to the school that company's in which they have an internships propose.

• The feeling of success and recognition comes from the companies and internship work and not from the school. School learning is just an obligation.

• They care more about being part of their company's professional community, rather than the school.

•No appreciation for school internship. The level of learning is bad, the wages are lower, and most importantly is considered by the students as a dead end.

• **Failure to Find an Internship.** According to the statistics, the higher dropout rates occur during GF2 and at the transition from the basic to the main course. The same period that students search for an internship. As they have no appreciation for school internships, not finding a company to work with is a dropout reason.

• **The Young Age of Choosing.** After finishing the 9th grade, a lot of the students don't feel ready yet to choose a career path, this in conjunction with the poor knowledge about vocational education is leading them to choose gymnasium. A choice that leaves more doors open. The young age could also be a contributing factor to the dropout rate. A lot of the companies in their interviews argued that the students don't have yet a clear view of everyday life work and work ethics.

USER PROFILES

Any building structure would have no purpose of existence without its users. Aiming to achieve a functional building with an accurate room program, the main and secondary user groups have been identified.

Main user groups:

a) The students attending one of the three programs of the school.
b) schoolteachers

Secondary user groups:

a) lower secondary education students and their parents,
b) architects and artists,
c) Aarhus tech students

In order to identify the needs of this project's main user groups four diverse user profiles were created.

Main User Profiles

16 Year Old Student: Digital Fabrication

Background

He is a young teenager who has just finished 9th grade. He was always inspired by technology. After participating last year in a workshop held by the school about digital fabrication, he decided that working with computer tools, robots, and other machines is an intriguing field.

Aspirations

Acquire the knowledge and skills to work with advanced technologies creating innovative and precise physical objects. Contribute to fields such as design, engineering, or manufacturing fostering creativity problem solving, and proficiency in digital fabrication methods.

Needs

A well-designed curriculum that covers the fundamentals of digital fabrication, including design principles, software proficiency, and practical application.

Access to up-to-date digital fabrication tools, such as 3-D printers, laser cutters, and CNC machines.

Training in the latest software tools in the field, ensuring that he can cope with industry standards and technology advancements.

Well-educated teachers, that inspire him and provide constructive feedback.

Company internship willing to teach him real-life implementation of his work, and give him initiative while at the same time he always having the support of his school and teachers.

To have fun with his co-students outside of school hours playing games and sports.

Digital Fabrication Workshops

Computer Lab

Teacher's Offices

Career Service Office

Sports Facilities

Canteen Area

Game Rooms

18 Year Old Student:
Building Waste Management

Background

She is a young woman who after lower secondary school has been working as a secretary for 3 years. Since she enjoys working with her hands, she decided to explore the realm of artisan crafts. Moreover, she is keenly interested in promoting sustainability through her work and lifestyle. For that reason, craftsmanship revolving around natural and recycled materials is an ideal choice. She aims to promote a circular economy focusing on reduce waste and minimize the environmental impact of construction and demolition activities.

Needs

A specialized curriculum, that covers knowledge of a variety of materials, management courses, and the existing recycling and reuse techniques.

A working space where she can practice and experiment with materials and machinery. Access to actual demolition material.

A research lab where she could work more in depth with the material composition trying to find new effective solutions for building waste.

Teachers who have a comprehensive knowledge of the field and also are willing to help her in her research attempts. Additionally, she would like their support, in adjusting back to the school environment, since she was out of school for some time.

School assistance in securing an internship position where she can participate in demolitions and material management.

Networking opportunities. As a not socially skilled person, she would like the school to help her network with guest lectures, industry events, and connections with professionals in the field.

Lecture Rooms

Event Space

Material Library

Teacher's Offices

Career Service Office

Event Space

Canteen Area

Pilates & Dance Studio

26 Year Old Student: Sustainable Building Construction Techniques

Background

He is an adult working in the construction industry as an unskilled worker for some years now. He decided that he would like to evolve in his field and be educated in sustainable materials and building techniques. He acknowledges that sustainable structures will be the future in his field, so this study seems to be the ideal next step.

Aspirations

To grow professionally in the construction field acquiring specialized knowledge in sustainable practices. He would like to work in this future-oriented field, having a more powerful position with higher responsibilities and a bigger salary.

Needs

Since his education starts with the main course directly, he needs a flexible curriculum where teaching and internship periods are interconnected and co-supported.

Workspace where he can test and be creative with natural materials.

Theoretical knowledge about material properties, modern construction techniques, and construction management.

Teachers who inspire him to explore the world of natural materials and techniques and also help him to implement his existing knowledge into this new learning area.

To work as an intern in a sustainable building company, where he can implement in real life, the knowledge and techniques that he is getting at the same time from school.

To have a workout routine and a place where he can relax and have constructive discussions with his classmates.

Material Library

Lecture Rooms

Teacher's Offices

Career Service Office

Gym Area

Canteen Area

35 Year Old Teacher

Background

He has worked as a teacher for the school for 3 years now.

Aspirations

To ensure students receive a constructive and meaningful education program, the focus is on preparing them comprehensively for the labor market. This involves not only acquiring up-to-date knowledge of software programs, new technologies, and techniques but also instilling strong work ethic and professionalism. The goal is to equip students with a well-rounded skill set that goes beyond technical expertise, fostering their success in the professional world.

Needs

Personally to constantly be educated about the new updates in his teaching field so he can pass them on to the students.

To work with sufficient and up-to-date equipment and software.

To have constant communication with his students even during their internship, mentoring and helping them.

To have a private space where he can work unbothered.

To have rlaxing coffee breaks and lunch breaks.

Lecture Rooms

Computer Lab

Workshop Area

Teacher's Offices

Break Area

EDUCATIONAL PATHS

Overview

This thesis will design a vocational school with a specific educational focus on artisanal education. Instead of only housing traditional vocational education paths new contemporary programs will be included. This is in response to the fact that there is a perception of vocational training as outdated and un-challenging. The creation of programs that educate skilled workers on evolving contemporary fields would assuage some of this sentiment. As such the three main education paths will be:

1. Digital Fabrication: It has already brought a revolution in building techniques, so more and more qualified artisans will be needed in the future.

2. Carpentry: In order to change the perception of skilled workers and address future shortages traditional paths such as carpentry should also be made more attractive

3. Sustainable Building Construction: Building techniques for green and zero energy buildings, environmental materials and techniques is the future of building construction.

Graduates from the above learning paths will have a solid educational background in contemporary building construction, while also having skills useful in more typical conditions. Each of the programs have areas in common allowing the common first year to be more useful and for collaborative projects to further engage the students. The students would be working with contemporary techniques, contributing to environmental sustainability, growing a diverse set of skills, while having a creative educational experience. Having an exciting collaborative education would be a way to improve student interest and engagement while providing exiting non-academic challenges. Additionally, it allows for the vocational school to be a place that supports continuing education for current artisans who want to continue to develop their skills. By creating areas of professional development, the idea that becoming a skilled worker is a dead end could begin to be addressed.

Digital Fabrication

Education: Individuals can pursue specialized education programs. Students can focus on CAD, parametric modeling, and 3D printing, or focus mote on automation covering subjects such as mechanics, electronics, and robotics.

Skills and Competences: Expertise in CAD, 3D printing, and additive manufacturing techniques. They should be creative, innovative, and detail oriented. Technical skills in troubleshooting, debugging, and maintenance of automated systems. They should also possess strong communication skills and service-mindedness.

Job Description: Digital fabrication is pivotal in shaping the future of manufacturing. Digital fabricators leverage computer-aided design (CAD) and additive manufacturing (3D printing) to produce intelligently designed products. They can also work with automated systems, troubleshooting, repairing, and optimizing processes in various industries.

Future Prospects: Graduates can work in prototyping, additive manufacturing, robotics, and technology selection roles. With industries increasingly adopting automation to enhance efficiency and competitiveness, the demand for skilled professionals in digital fabrication and automation technology is expected to grow steadily, offering ample opportunities for career advancement and development.

Carpentry

Education: The carpentry program combines classroom learning with practical internships, allowing students to apply theoretical knowledge in real-world settings. Students gain insight into the entire construction process, from drawing to completion, and learn traditional craft techniques. Additionally, they study environmental considerations, safety regulations, and building codes. It is important to note that carpenters also need to develop drafting skills in computer programs such as AutoCAD as well as a general understanding of physics and mathematics. After completing basic courses, students advance to apprenticeships in companies, where they receive hands-on training alongside continued schooling.

Skills and Competences: A journeyman carpenter can plan and execute assignments while adhering to quality standards and regulations. They possess knowledge of materials, structural methods, and assembly techniques. Carpenters stay updated on construction regulations, prioritize environmental considerations, and engage in ongoing training programs. They can specialize in building timber structures, installing flooring, roofs, windows, or creating furniture.

Job Description: A carpenter is responsible for a wide range of wood and construction tasks in both residential and commercial buildings, including new construction and renovations. This can involve setting up kitchens, laying floors, installing windows, and working on large roof trusses. Carpenters utilize both practical skills on-site and theoretical knowledge for tasks such as construction drawing and energy calculation.

Future Prospects: Trained carpenters have diverse career opportunities, including employment with construction firms or self-employment. Their skills are valued internationally, providing opportunities to work abroad. As wood becomes a more popular building material due to environmental considerations the need for such skilled workers will skyrocket.

Sustainable Building Construction

Education: Individuals can pursue specialized education programs. Students can focus on CAD, parametric modeling, and 3D printing, or focus mote on automation covering subjects such as mechanics, electronics, and robotics.

Skills and Competences: Expertise in CAD, 3D printing, and additive manufacturing techniques. They should be creative, innovative, and detail oriented. Technical skills in troubleshooting, debugging, and maintenance of automated systems. They should also possess strong communication skills and service-mindedness.

Job Description: Digital fabrication is pivotal in shaping the future of manufacturing. Digital fabricators leverage computer-aided design (CAD) and additive manufacturing (3D printing) to produce intelligently designed products. They can also work with automated systems, troubleshooting, repairing, and optimizing processes in various industries.

Future Prospects: Graduates can work in prototyping, additive manufacturing, robotics, and technology selection roles. With industries increasingly adopting automation to enhance efficiency and competitiveness, the demand for skilled professionals in digital fabrication and automation technology is expected to grow steadily, offering ample opportunities for career advancement and development.

ARCHITECTURAL APPROACH

Architectural Triad

In previous sections, specific methodologies and frameworks were defined to provide a basis as for how to achieve a high-quality architectural solution. The three aspects of Utilitas, Firmitas, and Venustas **(Pollio, 2019)** were identified as being important and historical architectural triad.

In order to respond to the information detailed in the previous sections the triad has been slightly modified to better suit the specific priorities of the project. This slight re-prioritization is a useful way of creating a targeted tool from a general framework.

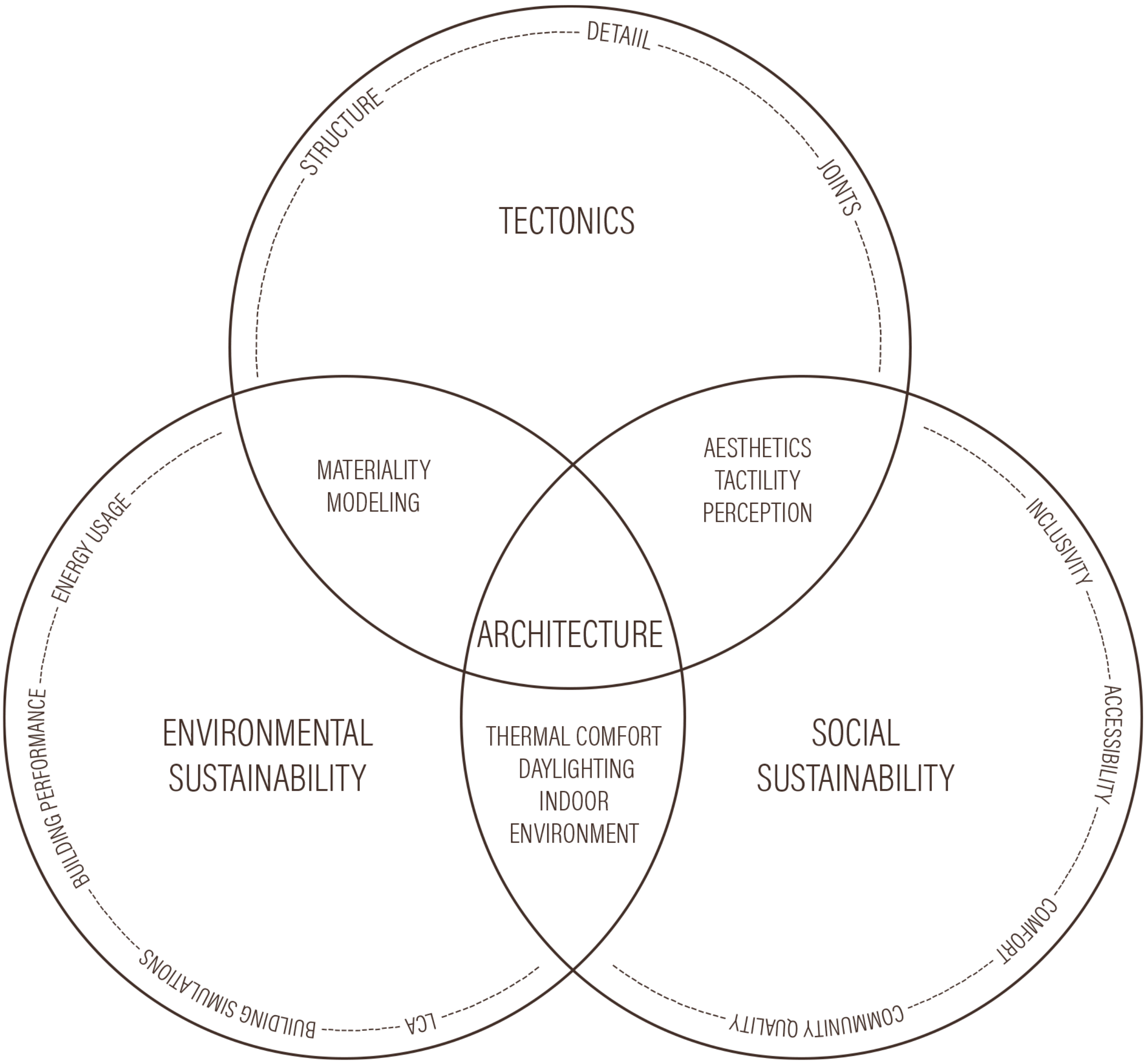
The three chosen project-specific fundamental aspects of architecture are:

ENVIRONMENTAL SUSTAINABILITY

TECTONICS

SOCIAL SUSTAINABILITY

Each of the aspects and their synergies will be defined in the following pages and will serve as guiding principles.



Social Sustainability

Social sustainability, within the realm of architecture, refers to the capacity of built environments to foster and support social well-being, equity, and cohesion over time. It encompasses the design and implementation of spaces that promote community engagement, and a sense of belonging among users. From an architectural standpoint, social sustainability involves creating environments that prioritize accessibility, safety, and comfort for all users, regardless of age, ability, or socioeconomic status. This may include considerations such as flexible space usage, adequate amenities, and integration with surrounding communities. Ultimately, social sustainability aims to enhance the quality of life and promote positive social interactions within the built environment.

Specifically, within the context of this thesis
Social Sustainability aims to address issues with the perception of vocational education in Denmark
mark.

As outlined earlier there are issues with student interest, retention, and generally respect for vocational education. Therefore, within this project the broad idea that social sustainability should facilitate positive social interactions becomes more specific when considering public perception of skilled workers. Improvement in these issues can be achieved through a project that increases student attendance and retention through nice environments, updated equipment, and intriguing classes. Creating a sense of community within the school with extracurricular facilities would also be helpful. Finally, spaces such as exhibition areas can enable interaction between the general public and the vocational fields in order to begin to make them less mysterious.

Environmental Sustainability

The significance of sustainability in contemporary architecture cannot be argued. All major architectural firms have a sustainability strategy, and it is becoming increasingly central in building legislation. One new method for evaluating environmental sustainability is the “cradle to cradle” approach that introduces a cyclical perspective which considers a building from its conception to its destruction **(Cradle to Cradle, 2018)**. These ideas are also embedded within a life-cycle assessment (LCA), where the environmental impact of the products used in a building are evaluated and mapped by taking into account their lifespan from sourcing raw materials, manufacturing, transportation, use, recycling and final disposal**(Life Cycle Assessment, 2018)**. This granular approach means that a building can be evaluated based on its impact.

Another tool that can be used when exploring environmental sustainability is building simulations. Building simulation involves the use of computational tools and models to simulate various aspects of a building’s performance, such as energy usage, thermal comfort, daylighting, and indoor air quality **(Hnin, 2023)**. By trying different design scenarios and parameters,it becomes possible to optimize building performance, reduce resource consumption, and minimize environmental impact throughout the building’s life-cycle **(Hnin, 2023)**.

These simulations allow the assessment the environmental performance of a building design before construction begins, enabling informed decision-making and design optimization. For example, simulations can help determine the most effective strategies for passive design, such as orientation, shading, and natural ventilation, to maximize energy efficiency and occupant comfort **(Hnin, 2023)**.

Furthermore, building simulations facilitate the evaluation of renewable energy systems, energy-efficient technologies, and sustainable materials, helping to identify the most cost-effective and environmentally friendly solutions. By integrating building simulation into the design process, architects and engineers can create buildings that not only meet functional and aesthetic requirements but are also environmentally sustainable.

Tectonics

To define tectonics it is useful to first reference the origin of the word. Its etymological origins are the Greek word tekton which meant a carpenter or builder **(Frampton, 2001)**. Incidentally the word tekton is also the root of the word architect from architekton which translates to master builder **(Frampton, 2001)**. It was also used in relation to poetry because "the tekton assumes the role of a poet by being the maker and connector of elements." **(Frampton, 2001)**. Embodied within the origin and meaning of the word tectonics there is the idea of building at a high level of quality and with a depth of meaning that can be said to "prioritize the poetic expression of construction" **(Mafalda Fabiene Ferreira Pantoja et al., 2012)**.

Eduard Sekler's 1965 essay Structure, Construction, and Tectonics provides a good foundation to creating a more in-depth and contemporary definition of the word tectonics. Within the essay he helpfully defines the three titular concepts and their relation to one another. According to Sekler, structure is a buildings conceptual system of how to deal with the forces acting upon it. Construction is the tangible and practical realization of this system through material selection and technique **(Sekler, E. F., 1965)**.

Sekler then explains that implementing a structural concept through construction produces results in a building's expression that visualizes the relationship between force and form, structure, and construction **(Sekler, E. F., 1965)**. This in a nutshell is Seklers definition of tectonics:

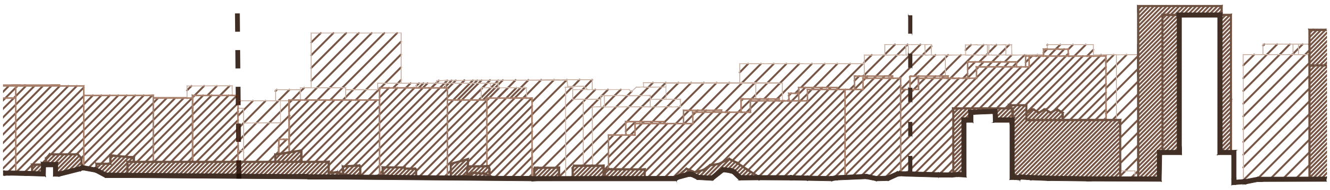
"Tectonics refers to the expressive qualities of architecture that result from the interaction between form and force. It encompasses the visual manifestation of structural concepts and their relation to the overall architectural expression. Tectonics emphasize how architectural elements convey the experience of forces related to forms within a building" **(Sekler, E. F., 1965)**

In addition to the tension between structure and construction various other elements are embodied within the definition of tectonics. The choice of materials, which should be somehow related to the climate cultural context of a building (**Semper & Mallgrave, 2010)**, have a great impact on tectonic expression as well as the use and spatiality **(Mafalda Fabiene Ferreira Pantoja et al., 2012).**

Therefore, for the scope of this thesis, tectonics can be defined as architectural expression arising from the interplay of structure and construction with an emphasis on selection of materials, influenced by environmental and cultural factors, as well as the spatial arrangement and functionality

Synergies

Now that the three aspects of architecture for this project have been defined, exploring how they overlap is also useful. To ensure seamless integration of these theoretical fields and to enhance the project's holistic value, careful leveraging of their synergies throughout the design process is needed. Environmental Sustainability and Social Sustainability synergize closely, as part of the project's objective is to improve user experience and facilitate a broad shift mindset and behavior while meeting environmental standards. It is important to use passive strategies that simultaneously ensure user comfort. Tectonics also overlaps the other two frameworks. A tectonic approach is crucial for effectively engaging users, introducing tools to manipulate sensory aspects of the project and influence perceptions of the built environment, and helps define the structure of a project. Material choice has a direct correlation to environmental impact and subsequently the structural strategy. On the other end the aesthetics and tactility tie into the perception and ambience of a design.

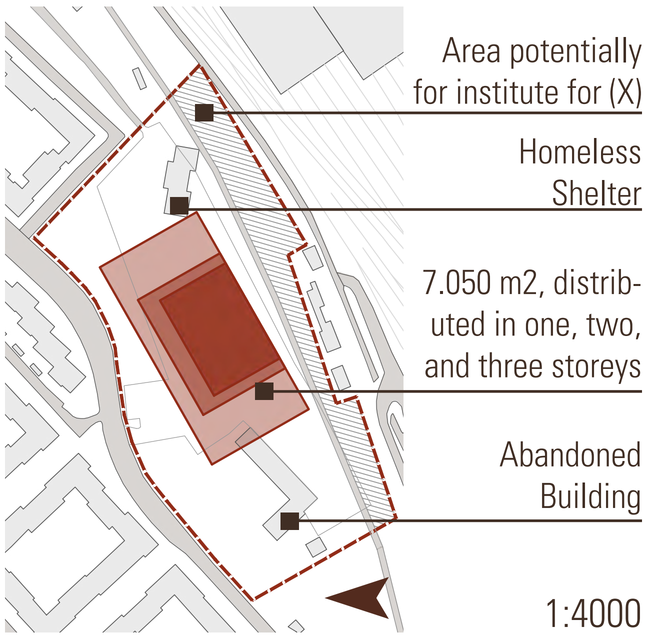


SITE

Site Uses

The site area chosen for this thesis project is located at the city center of Aarhus city, surrounded by a variety of building uses and organized infrastructure. Currently, the site is an open space area working as a parking space. The mixed uses of the surroundings mean that the site has a direct relation to many different types of spaces. An interesting characteristic of the location is that is surrounded by educational and cultural uses that can easily be related to a craftsmanship school. The proximity to Architecture school, Via University College, and Aarhus Tech provides opportunities for interaction and collaboration. At the same time, one of the site's closest neighbors is the Institute for (X), a scattered collection of small informal structures hosting cultural events, small businesses, and some residences. Students could possibly have the opportunity to collaborate with the organization or the hosted business and help them with building structures, and exhibitions or participate in other happenings. Furthermore, Godsbanen is also a cultural center that hosts multiple events and facilitates small workshops that can be used by the citizens, providing a connection between craftsmanship and the public.

On-Site Conditions



Design Generators

- Central location: interaction with the city
- Proximity to educational institutions
- Opportunities for collaboration
- Cultural institutions in the surroundings
- Possible to collaborate in events

Design Goals

Create spaces that facilitate future interactions with the surrounding uses.

Site Use Map: 1:6000

1 SITE
2 INSTITUT FOR (X)
3 STARK HARDWARE STORE
4 AARHUS TECH
5 VIA COLLEGE
6 AARHUS SCHOOL OF ARCHITECTURE
7 GODSBANEN
8 ARoS AARHUS ART MUSEUM
9 TRAIN STATION
10 SPORT FACILITIES

EDUCATIONAL
CULTURAL
COMMERCIAL
RESIDENTIAL- LOW-RISE
RESIDENTIAL- MID-RISE
RESIDENTIAL- MID-RISE MIXED USE


8
7
6
2
5
1
4
3
10

Figure Ground Map

This simplified visual representation of the built-up areas and open spaces helps to emphasize the most significant 'solid' areas while also showing the gaps between. The 'figures' around the site are between two extremes - dense residential development on one side and void space on the other. The shape of the city can be seen to follow the river in the north and the railway to the south. Residential blocks take up a large footprint but are actually very permeable, public and commercial buildings have a more dense character.

Design Generators

A designed interplay between the built and the open.

Design Goals

Keep with the character of the open spaces and built environment through an appropriately sized and shaped development.

Infrastructure Map

Typically artisan schools are placed outside city centers since they need big facilities, and their workshop areas are considered unattractive buildings. A good example is Aarhus Tech, which has its construction field education campus located 20 minutes from the city center by bike. In contrast its gymnasium and food field studies are centrally located.

The objective in selecting this site location was to create a centrally positioned building that would be easily accessible to all students, while also being prominently visible to the city and engaging with its surroundings. As can be seen from the map, many different bus routes provide a sufficient connection, while the proximity to the train station is an extra advantage. All roads around the site area have bike lanes, making accessibility with bikes easy. Car access is possible only in two of the site sides from Thomas Koppel's Gade and Dan Turrels's Gade, providing potential access points for loading.

Design Generators

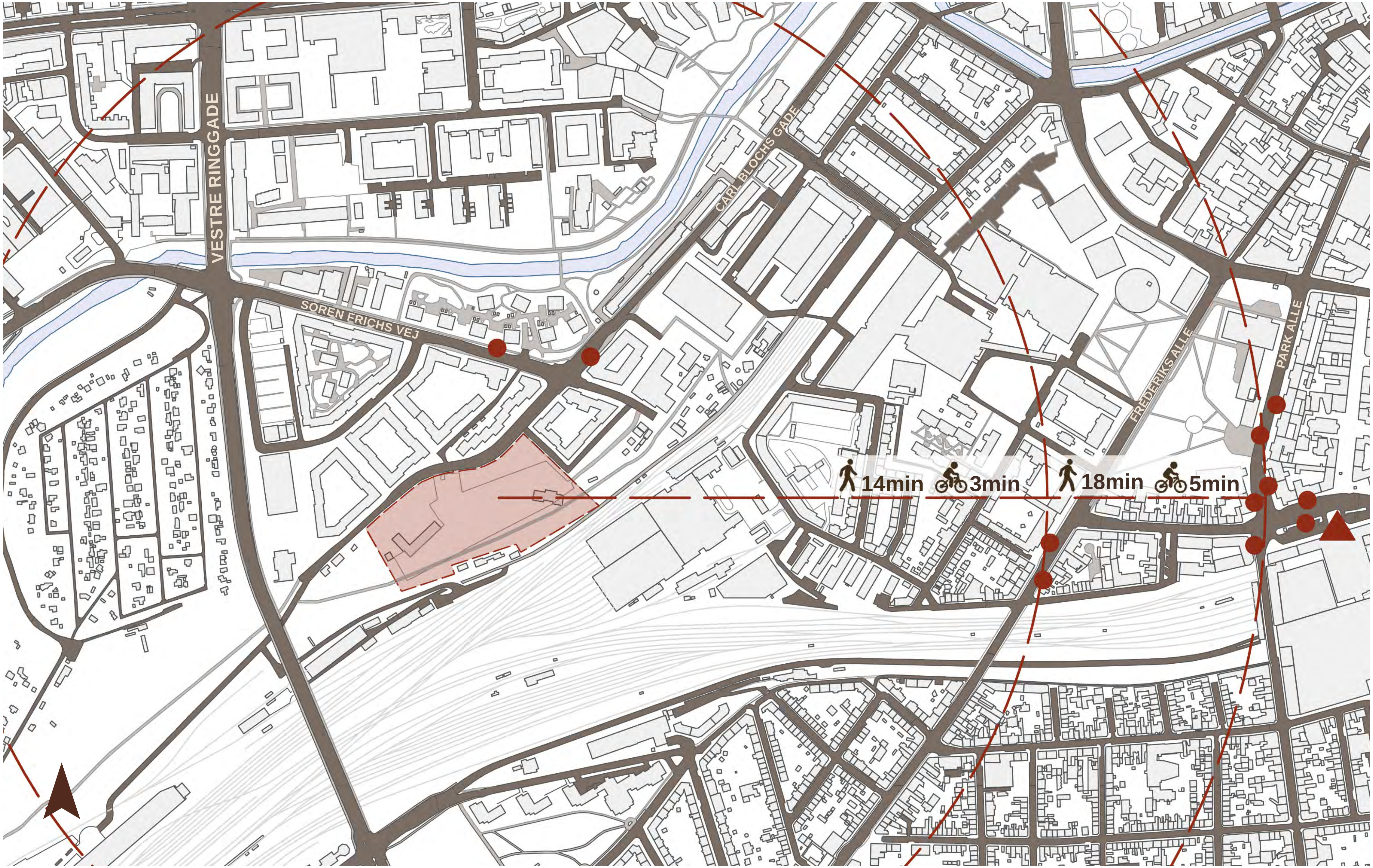
- Central location.
- Easily accessible by foot, bike bus, and train
- Only accessible by car from two of the site sides.

Design Goals

- Specify clear site entrances for both cars and abicycles.
- Define a strategy for material transport to the asite.
- Parking configuration: take into account the aparking building next to the site.

Infrastructure 1:6000

CAR - BIKE LANE
PATH
BUS STOP
TRAIN STATION



VESTRE RINGGADE
CARL BLOCHS GADE
SØREN FRICHS VEJ
FREDERIKS ALLE
PARK ALLE
14min
3min
18min
5min

Photo Map

1.-6. Site views

1.

2.

3.

4.

5.

6.

7.-9. Context Photos

7. Homeless shelter

8. Old tracks path

9. Train parking

22
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10.-17. Institut for (X)

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17.

18.-20. Neighboring Buildings

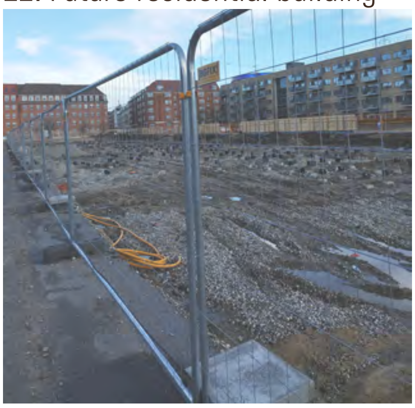
18. Godsbanen (Public Crafts)

19. Architecture School

20. Private parking Building

21. Commercial building

22. Future residential building



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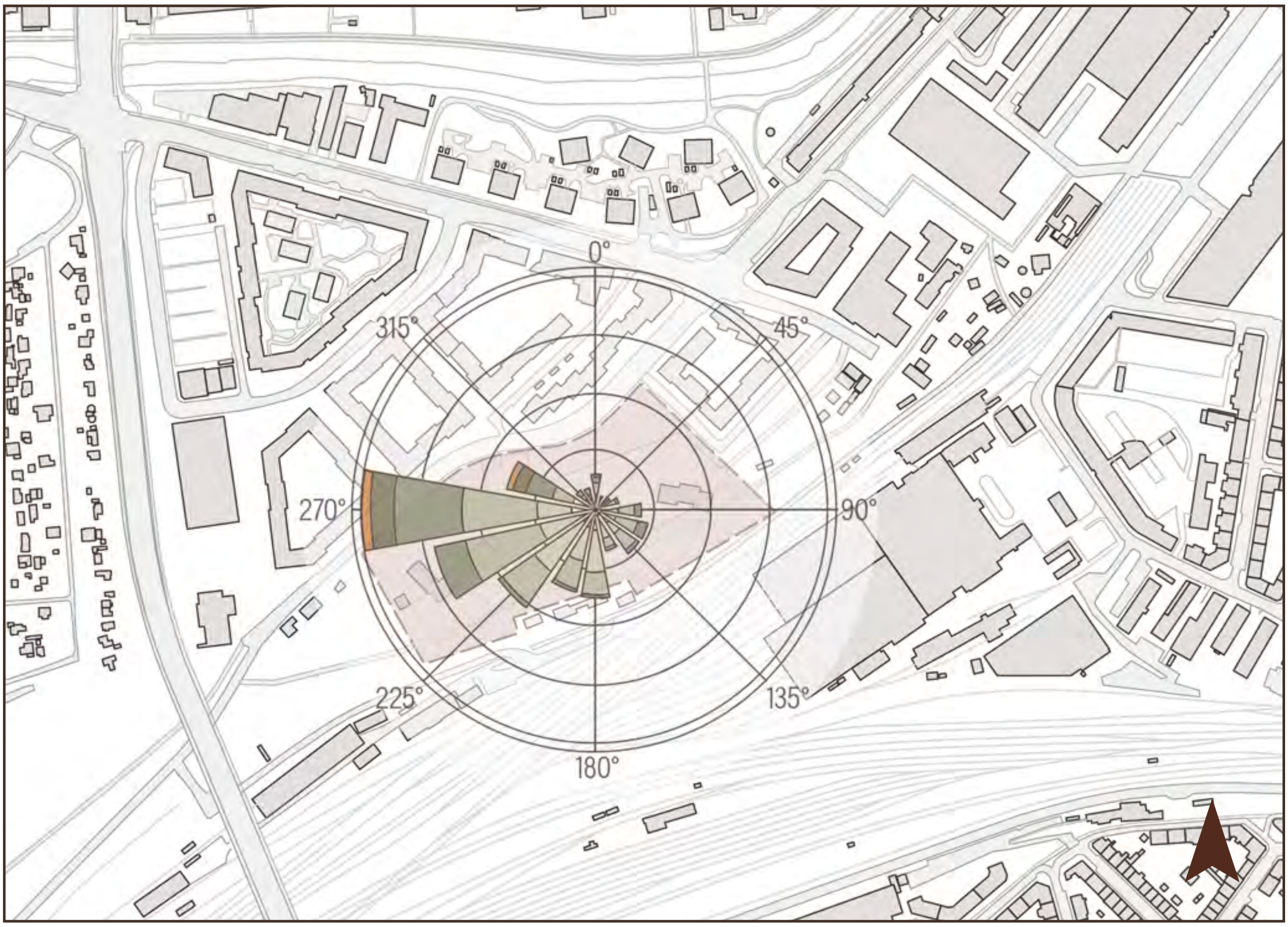
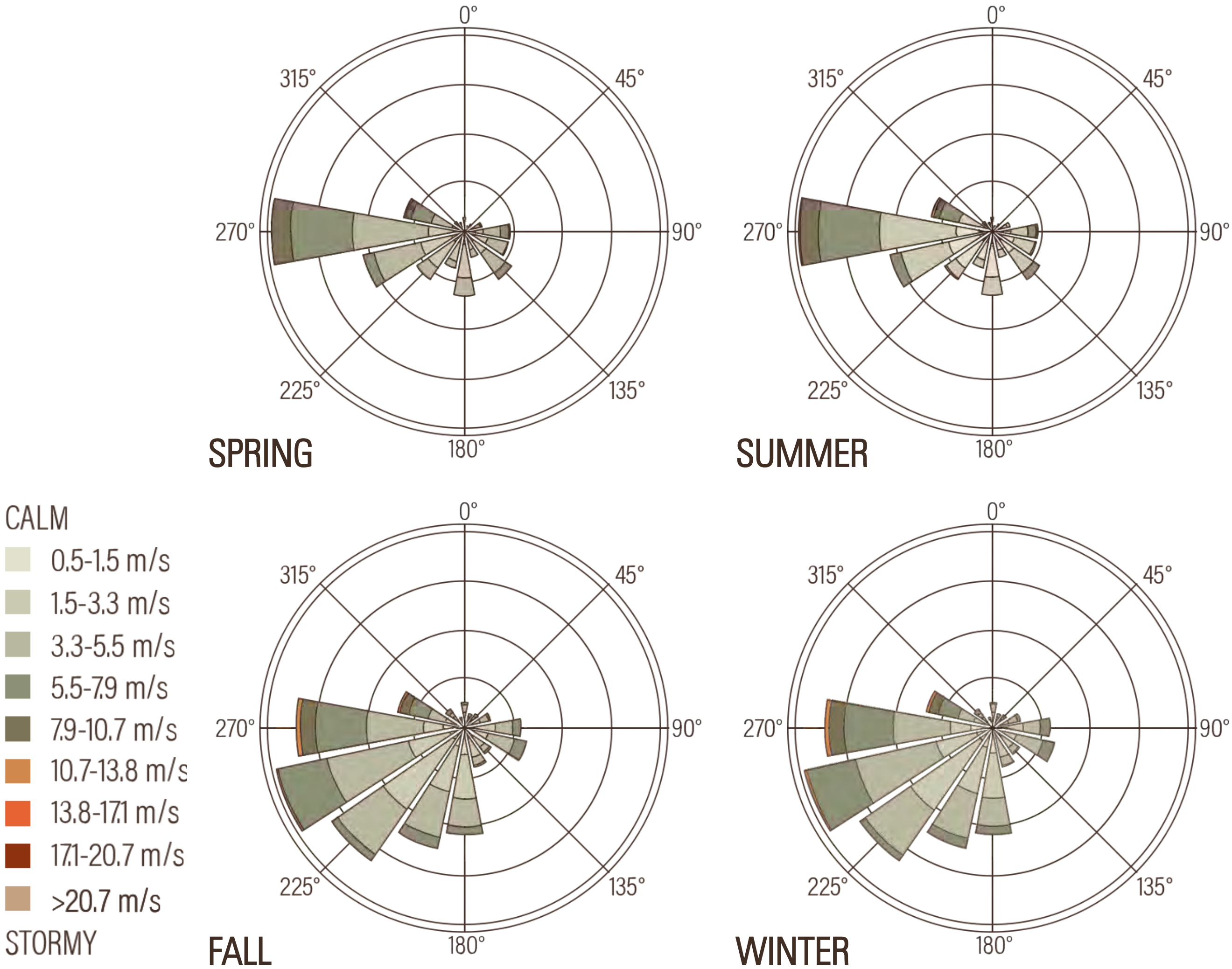
Wind Analysis

Generally, annually, the wind comes from the west and southwest with some seasonal variation in fall and winter. In the summer and spring, the wind coming from the west can be used for cooling and natural ventilation withing the building. Positioning openings on the building envelope accordingly is important. In, fall and winter the wind direction changes slightly to south-west. The ventilation strategies calibrated to the summer winds would still work, but the air temperature would provide an unwanted cooling effect on the interior. Smaller openings should be available to use when ventilation is necessary.

When configuring the site, it is important to implement wind sheltering strategies in exterior spaces to ensure user comfort, especially in the colder months. It is also important to accommodate openings of different sizes to allow for ventilation at different temperatures. Some of the wind sheltering strategies could also act as sounds buffers and some noise can be carried over from the large street west of the site.

Annual Wind Rose - 1:5000





Design Generators

Western and South-Western winds buffet the site, with opportunities to be used for cooling from the west & south-west in summer.

Design Goals

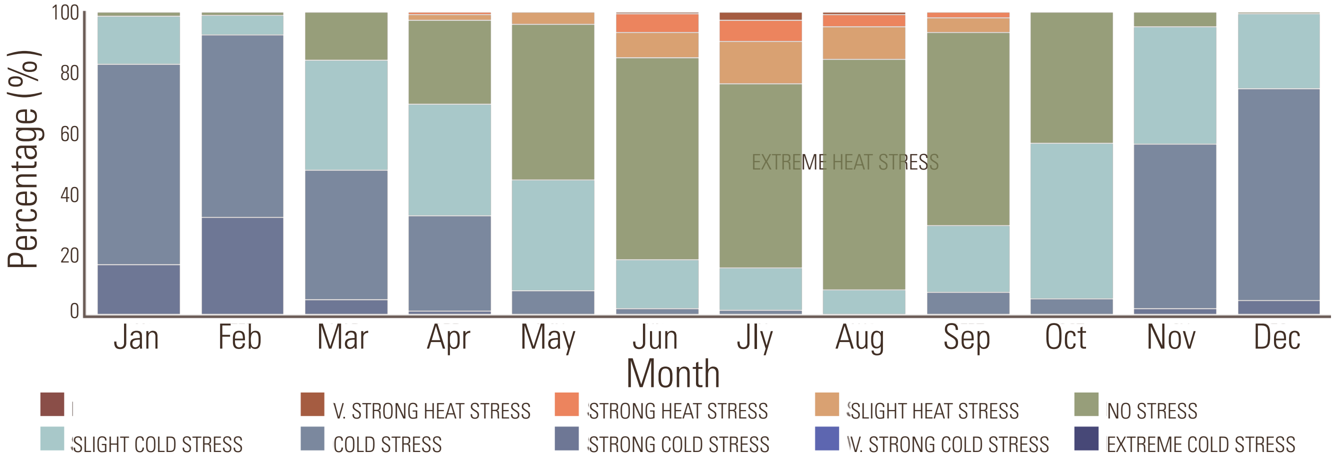
- Use the wind in passive building strategies such as natural ventilation in a way that keeps spaces cool in summer and warm in winter.
- Filter the wind through the site

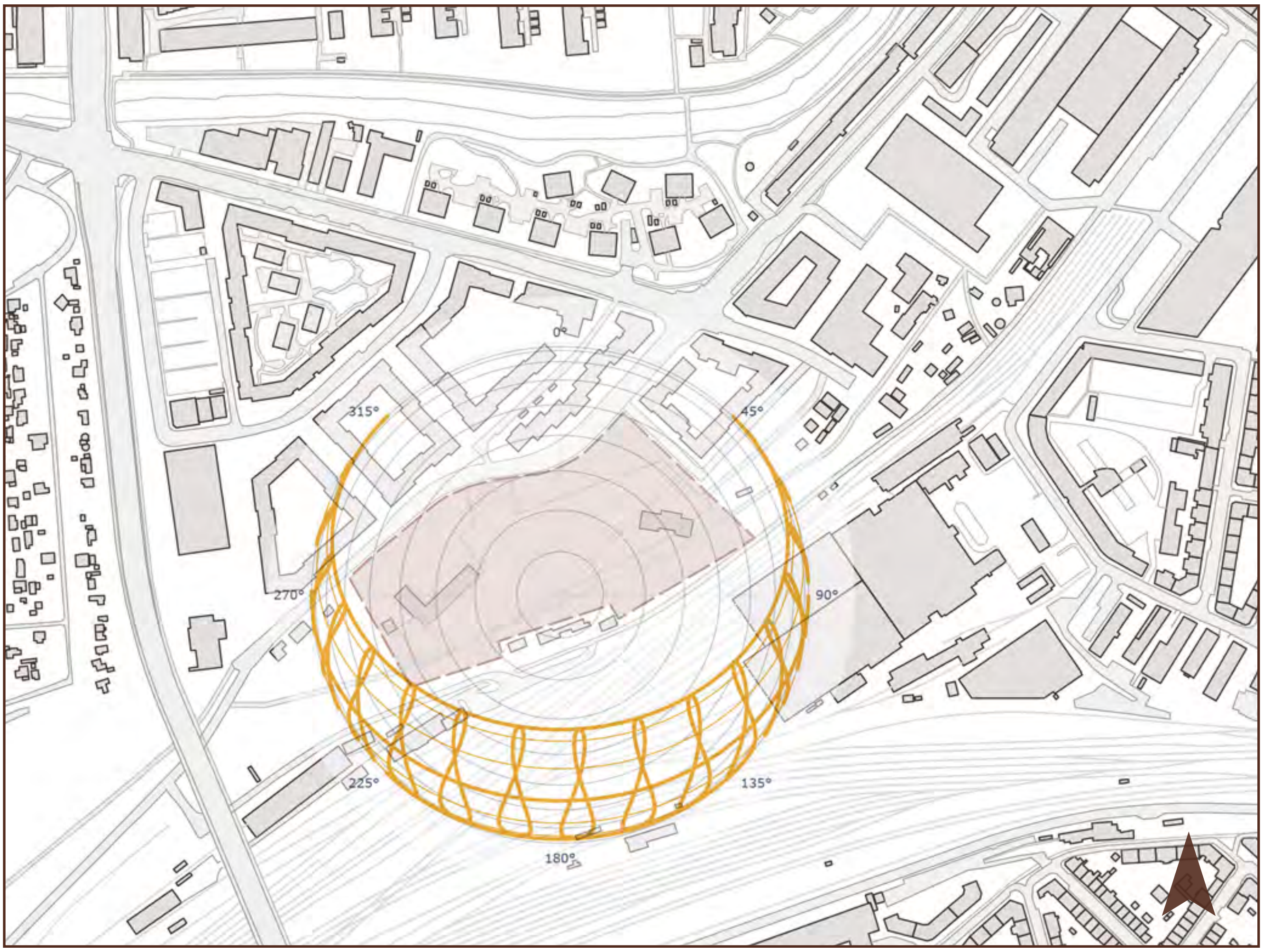
Solar Analysis

As typical, the high summer sun casts much shorter shadows compared to the winter sun. In both cases there is ample unobstructed sun exposure on the site. There are train tracks towards the south which ensure an open southern frontage, along with limited areas for development to the east and west. The north has already been built up with little room for further infill. When considering the thermal stresses typical throughout the year taking advantage of the sun can help address cold stress which is more prevalent in Denmark.

This is especially important in exterior and unconditioned spaces. Inversely it is important to be careful of overheating in summer due to passive strategies designed to combat cold thermal stresses.

UTCI - Thermal Stress Distribution





Sun Path - 1:5000

Design Generators

Unobstructed sun exposure from east to west, and no significant shading. Railway location ensures this persists into the future.

Design Goals

Ensuring as many spaces as possible get suitable amounts of natural light while using passive strategies like passive heating and avoiding overheating.

Flooding Analysis

This map illustrates the areas prone to flooding under a rainfall intensity of 70mm. The calculation incorporates factors such as soil infiltration and drainage. Given that a significant portion of the site is covered with pavement (hardscape) and is predominantly flat, it is apparent that certain areas accumulate water. This issue is expected to escalate with the addition of buildings and other hard surfaces in the landscape. In addition, due to climate change, flash floods are becoming more common and intense.

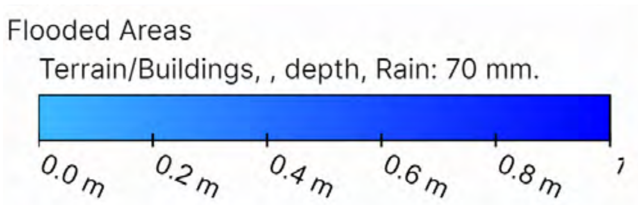
Design Generators

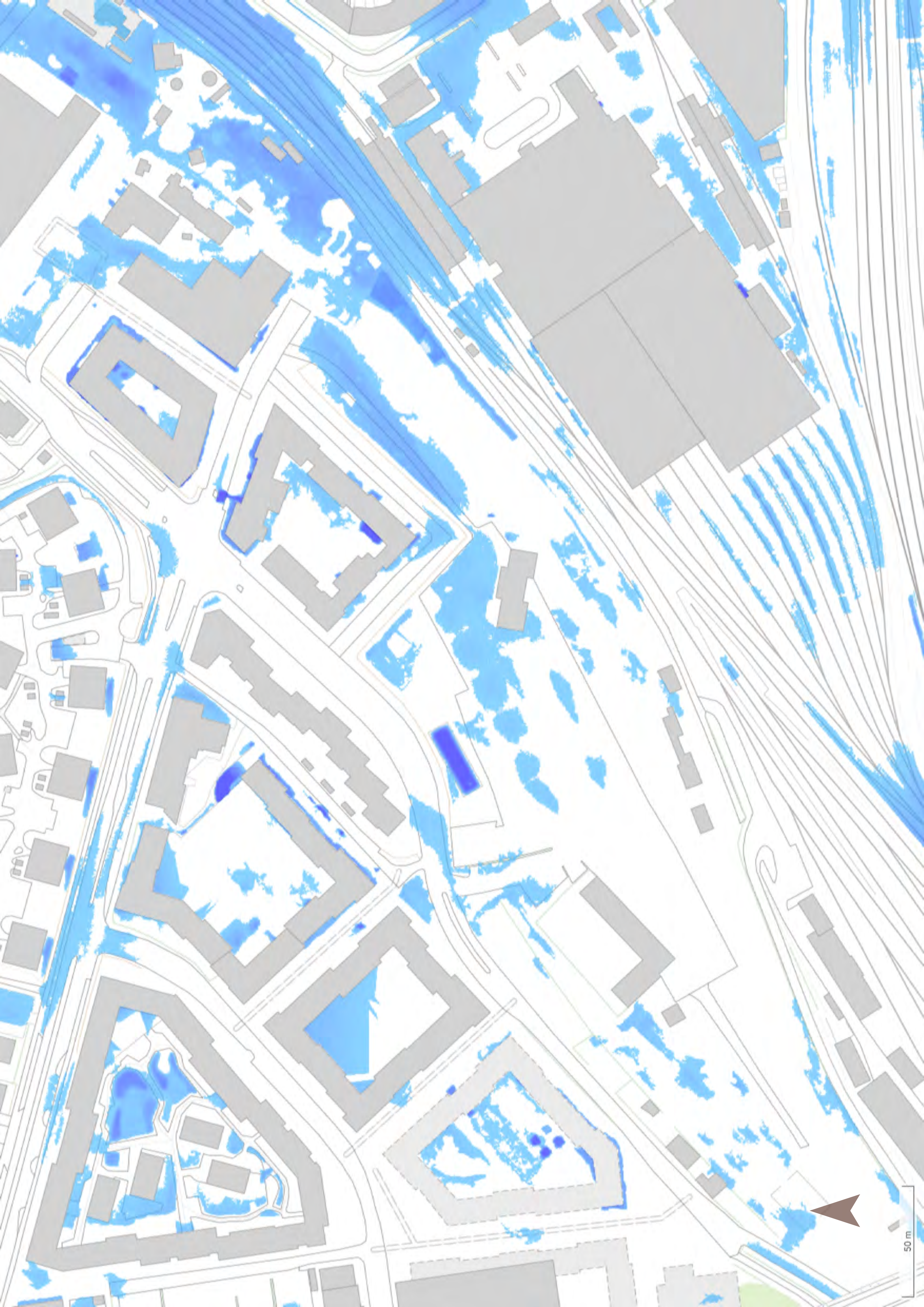
Water accumulation during flash floods.

Design Goals

Create efficient building and landscape water management.

Flooding Area Map - 1:2000




50 m

OCCUPANCY SCHEDULE

One of the things that separates vocational education from academic education is the amount of time students spend away from school. After the first year of study, students only spend roughly one third of their time in the school building and the rest at their apprenticeships. This means that a vocational school has very different occupation loads depending on the month or day, all of which need to be naturally accommodated without pushing the school over capacity or making it feel empty.

In the schedule to the right the different month to month peak is described. In the case of the school being developed in this thesis there are three programs, with 60 students in each for a total of 180 students per year. This breaks down to an average of 4 classes of 15 or 3 classes of 20. Students if their first year are present in the school year-round as they learn about their different options for specialization. After the first-year students begin their internships and main courses. The main courses take place in the school and interrupt the internships.

In this scenario the first of the main courses are staggered in the first three months with year 2,3, and 4 taking turns to be in the school. Additionally, those not attending their main courses will have biweekly check-ins on Mondays or Fridays. In this part of the year the students needing to check in are divided into four groups of 90, bringing the peak to 450. The second main course takes place after the winter holidays at half moth intervals and has the same monthly peak. After the main courses are done, the monthly check-ins shift to having the entire year of 180 checking in at the same time. This is the quietest part of the year with a peak of 360 students. Lastly, at the year's end, all students will be present for a collaborative course for a large peak of 720.

This variable occupation makes the presence of flexible spaces highly important. Areas such as event spaces and canteens should be able to be transformed to serve as study spaces for students when needed. The larges peak at the end of the year is scheduled to be at the warmest, most comfortable time of year so that exterior spaces can also be used.

	SEPT	OCT	NOV	DEC		JAN	FEB	MAR	APR	MAY	JN	JL	AUG
YEAR 1	180					180							
YEAR 2	180		90			180 90	180	180			180		
YEAR 3			180	90		180	90		180		180		
YEAR 4	90*			180		90	180			180	180		
PEAK	450					450	360				720		

*	WEEK	M	T	W	Th	F
YEAR 3	WEEK 1					
YEAR 4	WEEK 2					
YEAR 3	WEEK 3					
YEAR 4	WEEK 4					

YEAR 3 = 60 + 60 + 60 = 3 GROUPS

YEAR 4 = 60 + 60 + 60 = 3 GROUPS

YEAR 3 = (60 + 30) + (30 + 60 = 2 GROUPS)

YEAR 4 = (60 + 30) + (30 + 60 = 2 GROUPS)

Design Generators

Variable monthly occupancy peaks.

Design Goals

- Avoid having unused spaces.
- Avoid being overcapacity.
- Create flexible spaces that can accommodate different uses according to the current building needs.

DESIGN GOALS & ARCHITECTURAL SOLUTIONS

Design goals

Uses

• Facilitate an intriguing education program that corresponds to market needs and gives work opportunities.

• Accessible location that promotes interaction with the rest of the city

• High-quality architecture space both for learning and socializing activities. An inviting building where students are happy to be there.

• A building that works itself as an educative resource of architecture quality, aesthetics, sustainable techniques, and functionality.

• Well-functioning workshop areas with up-to-date equipment.

• Lecture rooms for providing also valuable theoretical knowledge.

• Socializing spaces where the students can spend their time with their co-students and feel part of the school community.

• Leisure activities, which allow the students to visit the building besides learning, for other fun activities.

• Facilities for the teaching staff, to ensure they have everything necessary to teach students without any disruptions.

Architectural Solutions

• A well-organized building program, with functions that complement each other.

• Make the campus inviting by creating transparency in some of the student-active zones.

• Determine the public and the only students' site areas

• A building that combines: Efficiency, Functionality, Indoor environment quality, Flexibility, and Zoning activities (intensity, operative temperature, acoustics)

• Well-detailed structure.

• Having construction and structural parts visible to the students

• Spacious configuration, high ceiling rooms, circulation strategies, well-lit, hand-washing, and shower accessible.

• Classrooms for small groups, with indoor environment quality.

• Couch areas for relaxation and communication, and a spacious canteen area.

• Playroom and puddle court for socializing and having fun. Work out opportunity with a gym and Yoga/ Pilates area.

• Office space with both private and open space areas and a break room.

Design goals

Uses

• A multifunction space, for exhibitions and other events accessible also to visitors.

• Sex equality in all the facilities and accessibility for all.

• Create spaces that facilitate future interactions with the surrounding uses.

Figure Ground

• Keep with the character of built environment through an appropriately scaled development.

Infrastructure

• Specify clear site entrances for both cars and bicycles.

• Define a strategy for material transport to the site.

• Parking configuration: take into account the parking building next to the site.

Wind

• Use the wind in passive building strategies such as natural ventilation in a way that keeps spaces cool in summer and warm in winter.

• Filter the wind through the site

Sun

• Spaces get suitable amounts of natural light using passive strategies, avoiding overheating.

Flooding Analysis

• Water accumulation during flash floods.

Occupancy Schedule

• Avoid having unused spaces.

• Avoid being overcapacity.

Architectural Solutions

• Flexible room for different kinds of events. Careful transition from the private to public areas.

• Open collaborative spaces with good visibility. Restrooms and changing rooms for women.

• A Multipurpose event space to tie in the building with the community

• Study spaces that allow for collaboration between programs and possibly the neighboring architecture school

• Have a building volume and height that fits into the surrounding context, maximum of 6 storeys

• Create circulation diagrams for tracks cars bikes and pedestrians

• The storage and loading areas needed to support the building happening in the assembly studios should have convenient access to the streets to make loading more efficient.

• Large South-Western openings for the summer, with smaller openings to the west to avoid heat loss during winter.

• Landscape features to filter out the wind during the winter months

• Large south-facing windows, with ventilation opportunities. Thermal masses.

• Water management strategies (In and Outside).

• Create flexible spaces that can accommodate different uses according to the current building needs.

BUILDING PROGRAM

Besides the decision concerning the three types of education hosted in CraftTech, a more detailed building program with all the functions that should be facilitated was created. This table is a result of careful research combined with all the outcomes of the chapters above.

The investigation of the existing situation and how architectural solutions could contribute towards solving some of the problems was one of the inspiration sources. Another source of inspiration was the method of user analysis and the creation of specific personas trying to figure out their needs, preferences, and expectations. In addition, the occupancy schedule analysis highlighted the need for flexible spaces. Nonetheless, those investigations were not enough to create a detailed building program.

Focused research was made on the existing vocational schools in Denmark what programs they offer, and how are their facilities. The focus was mainly driven by two of them Aarhus Tech, and UCH Holstebro. Those two schools offer programs like builder, carpenter, and automation technician. Information from their website was extracted along with a Google Maps investigation of their facilities that gave useful results to the research. There was also an attempt to communicate in person with Aarhus Tech, aiming to talk with some of the teachers, visit their facilities, or learn some numbers about the sizes of their student groups in each specialization. Unfortunately, the response from them was negative.

Continuously the research was focused on finding architecture plans from other vocational schools. Although some architecture studios have published their plans concerning vocational schools, those were useful up to a certain level since none of them was focused on craftsmanship.

Finally, the investigation led to the floor plans of the Aarhus School of Architecture one of the building neighbors of the project. As mentioned before, the nature of architecture is directly associated with craftsmanship and even more specifically with the education specializations of CraftTech. The school facilitates one big assembly studio and various workshops as a wood workshop and robot lab. Besides the various facility types, the floor plans were used also as a main source of dimensioning the various spaces, from the workshops to the canteen and the library of the project. Additionally, the standard dimension for classroom spaces per student number was used for the traditional school classrooms.

All the above led to a detailed building program with various spaces, specific people capacity, and m2. The next step would be to define the appropriate indoor environment quality specifications for each of those spaces including some of the main factors: Indoor air quality, daylight, and temperature levels. All the numbers were based on the Danish standard regulations and are explained further in the process chapter.

Function Diagram

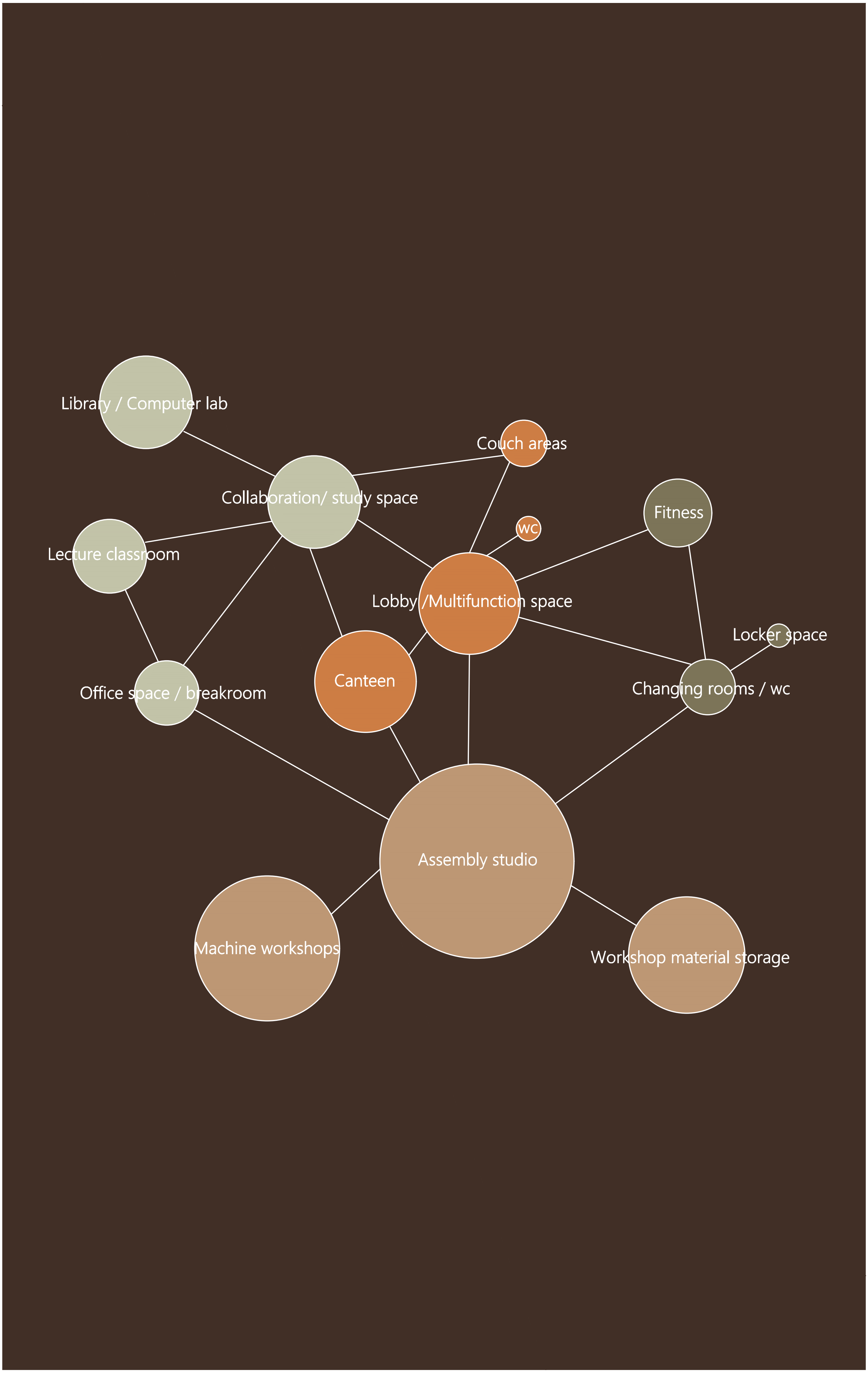
The diagram to the right illustrates the relationships between the spaces included in this vocational school. In turn these spaces are based on the architectural solutions derived from the project's design goals. The size of the circles represents the area dedicated to each space, further detailed in the following pages.

The building's functions can be divided into three categories: public spaces, passive areas, and active areas.

The public spaces are in orange and include areas like a multifunction event space. This could be used as a gallery depending on the time of year, or as work areas at busier times.

The areas in green include spaces also typically found in academically focused programs such as lecture rooms or study spaces. These are the passive spaces. These areas typically have a lower activity level and are only for student use. Some places like the fitness studio are more active, but once again are separated from the public.

Lastly the spaces indicated in tan are directly related to artisanal education and can be seen as more active. As vocational students spend most of their time in these spaces, and because of their very nature they tend to be large they take up the most area.



Library / Computer lab
Couch areas
Collaboration/ study space
Fitness
wc
Lecture classroom
Lobby /Multifunction space
Locker space
Canteen
Office space / breakroom
Changing rooms / wc
Assembly studio
Machine workshops
Workshop material storage

Program table

					Ventilation	
Program	User	Area / m2	Capacity	Number of Rooms	Strategy	IAQ (l/s)
Machine workshop 1	Students Teachers Workshop stuff	400	20	1	Mechanical	700
Machine workshop 2	Students Teachers Lab technicians	350	20	1	Mechanical	630
Assembly studio	Students Teachers	500	60	3	Hybrid ventilation	1120
Lecture classroom	Students Teachers	50	20	15	Hybrid ventilation	175
Library / Computer lab	Students Teachers	380	60	1	Hybrid ventilation	686
Workshop material storage	Students Stuff menbers	450	2	1	Hybrid ventilation	-
Collaboration/ study space	Students	300	100	3	Hybrid ventilation	910
Lobby / Multifunction event space	Students Teachers Visitors	380	150	1	Hybrid ventilation	1316
Changing rooms / WC	Students	150	100	1	Mechanical	805
WC	Students	35	5	4	Mechanical	59.5
Locker room	Students Staff members	-	-	-	Hybrid ventilation	-
Teachers Office space	Teachers	200	20	1	Hybrid ventilation	280
Stuff Office space	Stuff members	50	6	1	Hybrid ventilation	77
Breakroom	Teachers Stuff members	50	26	1	Hybrid ventilation	217
Canteen	Students Teachers	450	225	1	Hybrid ventilation	1890
Kitchen	Stuff members	40	4	1	Hybrid ventilation	84
Yoga/Pilates/dance studio	Students	50	15	2	Hybrid ventilation	140
Gym	Students	80	30	1	Hybrid ventilation	266
Mechanical room	Stuff members	350	3	1	Mechanical	511
Circulation / Couch areas	Students Teachers Stuff members	2100	420	-	Hybrid ventilation	4410
Total m2		8820				

Daylight			Operative Temperture		
Type	lux	Activity	Cooling Months	Heating Months	Orientation
Diffused	500	1,5 met	23-26	16	North
Diffused	500	1,5 met	23-26	16	North
Direct	500	1,5 met	23-26	16	South
Diffused	500	1,2 met	23-26	20	East
Diffused	Reading area 500, Book area / Computer 300	1,2 met	23-26	20	North
-	-	-	35	0	North
Diffused	500	1,2 met	23-26	20	South
Direct	300 -500 (during summer peak)	1,5 met	23-26	16	South
-	-	1,5 met	23-26	16	-
-	-	1,5 met	23-26	16	-
-	200	1,5 met	23-27	16	-
Diffused	500	1,2 met	23-26	20	East
Diffused	500	1,2 met	23-26	20	East
Direct	300	1,2 met	23-26	20	East
Direct	300	1,2 met	23-26	20	South
Direct	500	1,5 met	23-26	16	East
Direct	300	1,5 met	23-26	16	North
Direct	300	1,5 met	23-26	16	North
-	-	-	-	-	North
Direct	-	1,5 met	-	-	North

PRESENTATION

The following pages present the final architectural solution of this thesis. The resulting vocational school is called Craft Tech, and has many design goals it aspires to reach architecturally, tectonically, and sustainably. How these goals were addressed and the logic behind the chosen methods can be found on the following pages.


STUDIO 1

SITE PLAN

1:600

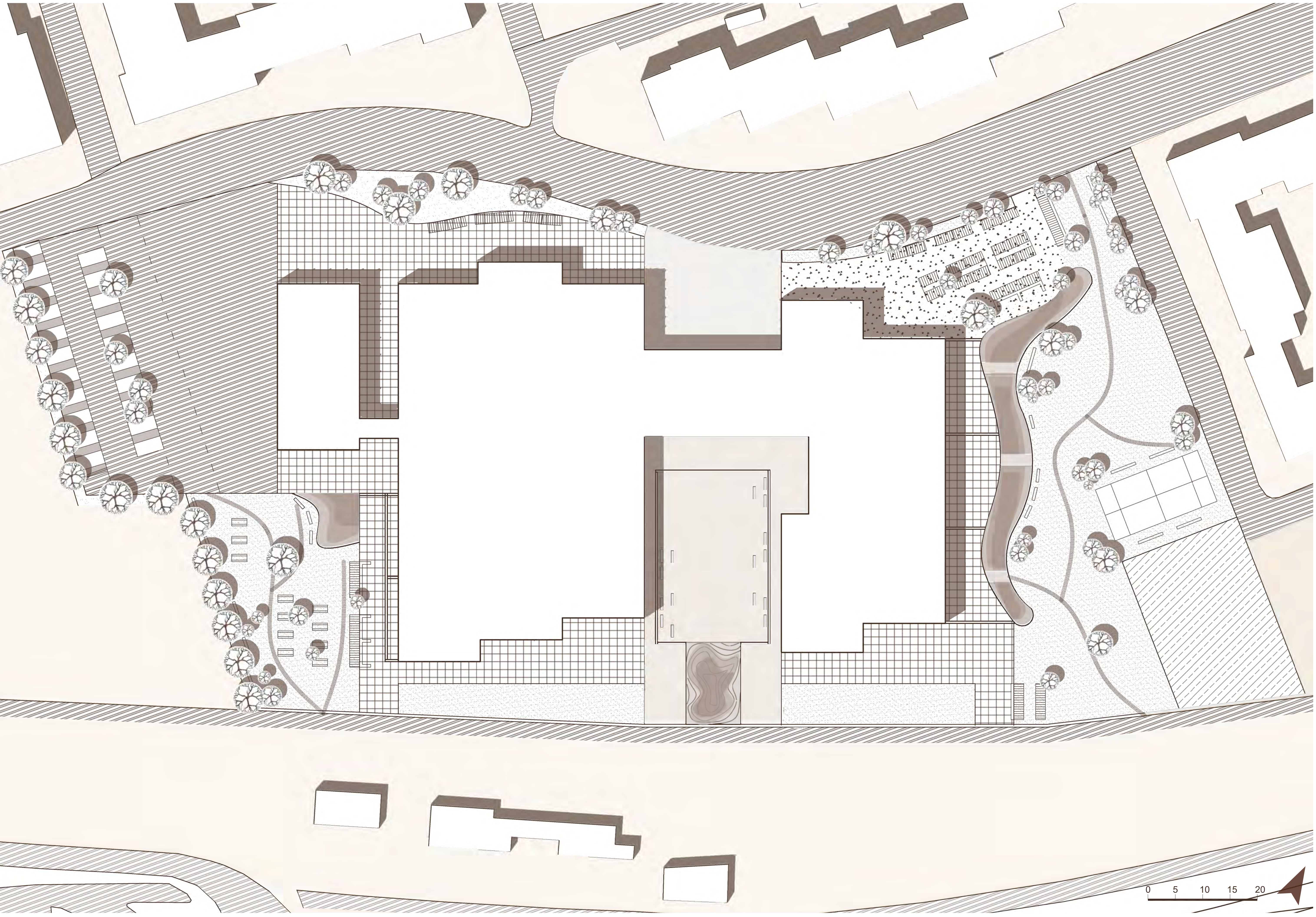
The way the building ties into it's surroundings is vitally important. One of the reasons students don't choose vocational education is due to unattractive locations, therefore tying in with the urban fabric of a city like Aarhus is a way to make students feel like they're part of a broader community.

Traffic, both pedestrian and vehicular, runs east-west along the north and south facades. Different types of pavings are used to control this traffic, and separate key spaces. In the west is the car parking as well as a loading area located right beside the storage building of the school. Here asphalt is used to accommodate the weight of trucks delivering the construction materials the students will be using. The rest of this area is tied off by the parking lot. It is intended mainly for staff use and is supplemented by an existing parking garage a block away. The spaces between the parking spots are filled with trees and tall grasses to minimize their visual impact. This area is protected from the western wind by trees which also frame the quiet garden to the south, used by students on their breaks.

Centrally located, the main points of entry are intended for pedestrians and bicyclists, which make up the majority of our users. There is bike parking on both sides of the building - along the west facade and the north-west. The main parking is the latter and both have inbuilt flexibility. Due to our variable occupancy schedule and key points throughout the year the overflow users can use the paved areas to the north of the building. This paved area wraps around the building allowing the building to open up to the outside as supplementary space during peak loads or in good weather.

Along the border of the main southern courtyard there are drainage canals converging in a rainwater feature right at where the school borders the public path to the south. Similar channels exist on the west, and both are ultimately channeled to the east area of the building when into a large rainwater collection pond. These water features, along with vegetation, are used to separate the public areas from the more private spaces meant for staff and students. They either serve as gateway objects or as barriers as in the east.

This is especially important as to the east there is a public park, serving as an interface to the neighboring Institute for (X). Hosting padel courts and pubic paths the park is meant to draw in the public closer to the building so that they can be more exposed to vocational education. This will allow them to see student projects exhibited in that area and become aware of events hosted by the building, promoting the trades as a whole. However, perhaps the most important space in the park is the flexible space that is set aside for the use of Institute for (X). In this space students, in collaboration with the needs of their neighbors, will build a structure built for disassembly every year as a semi-permanent instillation. This will be a collaborative project for students of all three years and the resulting structures will reuse the materials in different ways each time.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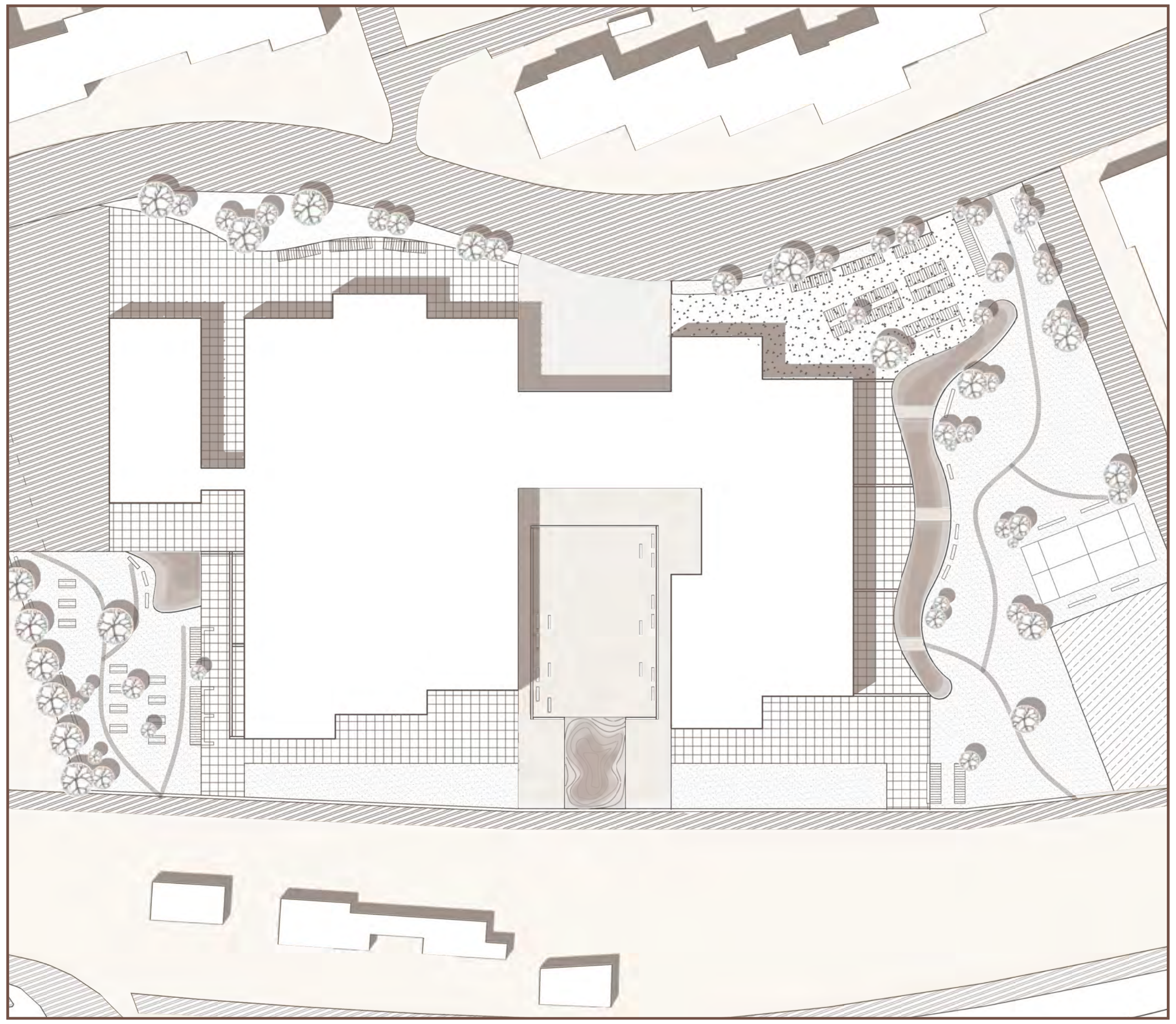


ROOF PLAN

1:400

PV Panels & Energy Framework

All of the southwest roofs of the building are 70% covered by photovoltaic panels aiming to provide all the necessary building energy needs. The type of pv panel chosen is the thin film. Even though this PV type has less efficiency than the monocrystalline and polycrystalline has other advantages. Thin film panels use significantly less material for manufacturing, they have lower cost and due to their lightweight, their transportation and installation are much easier. Lastly and most importantly, this type of pv panel fits better the aesthetic of the building design. The lack of a thick frame and their matte finish with less visible grid helps to be integrated more smoothly into the roof assembly. It was designed to be placed between the roof corrugation creating a pattern. Their color will be dark red, creating a nice connection with the sedum roofs of the project.

Using the program Be18, we calculated the total energy framework for the east building volume of the school. The calculations indicate that the building requires 48.8 kWh/m^2 per year. Based on the solar cell margins provided by the program, this result qualifies the building for a low-energy framework class.

The next step ofter those calculation would be to calculate the total energy that can be produced by the project's panels. A solar radiation analysis, was held using the program Grasshopper taking into account the specific orientation and angle of rotation for the project. Leading to the following results:

Incident solar radiation received: 1156.97 KWh/m^2

Solar panel efficiency: 16%

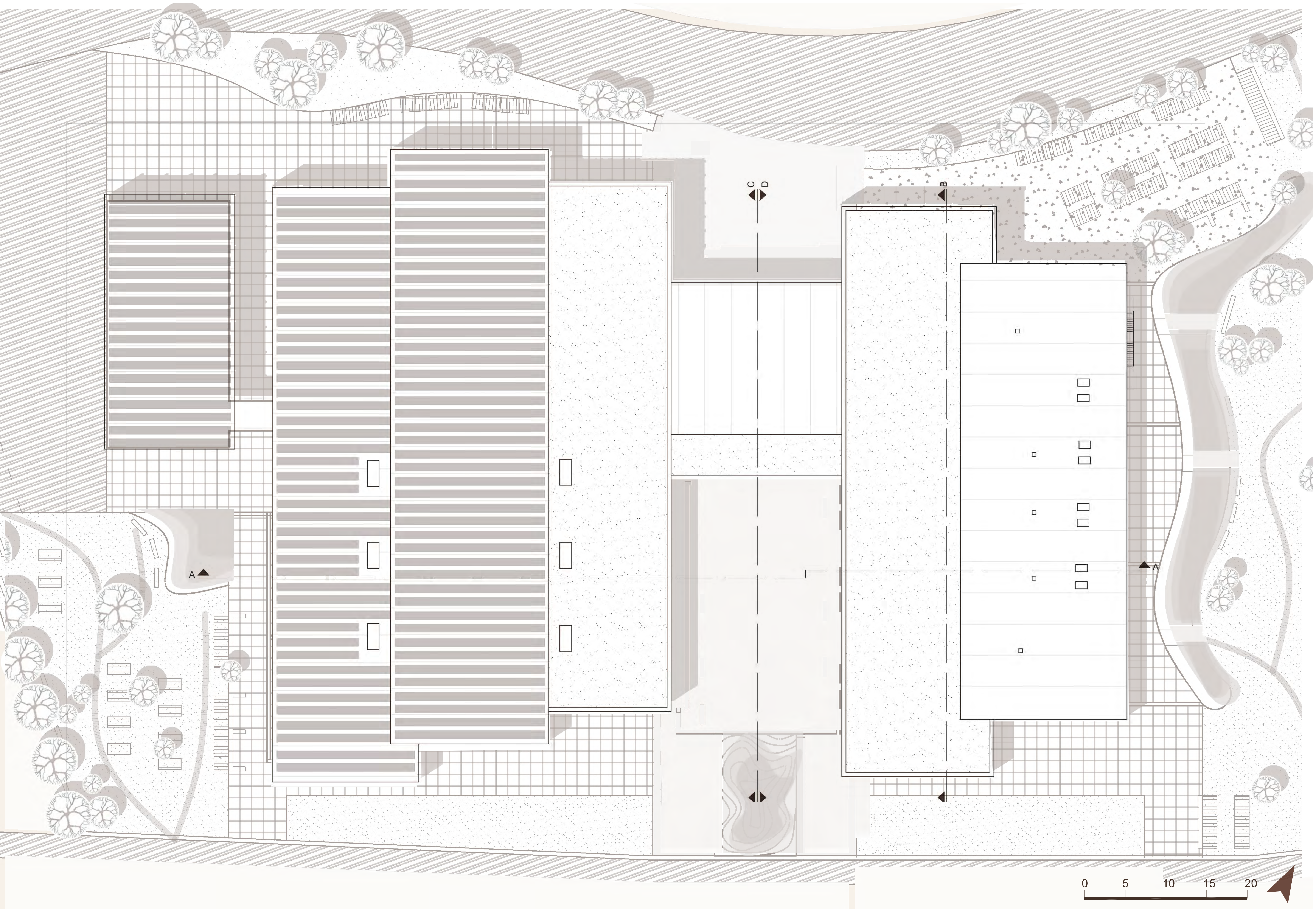
Energy produced by the panels:1156.94 x 0.16=185.11 KWh/m^2

Total SW roof area= 3231 m^2 , pv panel actual area = 3231*0.7 = 2261.7 m^2

Total energy produced = 2261.7x185.11= 418663.28 KWh/yr

Energy needed for the east volume= 48.8 KWh/m^2 x 3856 m^2 = 188.172, 8 KWh/m^2

According to the calculations, 45% of the project's solar panels can cover the energy needs of the east building volume. This suggests a strong likelihood that the solar panels will meet the energy requirements of the entire building. This assumption is based on the fact that the west volume has a lower heating threshold of 16°C compared to the east volume's 20°C, although the west volume also has a higher volume-to-room ratio.



C
D
B
A
A
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15
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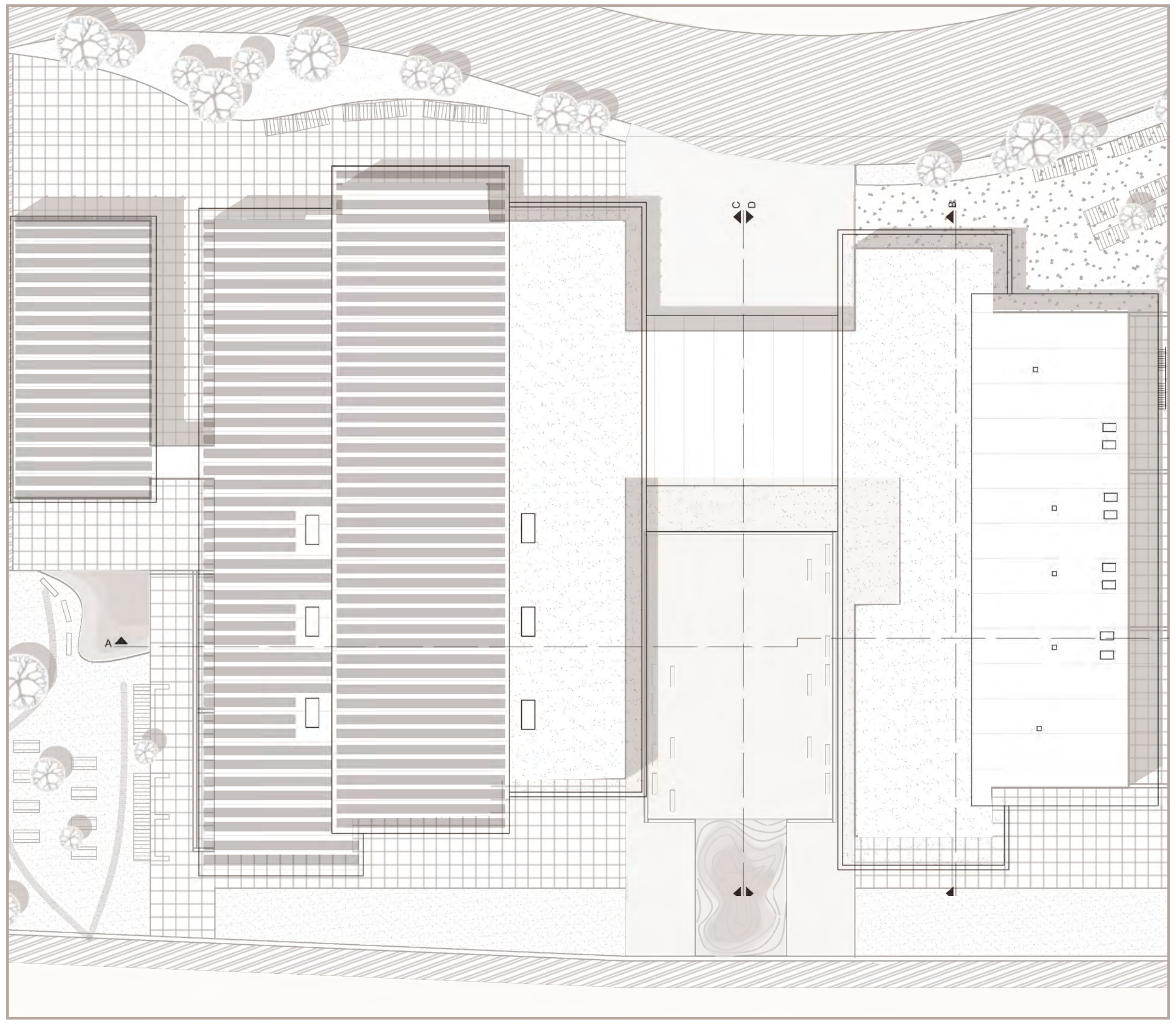
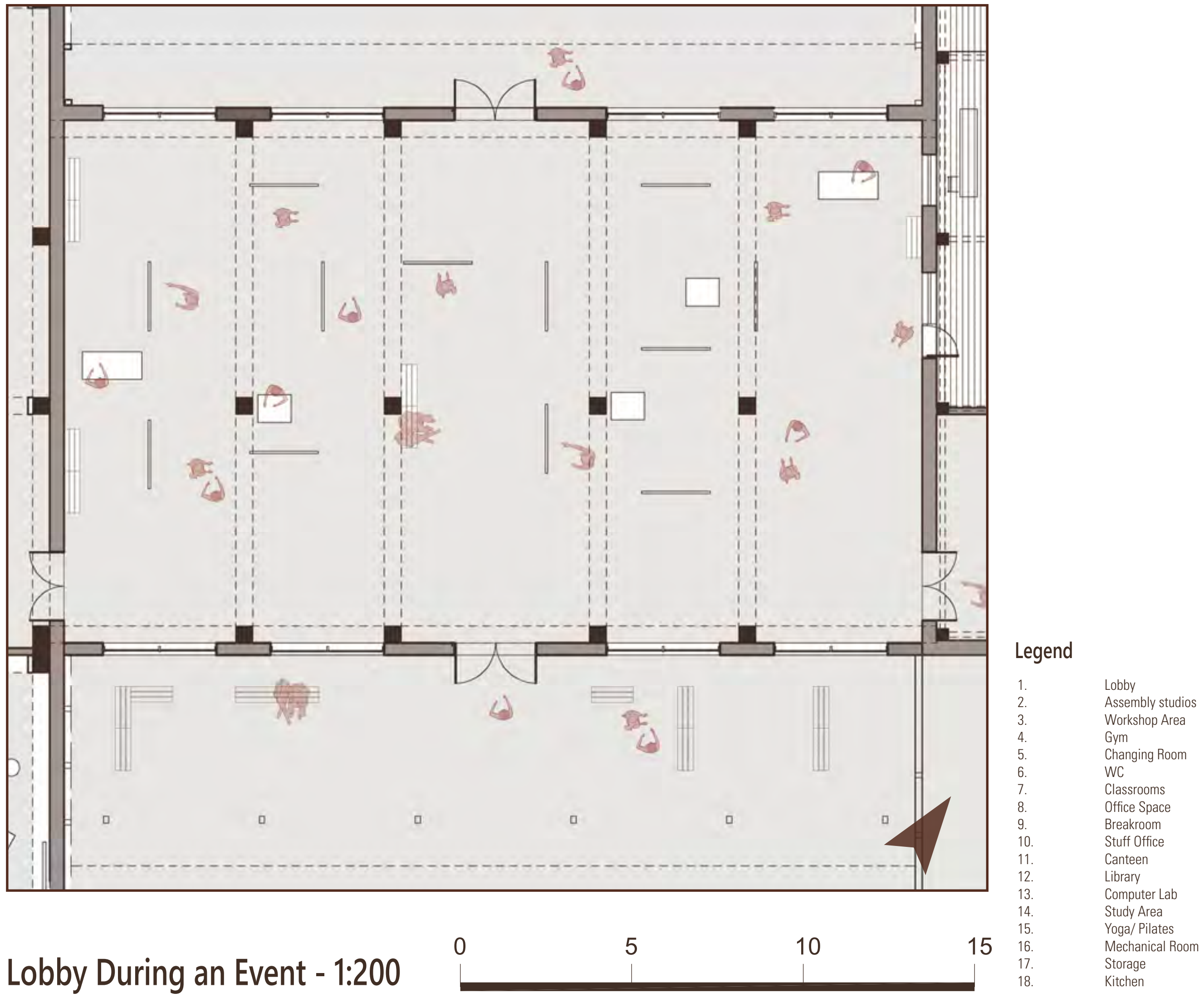




Lobby During an Event - 1:200

GROUND FLOOR

1:400

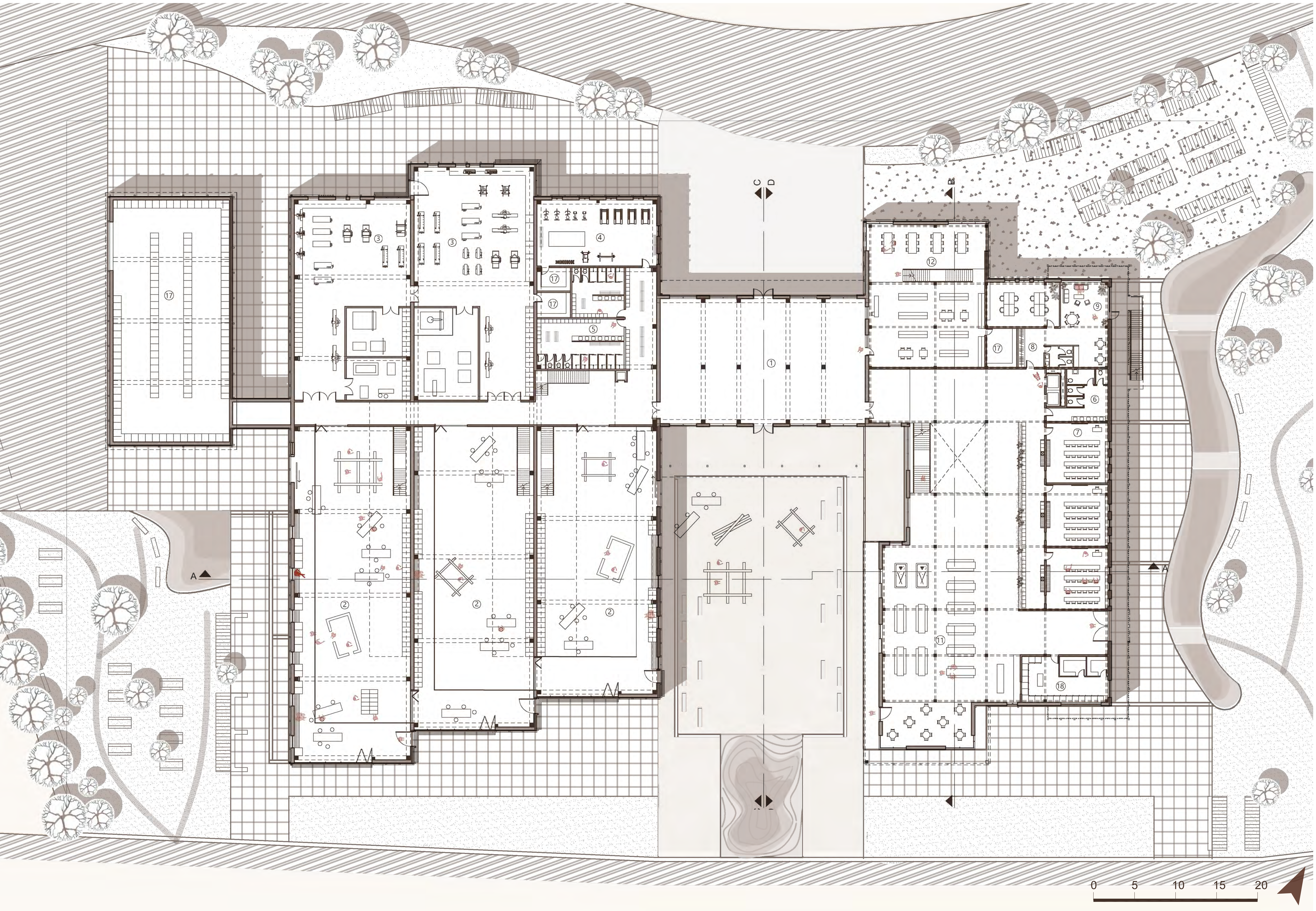
Some of the most important spaces in this building are the assembly studios. Alongside the workshops they act as the heart of the practical curriculum as the place where skills are learned an practiced. There are three studios, to accommodate the three educational paths. Additionally the central south courtyard is meant to be used as a fourth studio whenever needed, with the possibility of being covered by tarps or tents in sub-optimal weather conditions. These work areas are located in close proximity to the storage to minimize travel distance. The workshops house machines for digital fabrication such as 3D printers as well as more traditional tools. Also close by there are change rooms that allow students to change into their work clothes due to the nature of the work being performed in these spaces. These change rooms also support the sports facilities. This grouping defines the eastern side of the building as a 'hands on' area for more physical types of activities.

On the other side to the east is the academic side of the school. With spaces such as a library, classrooms and the canteen this is the volume that houses what many would

On this floor the canteen is set back from the facade to create an arcade beside the courtyard. This allows for the sliding doors of the canteen to open up to the courtyard during differing weather conditions as the openings are sheltered. To the upper-east end of the courtyard the building is inset further to create a more private sheltered area for breaks.

The two sides of the building are connected by the lobby which also functions as a multi purpose event space and additional study space whenever needed. It can house exhibitions or host networking events for the students. The former would enhance public engagement with the trades while the latter would provide the additional support to students An example of how the lobby could be configured during an event can be seen above.

Lastly there is a separation between more publicly accessible areas and the ones meant for staff and students. The lobby and secondary entrance to the east delineate these public areas, with a partial locker wall separating the lockers from this circulation space.



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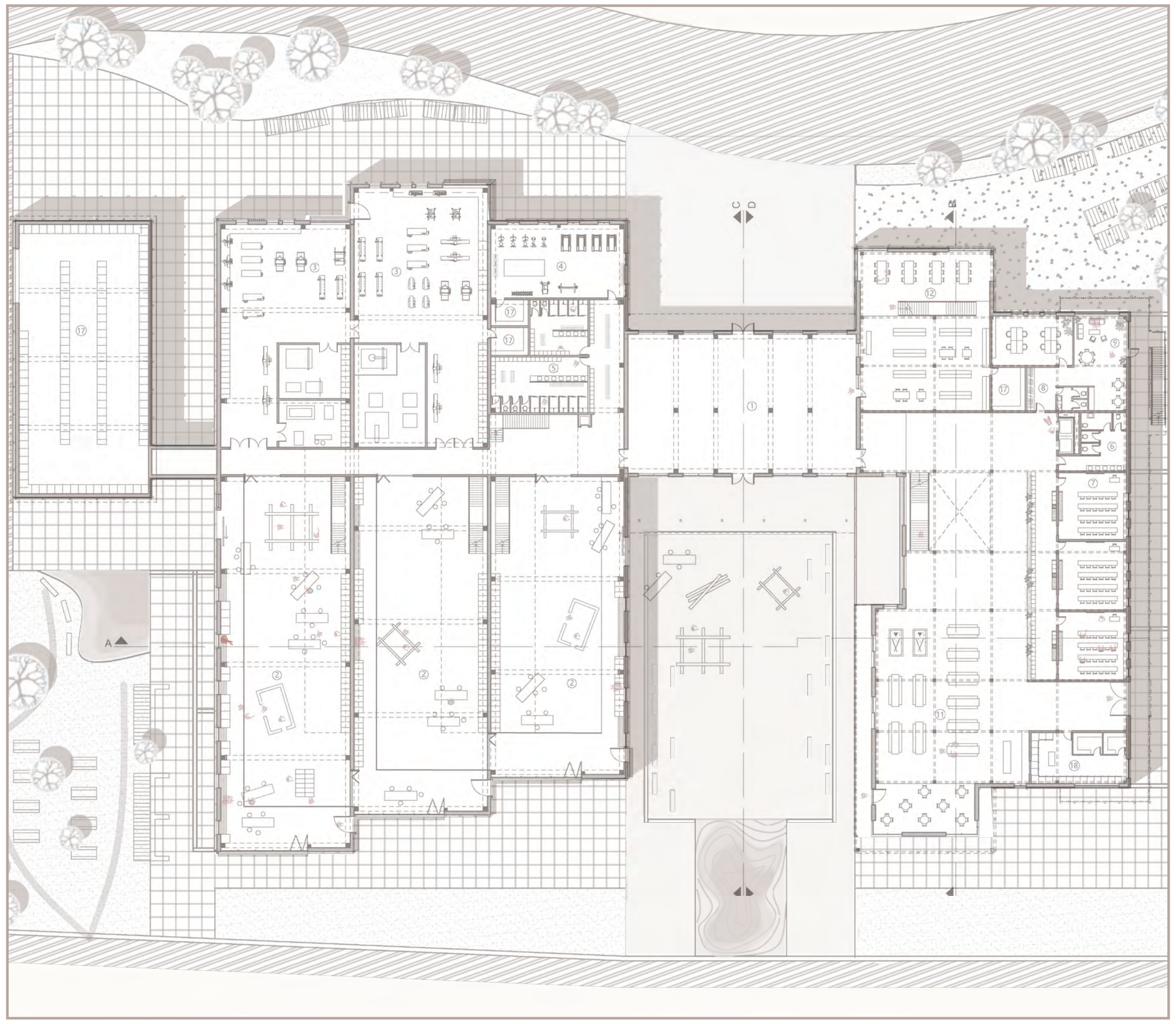


FIRST FLOOR

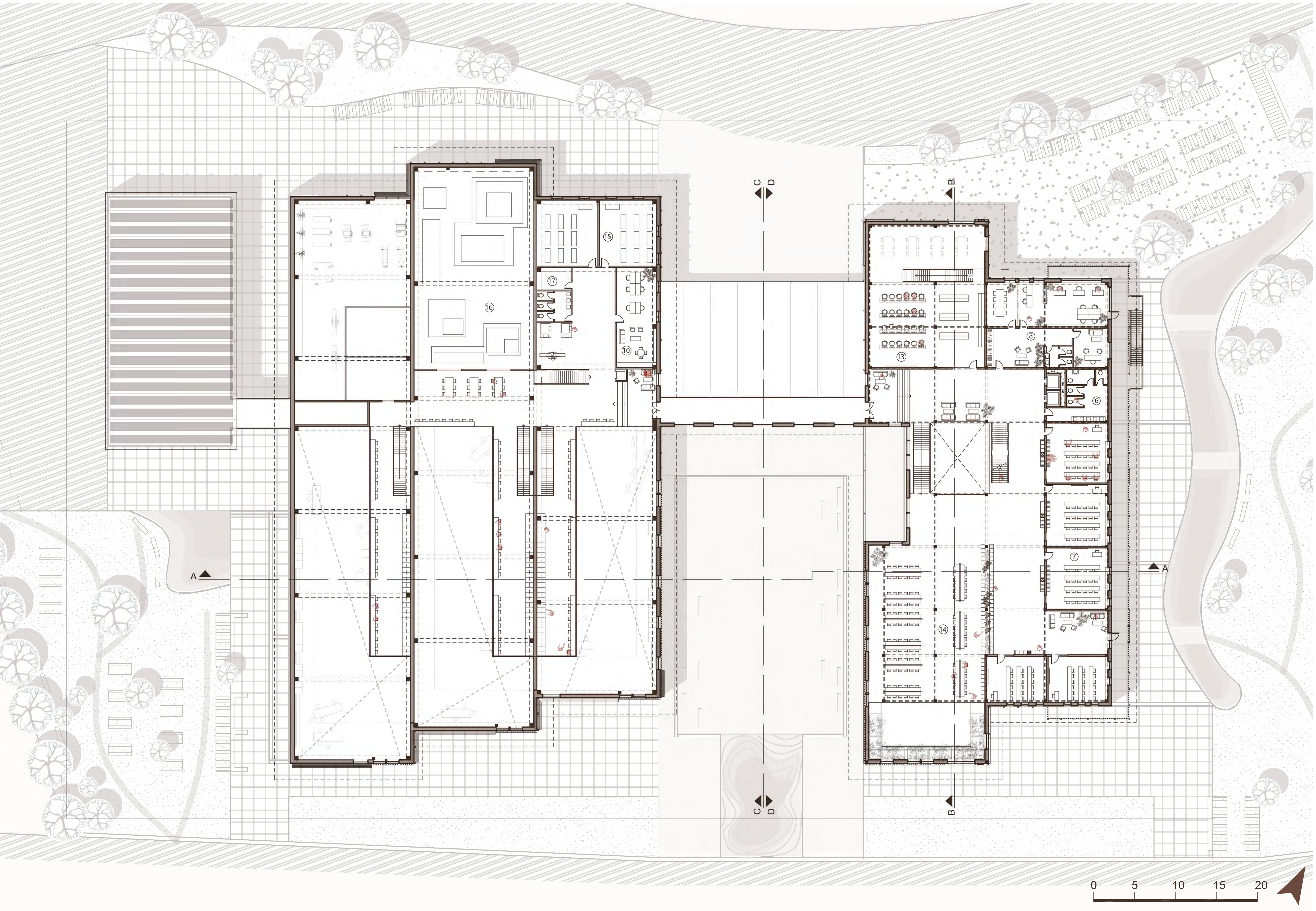
1:400

From the west, the assembly studios are all double height spaces that have mezzanines overlooking them. These spaces allow students to work on their laptops in a safe area while building objects in the areas below. This is crucial as carpenters and sustainable constructors make use of programs such as CAD, while digital fabricators use even more programs then the other two. This also allows for a visual connection between the digital representation, and the physical realization of assignments. This mezzanine area has printers and staff areas to further support the students. The machine room of the building is also located on this level, allowing teachers the opportunity to show students how technical building areas function, as a way to supplement their education.

A walkway connects the western mezzanine to the second academic floor. This is separated by doors on either end creating three distinct building zones for ventilation as well as fire separation. On the east there is a study space to further support student collaboration. There is a computer lab on the second floor of the library overlooking the presentation area on the ground floor. This space can be used for classes if needed during occupancy surges, along with the study area at the end of the year at peak capacity.

LEGEND

1. Lobby
2. Assembly
3. Workshop
4. Gym
5. Changing room
6. WC
7. Classrooms
8. Office space
9. Breakroom
10. Stuff office
11. Canteen
12. Library
13. Computer lab
14. Study area
15. Yoga/ Pilates
16. Mechanical
17. Storage
18. Kitchen



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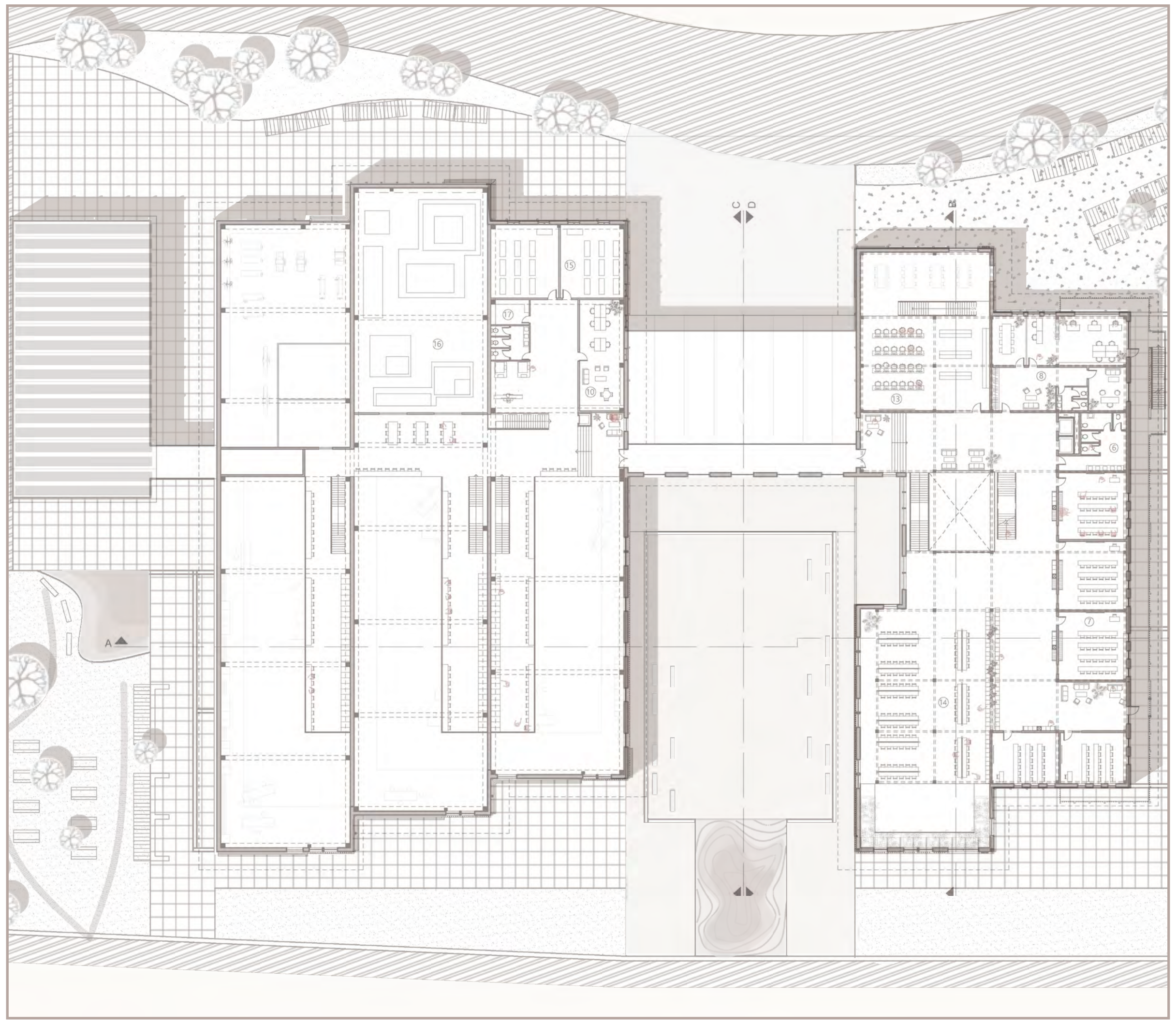


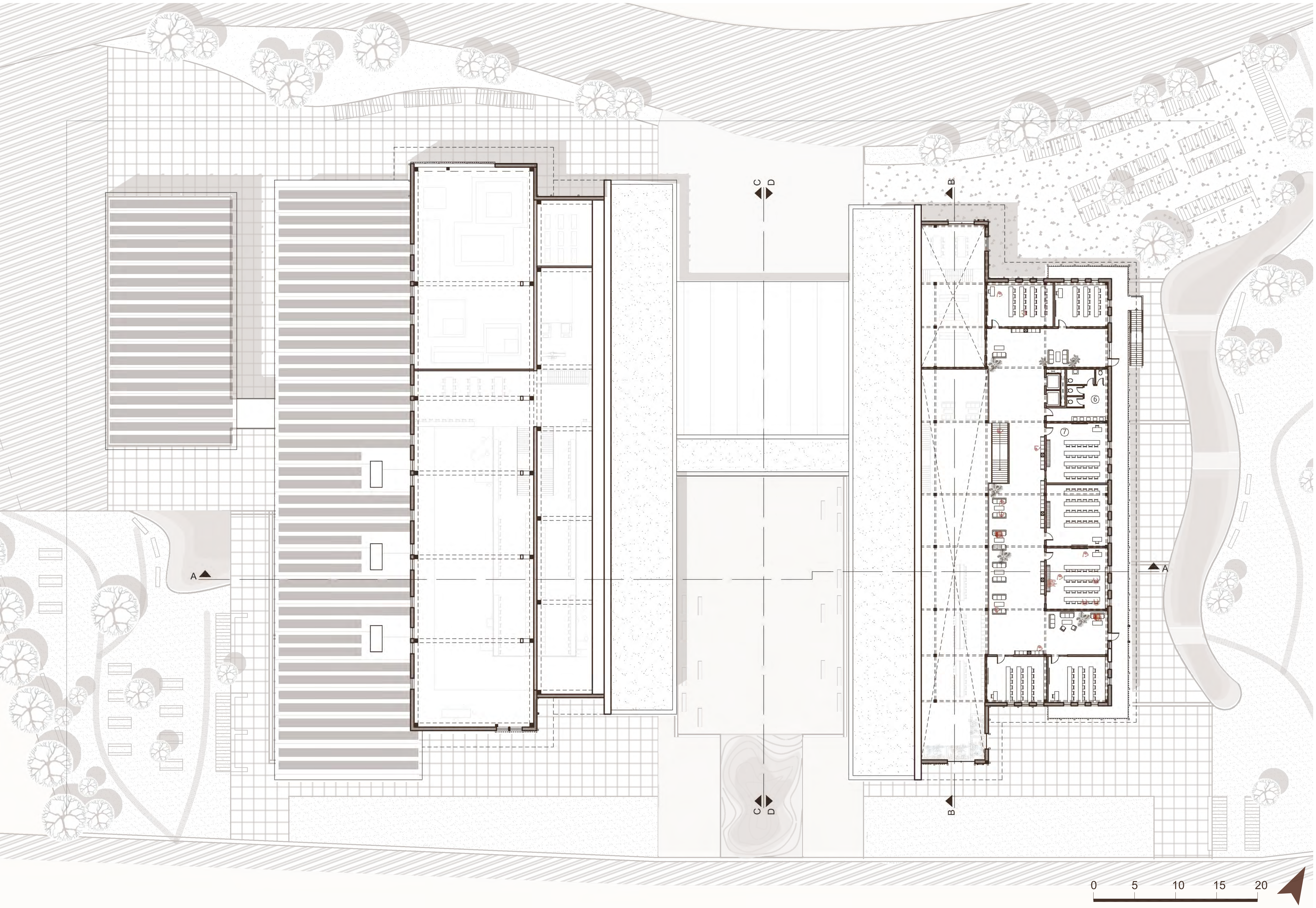
LEGEND

1. Lobby
2. Assembly
3. Workshop
4. Gym
5. Changing room
6. WC
7. Classrooms
8. Office space
9. Breakroom
10. Stuff office
11. Canteen
12. Library
13. Computer lab
14. Study area
15. Yoga/ Pilates
16. Mechanical
17. Storage
18. Kitchen

SECOND FLOOR

1:400

Only the academic volume to the east has a third floor, housing the rest of the classrooms and some flexible couch areas. These spaces have an interior view the study area and circulation below them, creating an inter level connection. To the east there are also to exterior access points to the balcony spanning the east facade, overlooking the public park. This provides a sheltered outdoor area which connects to the exterior access stair. This serves as a secondary exit in times of emergency as well as direct access to different floors.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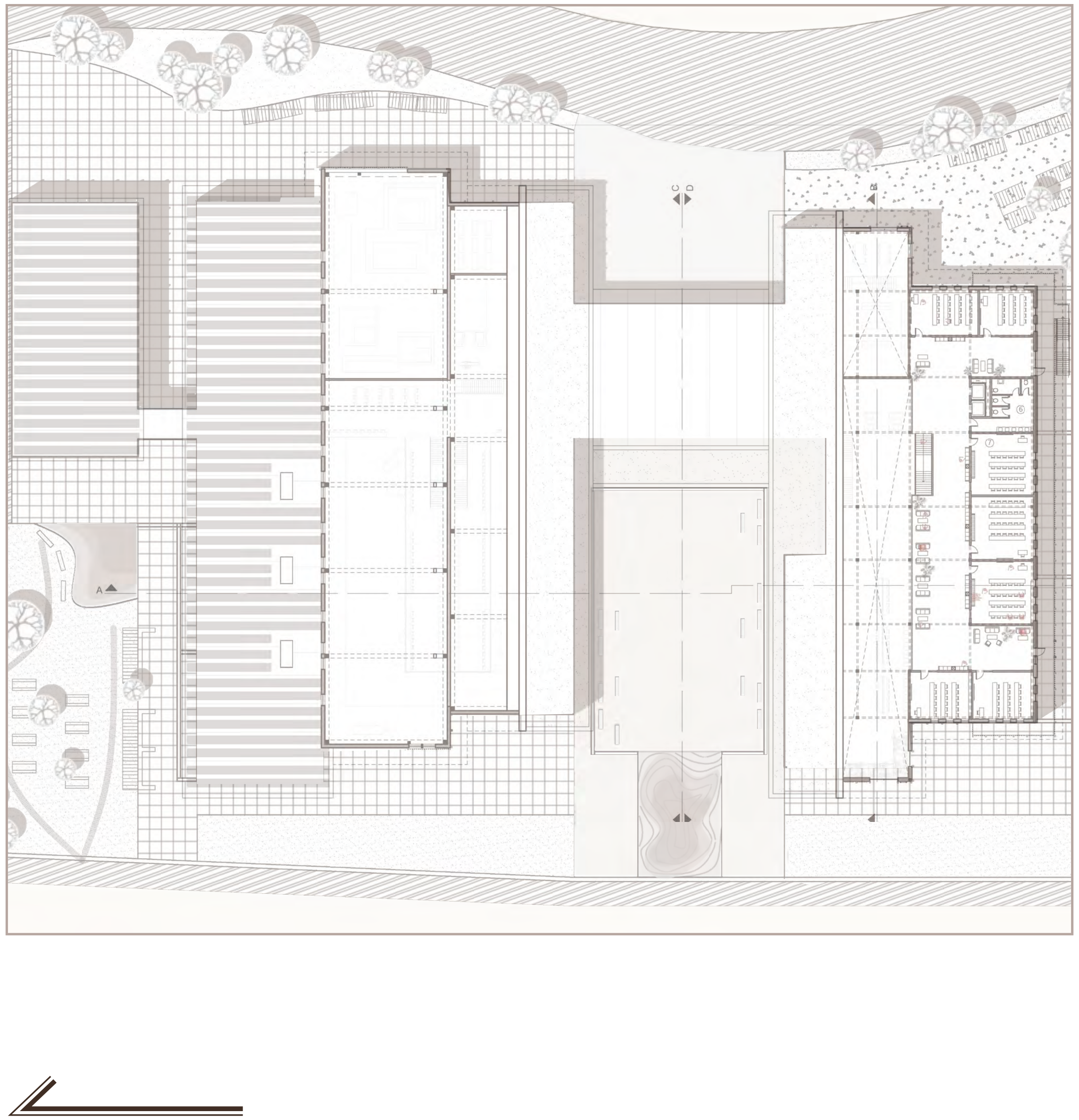
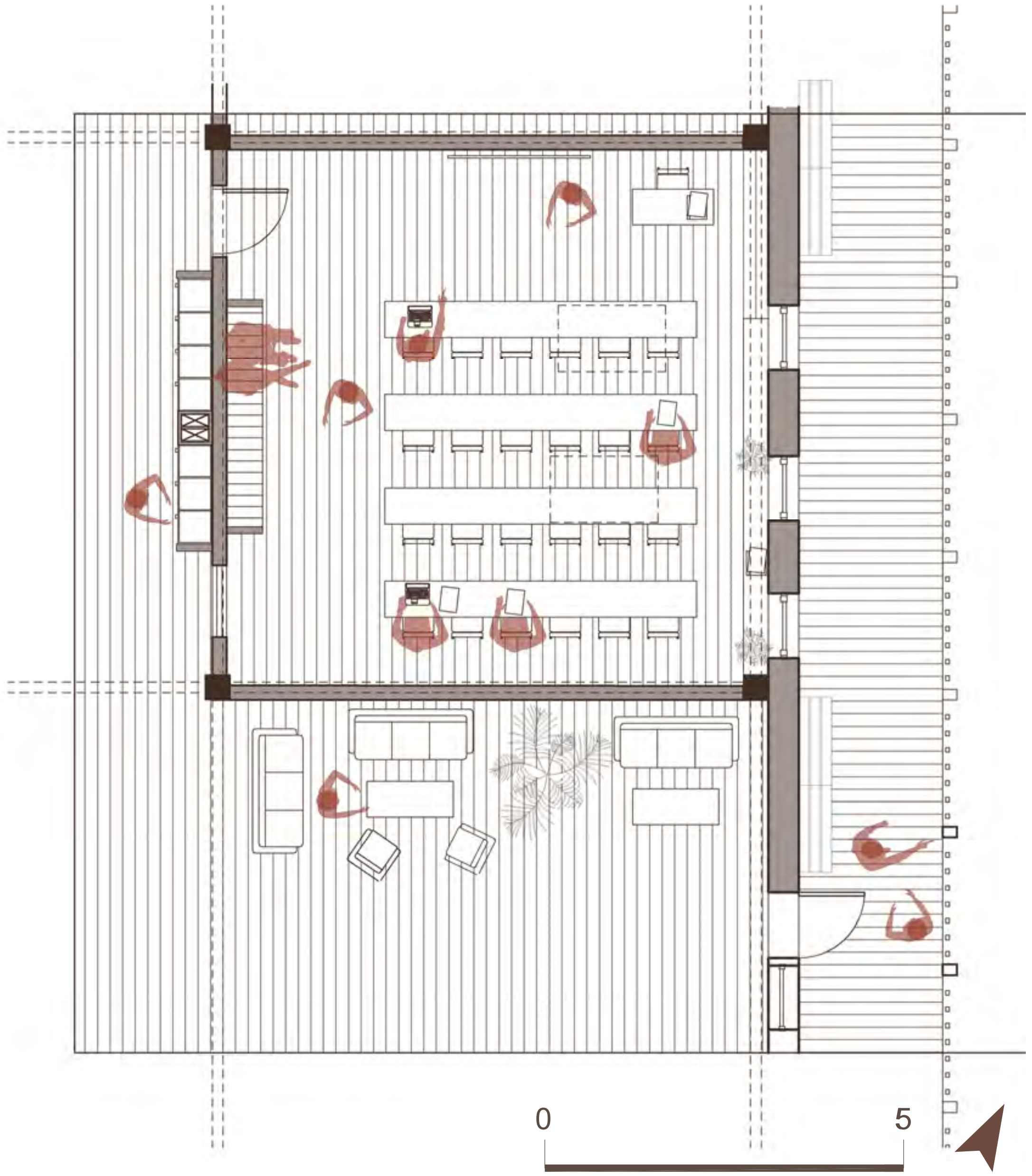


Second Floor Classroom - 1:100



THE CLASSROOMS

Layout

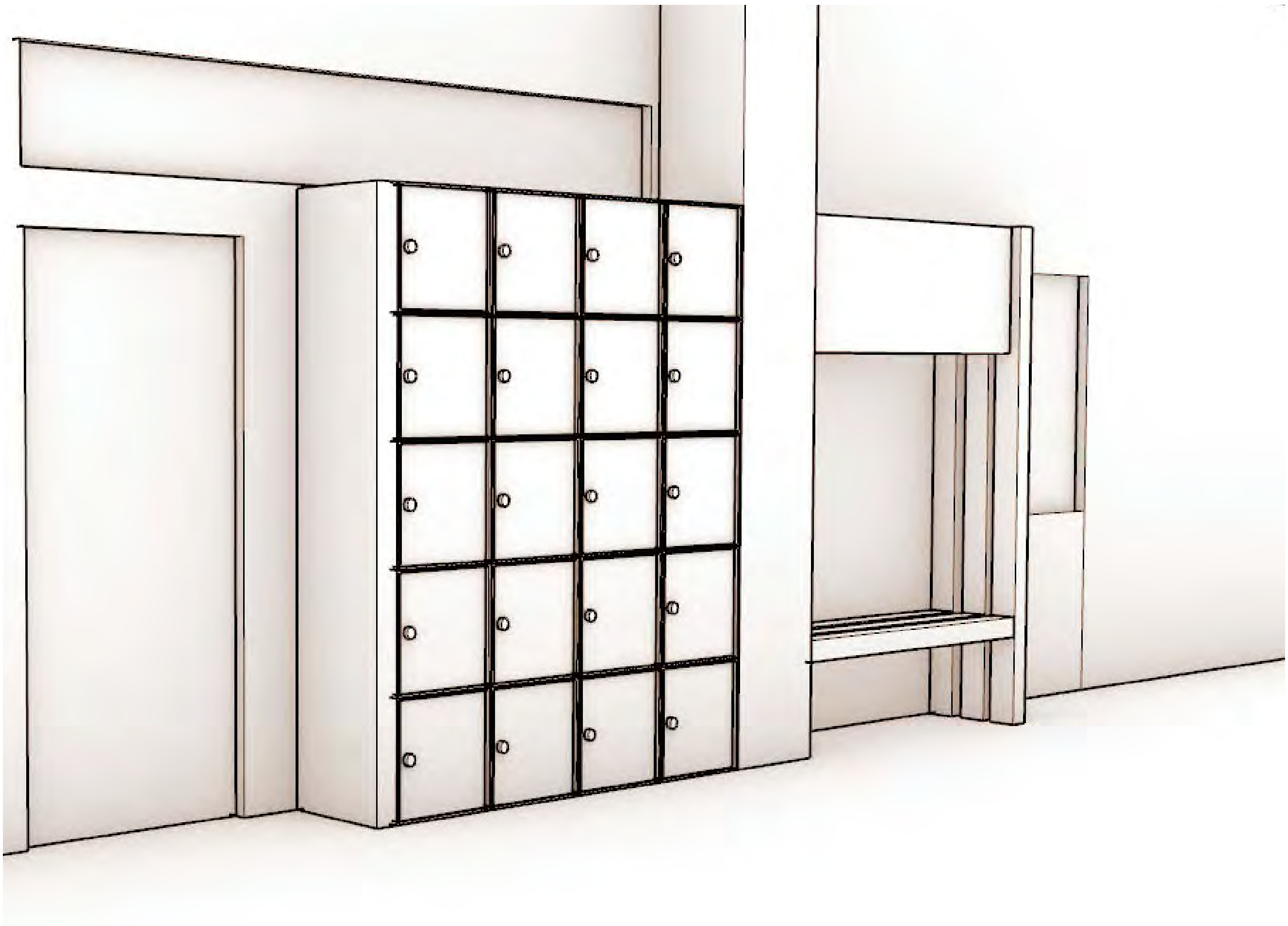
At the heart of academic life at Craft Tech the classrooms are one of the key spaces in the building. Talking a closer look at this space reveals important details about how the building functions. Each class is designed to accommodate approximately 20 people. On the interior wall of each classroom there is a program wall that houses three functions:

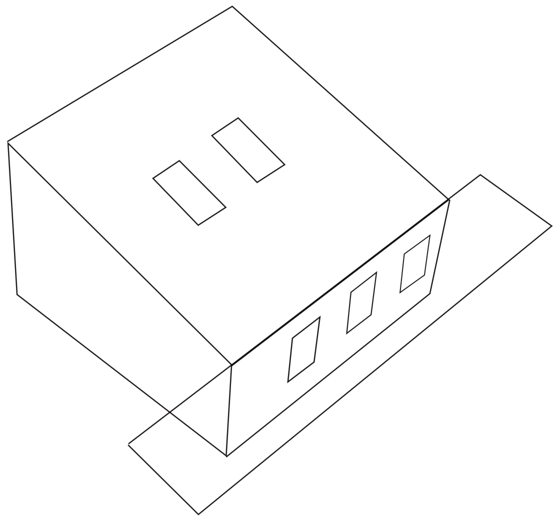
Lockers: Towards the hallway lockers run along the wall occasionally replaced with seating nooks. Having private storage space is particularly important in vocational education where people often have to get changed.

Ventilation: One locker in each in each program walls is replaced with the shaft for the solar ventilation chimney for each classroom. The classrooms on the second floor ventilate directly thorough operable skylights.

Seating: On the inner side of the program wall there is a seating nook that can also work as an open closet for jackets.

Along the exterior wall under the windows there is classroom storage in the form of cabinets. The materiality of the exterior continues inside into the classroom, with a exposed wooden structure and wooden floor.





Simulations

To create an integrated design simulating building performance is a necessary. To understand the indoor environmental quality of the classrooms Grasshopper was used to evaluate the following

1. The amount of natural light.

2. Indoor temperature using natural ventilation.

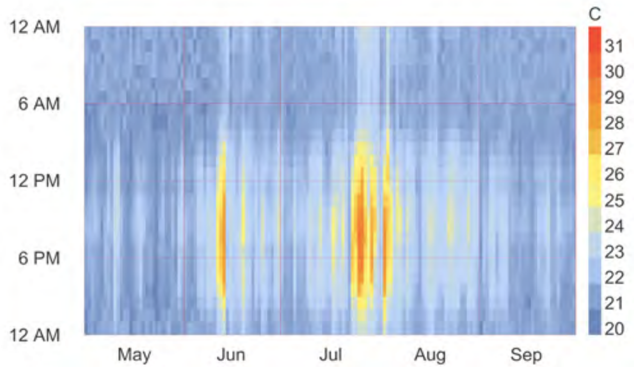
3. Air quality using natural ventilation.

Simulation Parameters & Targets

Orientation:	North East
Shading:	2m
Windows:	0.9m x 2m
Window U Value:	0.98 W/m²K
Window g Value:	0.5
Skylights:	0.9m x1.5m
Skylight U Value:	0.98 W/m²K
Skylight g Value:	0.23
Wall U Value:	0.13 W/m²K
Nat. Vent. Set Point:	22 ˚C
Min. Daylight Factor:	2%
Lux Levels:	500lux in 50% of the spaces 50% of the time
ACH:	$(0.175m^3/s * 3600)/207m^3 = 3.04$ changes/hr
Hours Over 26 °C:	<100
Minimize hours	>27 °C

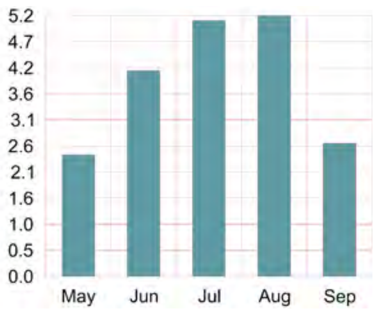
Temperature and Ventilation

The targets for the indoor temperature are met using solely natural ventilation in the cooling months. Additionally, many of the hours over 26ºC occur after 6 pm when the building is either closed or at a lower occupancy level. As they also occur in the summer months it is possible to create a building schedule for summer classes that avoid taking place in the afternoon. The indoor temperature remains comfortable throughout the simulated period.

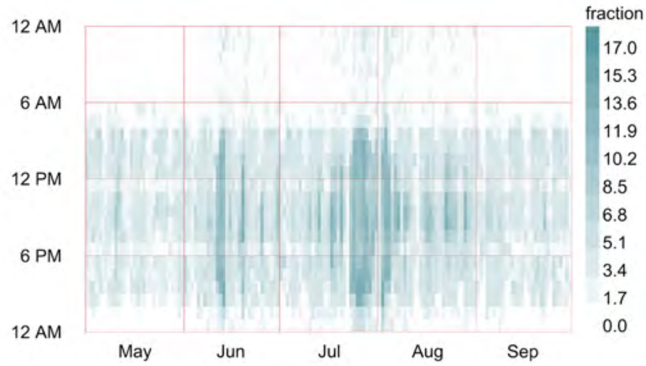


Indoor Temperature

Hours Over 26ºC: 97
Hours Over 27ºC 43
Hours Over 28ºC 22
ACH in Cooling Months: 3-5 changes/hr (Summer)



ACH Monthly Average

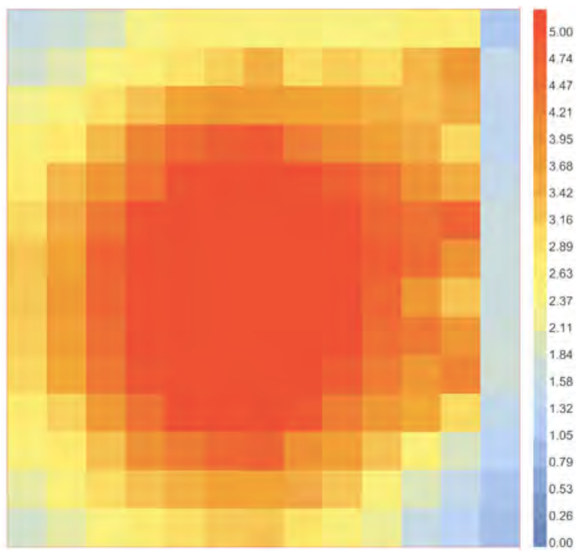


ACH Houly Plot

Natural Light

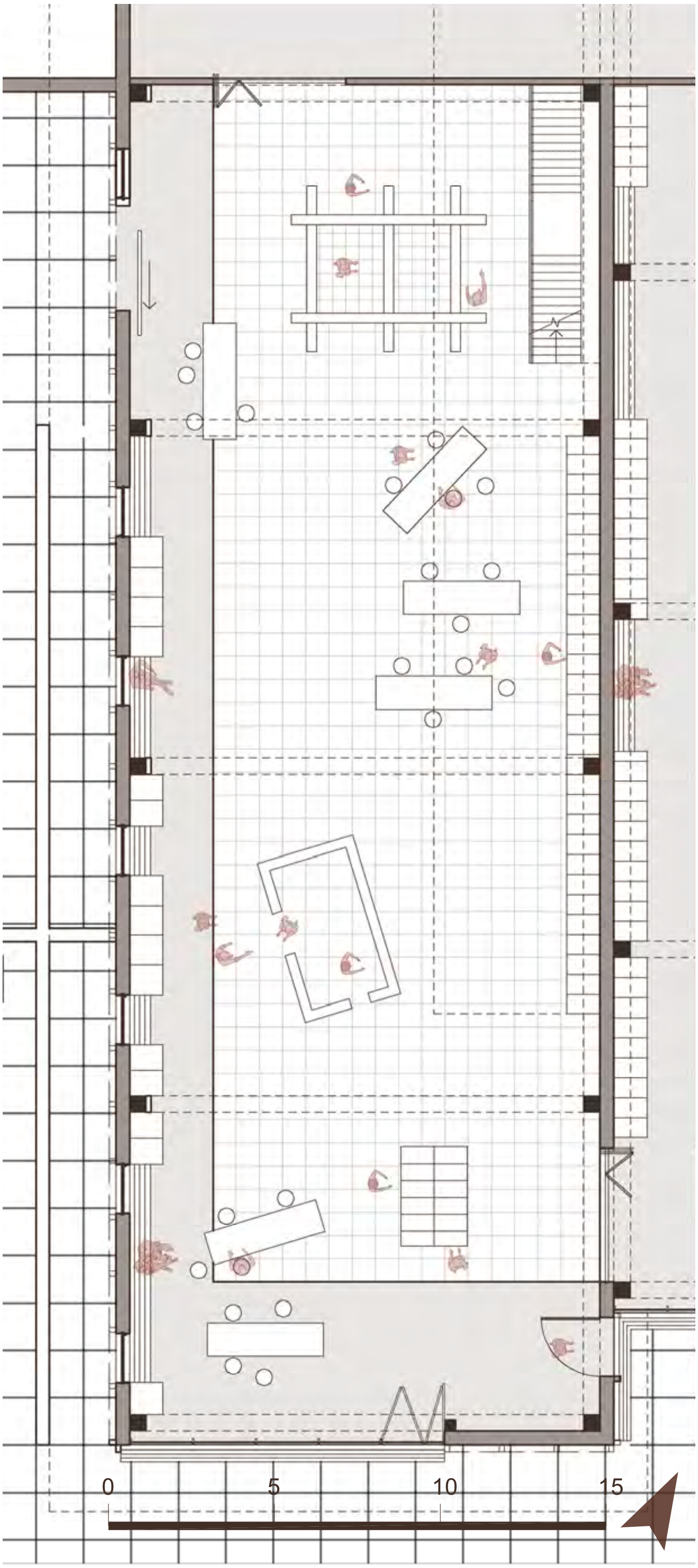
With the specified conditions the target lighting conditions are being met. As these targets are based on stringent standards the indoor light quality is excellent.

Daylight Factor: 3.6%
Lux Percentage: 51%



Daylight Factor

West Assembly Studio - 1:200



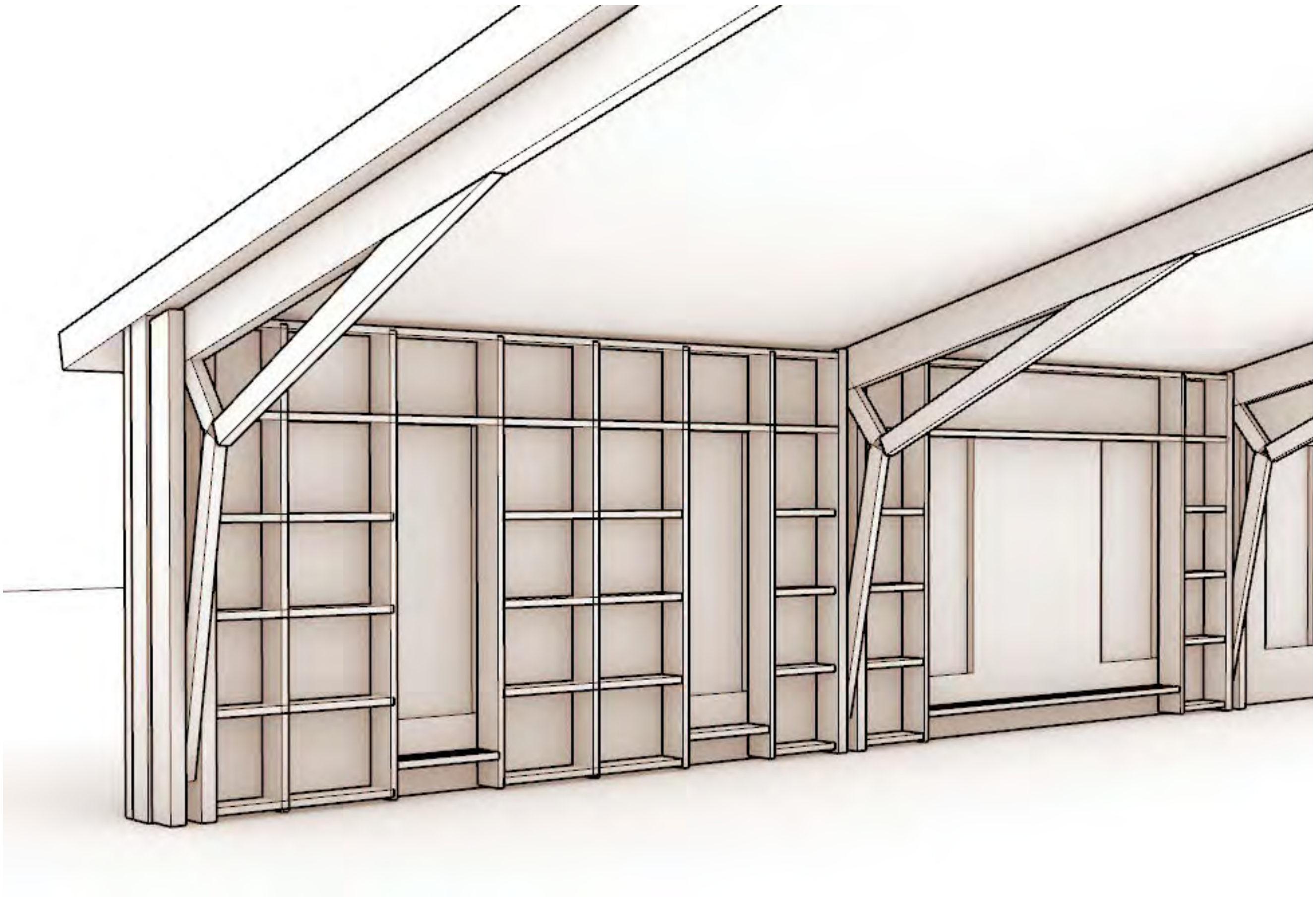
THE ASSEMBLY STUDIO

Layout

The counterpart of the classrooms at Craft Tech are the assembly studios, whose function is crucial to the building program. Each one is designed to house at least one entire year of a program, which is around 60 people. The studio shown to the left is the west-most one with access to the outdoors via a large wooden sliding door. Additionally to the south there are foldable glass doors allowing for indoor-outdoor connection, and visual engagement with the public.

The walls of the studios are lined with material storage and benches. The seating is coordinated with the openings in the facade and the floor finishes, indicating break areas within the space. The work area has a linoleum finish to provide a more physically-friendly work surface for the students. The border break area has the concrete slab exposed, relating to the concrete panels on the exterior. These outdoor areas serve as overflow of the work area whenever needed.

The structure in the space is left exposed to the interior to serve as a teaching tool for the students as they learn how to work with sustainable materials, particularly wood. Lastly each studio has direct access to a circulation corridor to the north that connects directly to the workshops, storage area, and change rooms.



Simulations

The operable windows are indicated in orange. To understand the indoor environmental quality of the classrooms Grasshopper was used to evaluate the following:

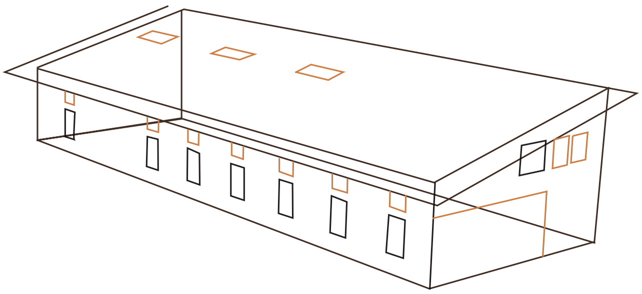
1. The amount of natural light.

2. Indoor temperature using natural ventilation.

3. Air quality using natural ventilation.

Simulation Parameters & Targets

Orientation:	West South
Shading:	2m
Windows W. (operable):	1.3x1m
Windows S. (operable):	9.8m x 4.0m & 1.4x1.8m
Skylights (operable):	3.5m x1.5m
Wind. & Skylight U Value:	0.98 W/m²K
Wind. & Skylight g Value:	0.5
Wall U Value:	0.13 W/m²K
Nat. Vent. Set Point:	19 ˚C
Min. Daylight Factor:	2%
Lux Levels:	500lux in 50% of the spaces 50% of the time
ACH:	$(1.12m^3/s * 3600)/5345m^3 = 0.75$ changes/hr
Hours Over 26 °C:	<100
Minimize hours	>27 °C

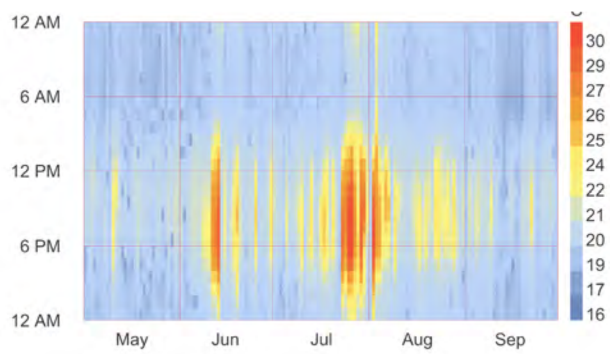


Temperature and Ventilation

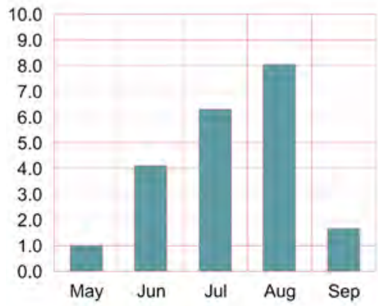
The indoor temperature remains comfortable and meets the targets using solely natural ventilation, in the cooling months. These targets are a lower temperature compared to the classrooms as the activity level in the assembly studios is high. Many of the hours over 26°C occur during weekends and in summer which can be partially accommodated by an appropriate building schedule. A seasonal schedule would be very helpful. In general due to the limited hours of uncofortable temperatures it is possible to assume a higher level of user adaptability when issues occur.

The Air change rate is variable meeting and exceeding the 0.75 ACH's needed for the air quality. However these exeedances are occurring at temperature spikes where cooling is needed and drafts would be pleasant. Therefore the air changes per hour needed for the air quality differ from those needed for the indoor temperature requirements.

Hours Over 26°C:	83
Hours Over 27°C	53
Hours Over 28°C	14
ACH in Cooling Months:	1-8 changes/hr (Summer)



Indoor Temperature

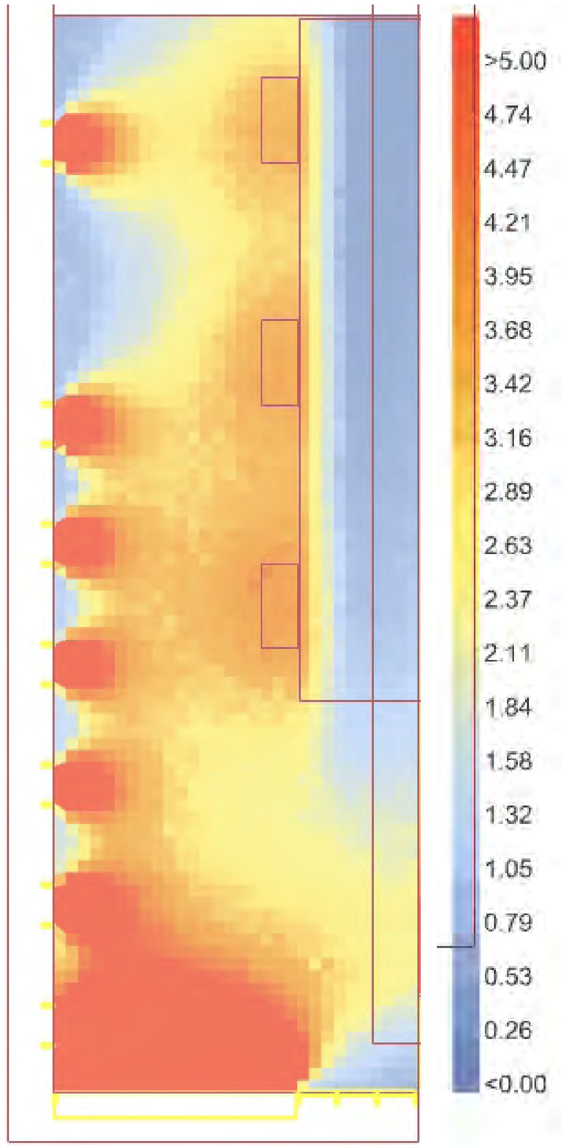


ACH Monthly Average

Natural Light

With the specified conditions the target lighting conditions are being met and exceeded. As these targets are based on stringent standards the indoor light quality is excellent.

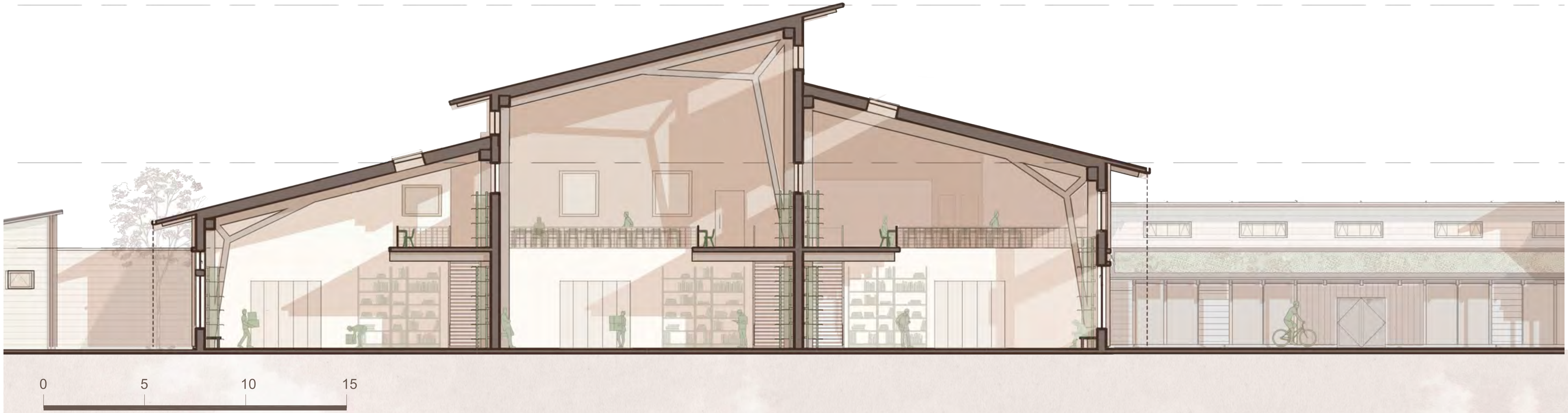
Daylight Factor: 3.07%
Lux Percentage: 69.0%



Daylight Factor

SECTION AA & SOUTH ELEVATION

1:200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STUDIO 3
STUDIO 2
STUDIO 1


CRAFT TECH

SECTION AA

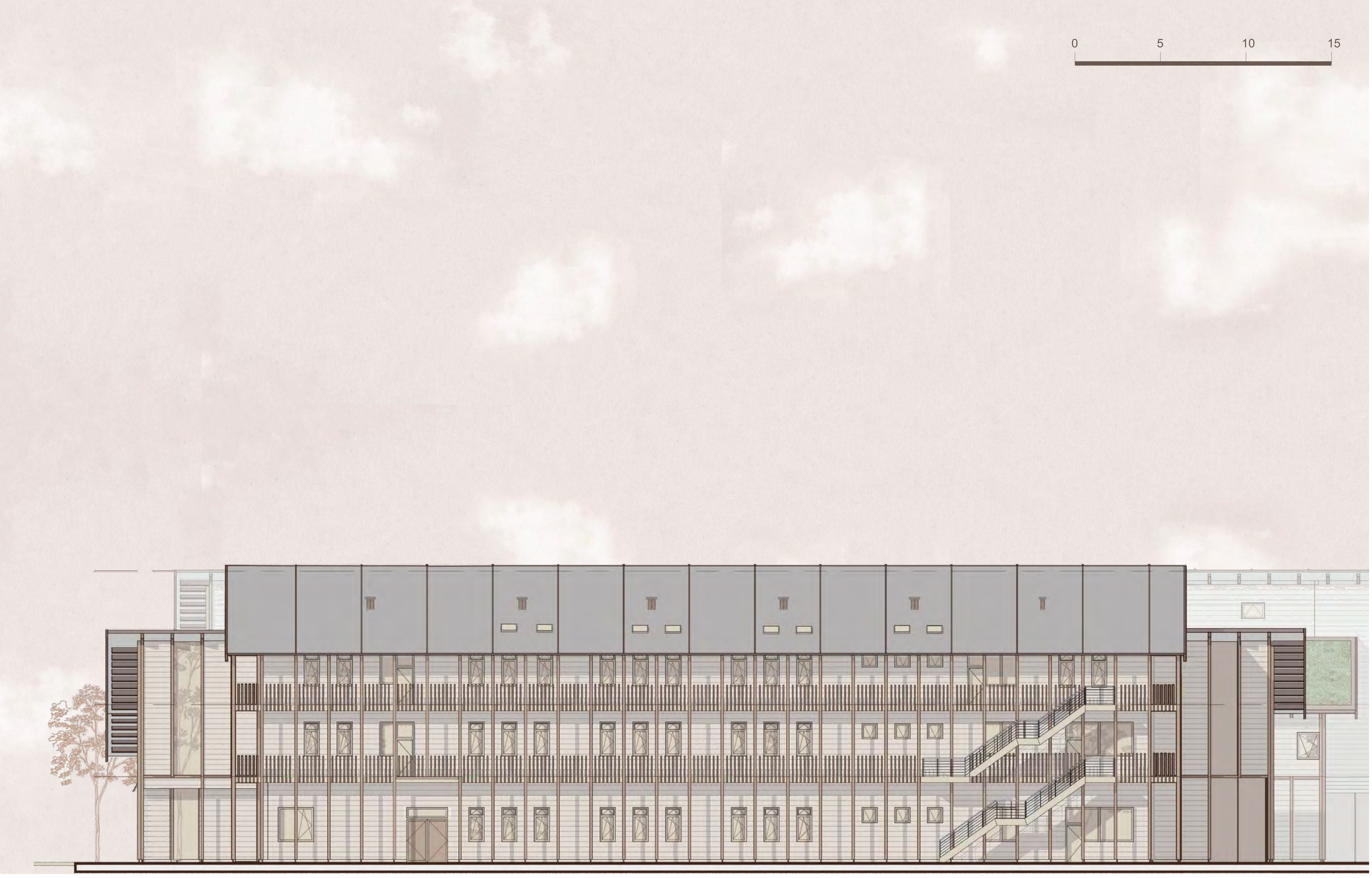
The character of the east volume is much more open then the western volume. The large rooms with tall ceilings are suitable for building large educational mock-ups for the students, which can be observed from multiple levels using the mezzanine.

SOUTH ELEVATION

The four main elements used to design each facade are visible in the south elevation on the previous page. These are lamellas, solids, screens, and windows. The lamellas divide the facade into evenly distributed bays which are filled in accordance to the program of the building. Therefore each volume has a distinctive appearance. The west end of the building has facades that all seem similar indicating their common function as assembly studios. Large windows on the ground floor invite people to look inside these spaces, showing the interesting activities taking place there. The ground floor is indicated by the sliding doors and lamellas on this facade. This is important because the ground floor is of a different more public character and needs different porosity and treatments compared to the other floors.

The east volume hosts the buildings southern signage, located in the study and canteen building, characterized by open plan areas on the first two levels. Here screens help protect from southern light on the first floor and the building steps back for the same reasons on the ground floor. Lastly the rhythm of windows on the east-most volume hints at the small rooms behind, which are for the classrooms.

This facade has unstuck the lamellas from the building face and moved them forward to frame an exterior balcony. This creates outdoor spaces on each level and a sheltered arcade on the ground level. The openings on this facade are small and in discreet units to indicate that this volume houses many small spaces. The roof is facing North-West and as such isn't used for solar panels. It has a simple metal corrugated finish.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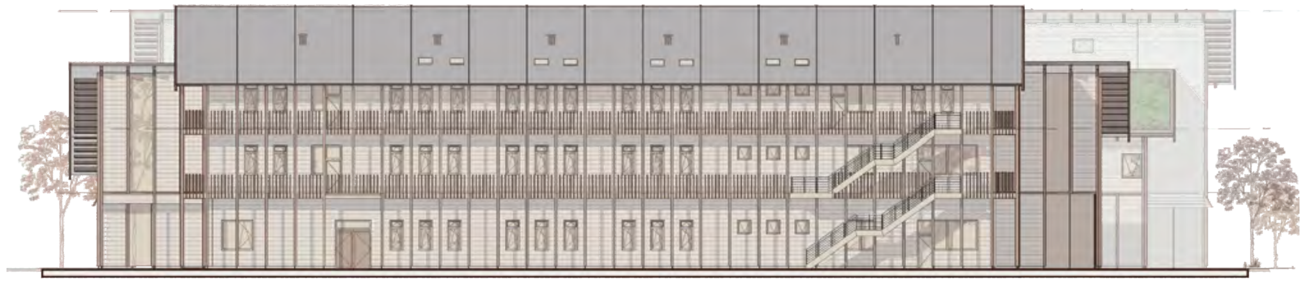
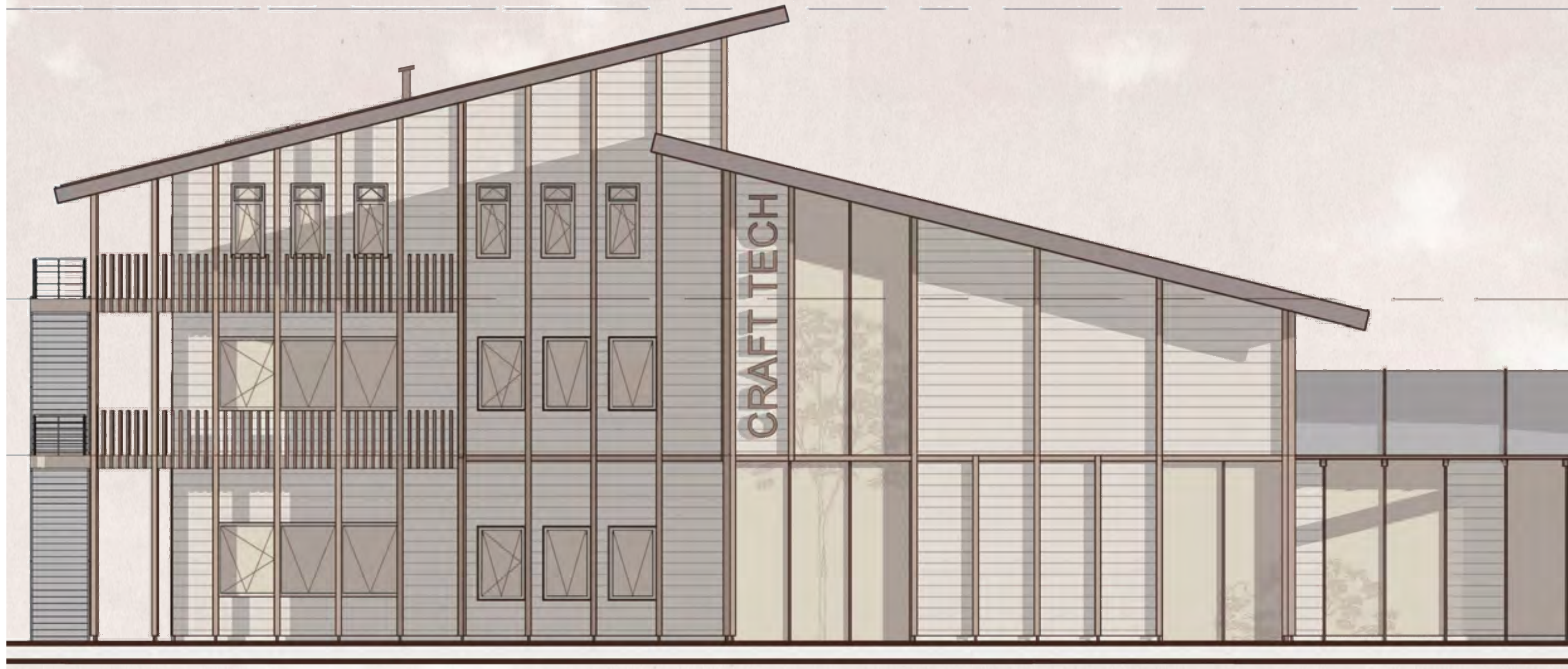
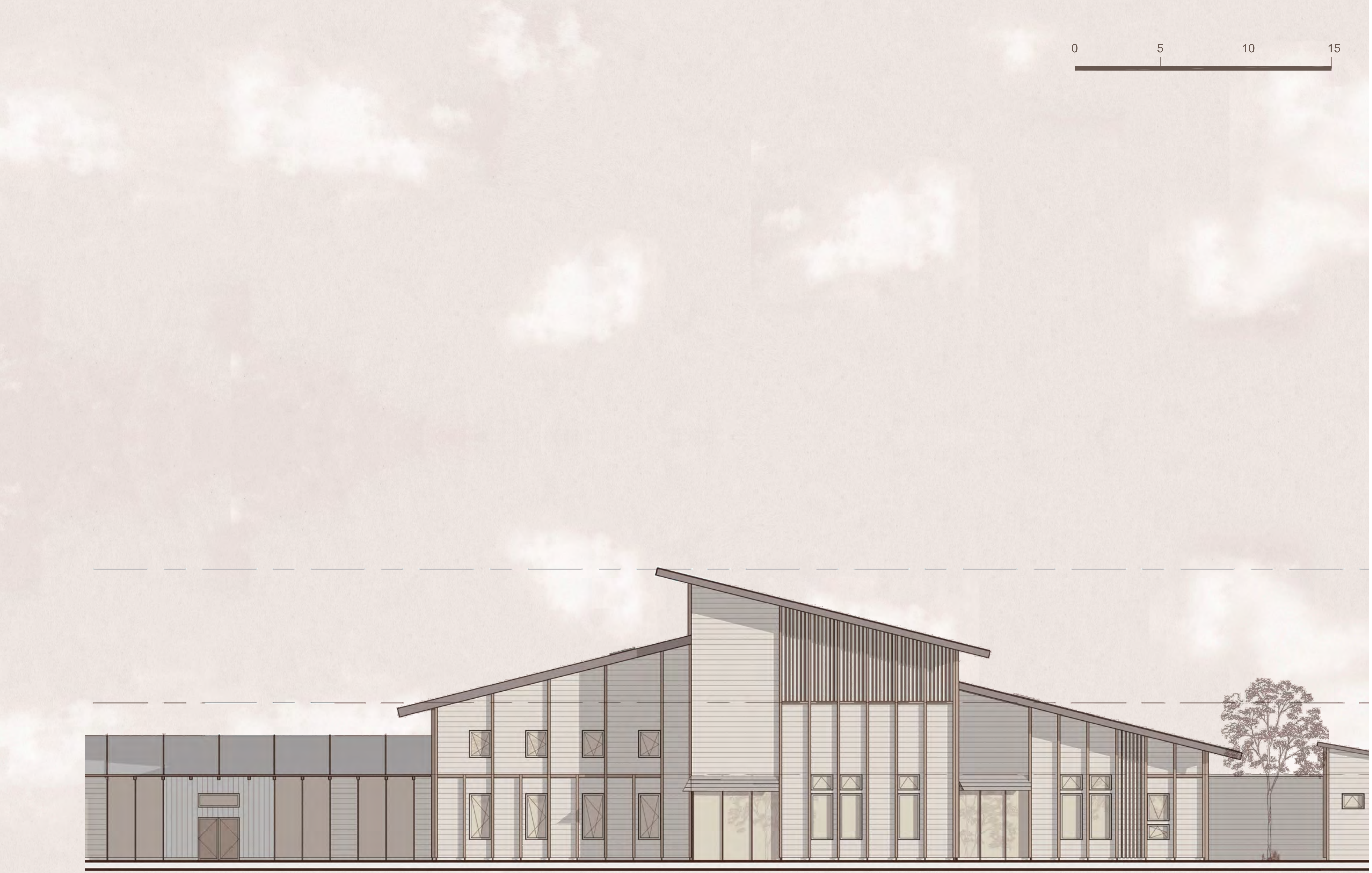


EAST ELEVATION

1:200

Towards the left the small openings characteristic of the classrooms continue. To the right the workshops are finished with a similar pattern with the screens on this facade serving as exhaust areas for the machinery in the workshops and mechanical room beyond. The gym areas and library framing the lobby each have their own character.

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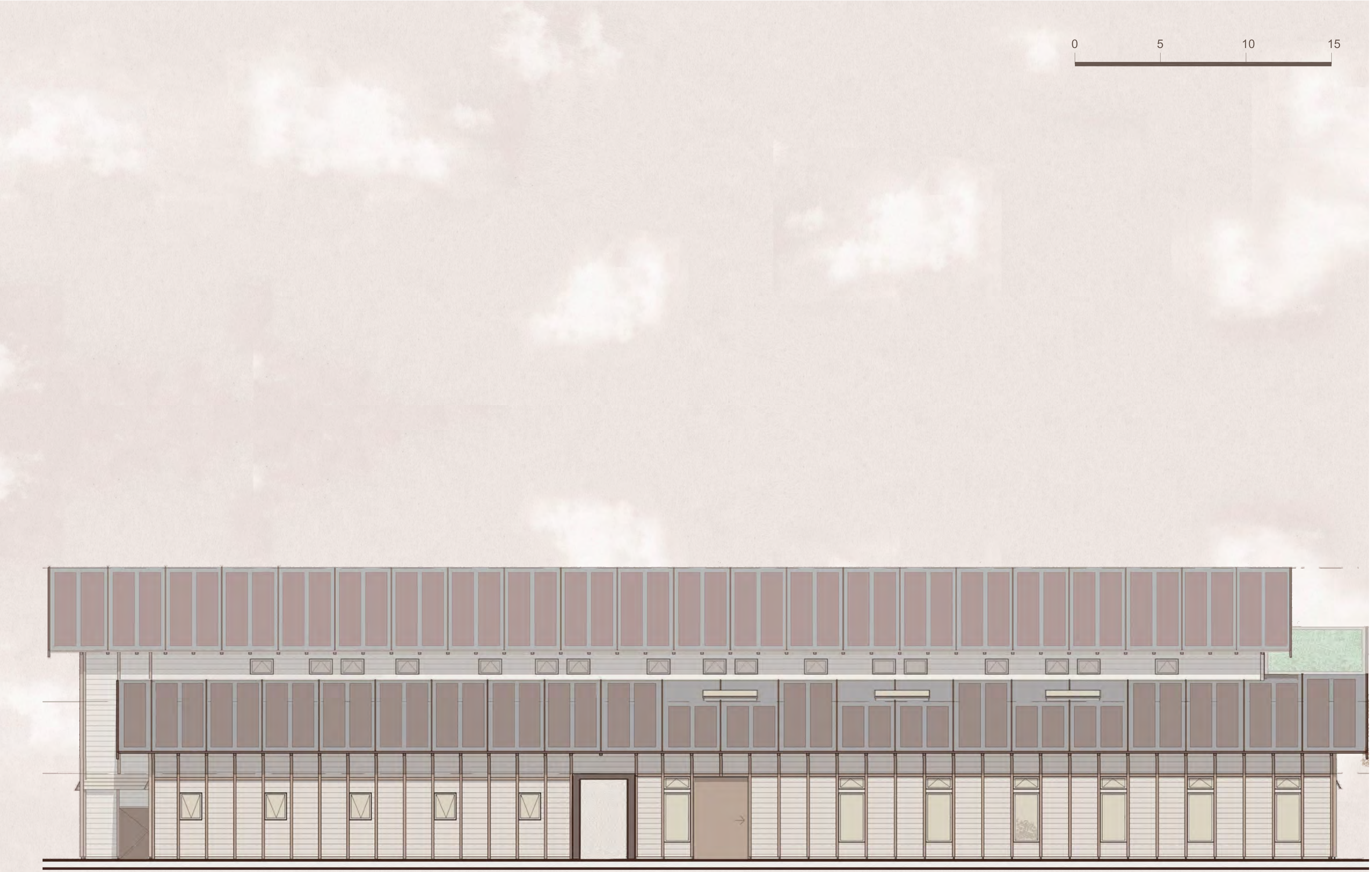
NORTH ELEVATION

1:200

Here the second of three roof finishes is visible. Red thin film photovoltaic panels are used together with a silver corrugated green roof. The PV's provides contrast to the wood facade and allows for the building to produce energy. The reason these roofs have PV's is that they are South-East facing which is the most suitable orientation in our building for energy generation.

The openings to the assembly studio are also visible. In this case the large lower windows are fixed while the small upper windows are operable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WEST ELEVATION

1:200

The last of the roof finishes is a sedum roof. Each of the roof planes sloping towards the central courtyard have this finish applied highlighting the importance of that space.

Screens on the upper floor filter the afternoon light and create a more private character for the study spaces. The lower floor is more outward facing with sliding panels under an arcade opening towards the courtyard.


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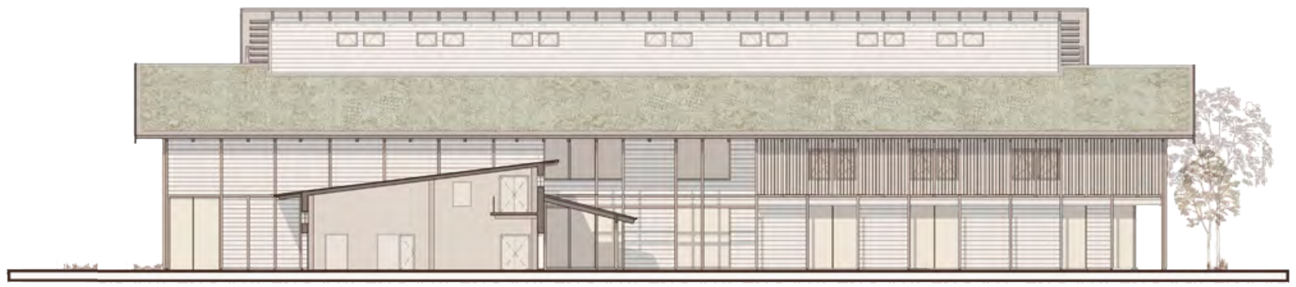
The denser character of the eastern volume comared to the west is readily apparent in this section. The stairs are used to create interesting double height spaces, such as the presentation area on the library's ground floor.



COURTYARD ELEVATION DD

1:200

The other side of the courtyard. This facade is not setback on the ground floor. Also highlighted is the walkway connecting the east and west volumes, and the arcade running east-west along the lobby.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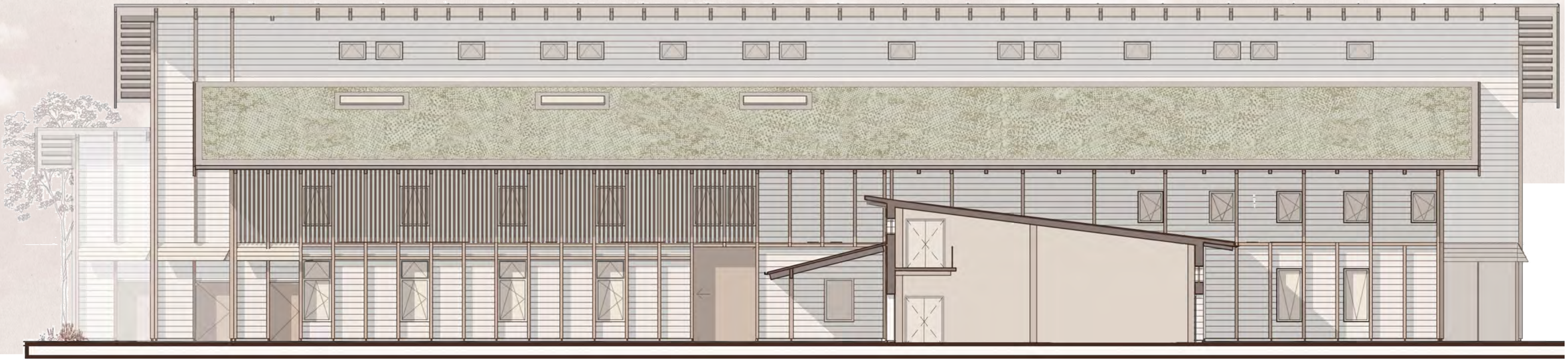


SECTION BB & COURTYARD ELEVATION CC

1:200

STRUCTURE

The Structural System

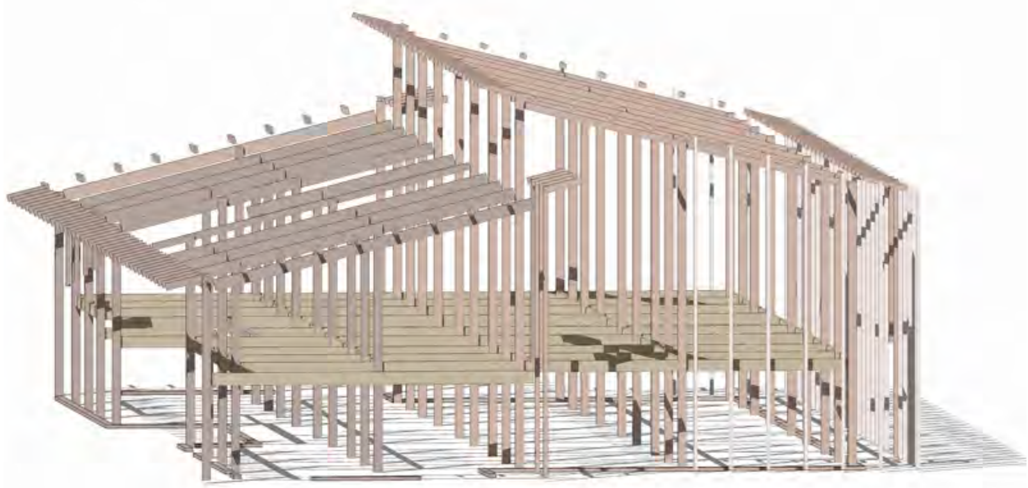
From the beginning of this thesis project, there was a deliberate decision to primarily use natural materials. This led to the selection of wood as the main structural material. Another significant reason was the school's educational focus, builders working with natural materials, and carpenters. The goal was for the building to serve as a learning and inspirational tool for the students. This would lead to the second decision of designing the structural framework to be exposed on the inside, allowing students to experience a structural system on a real-life scale.

Concerning the form of the skeleton, it was inspired by the two faces of the CraftTech school: craftsmanship and academic learning. As two different volumes facilitate those two sides, different strategies were followed for the structural system.

Since structural analysis was not the primary technical focus of this thesis project, the dimensions for beams and columns were derived from "The Architect's Studio Companion: Rules of Thumb for Preliminary Design." By applying these guidelines to various wood types and load-bearing areas while also considering the height of the structures and the types of roofs (metal roofs with PV panels and sedum roofs), appropriate final dimensions were determined.

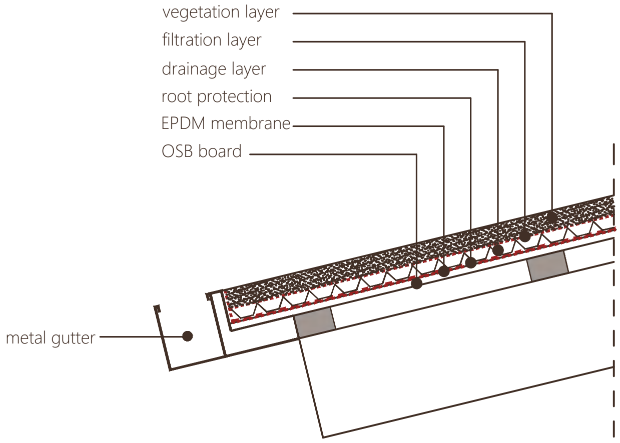
The west building volume, hosts the assembly studios and the workshops. Because of the large work areas needed it was decided a large structure system covering long spans would be an ideal choice. The forces are expressed through large structural members able to cover the whole span of 15m clearing each studio without interruptions. This capability is important both for the studios where the students will construct multiple model scales and the workshops that are hosting big machinery. Since structural integrity was the fundamental property, glulam wood was chosen for its higher load-bearing capacity than normal wood. Multiple structural beam and column combinations were tried and distilled into a final skeleton that fits its purpose. That is to say to be structurally efficient, but also aesthetically pleasing and in harmony with the building volume and scale.

The east building volume, which facilitates conventional academic learning, there is no special need for covering large spans. As a result, a denser structural grid of mass timber, specifically pine wood, was chosen. As the strength of timber is less than that of glulam the dimension of the beams is similar but the spans covered substantially smaller. In this way, students can experience two different types of structural skeletons that suit different scales and are expressed with different joints. Both are built of natural materials that will be prevalent in each of our educational paths.

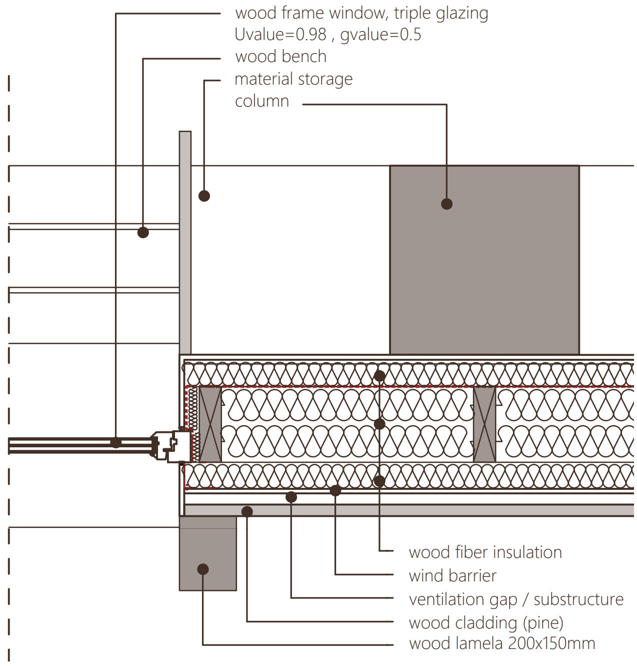


Structural Details

These structural details are all taken from the west assembly studio.



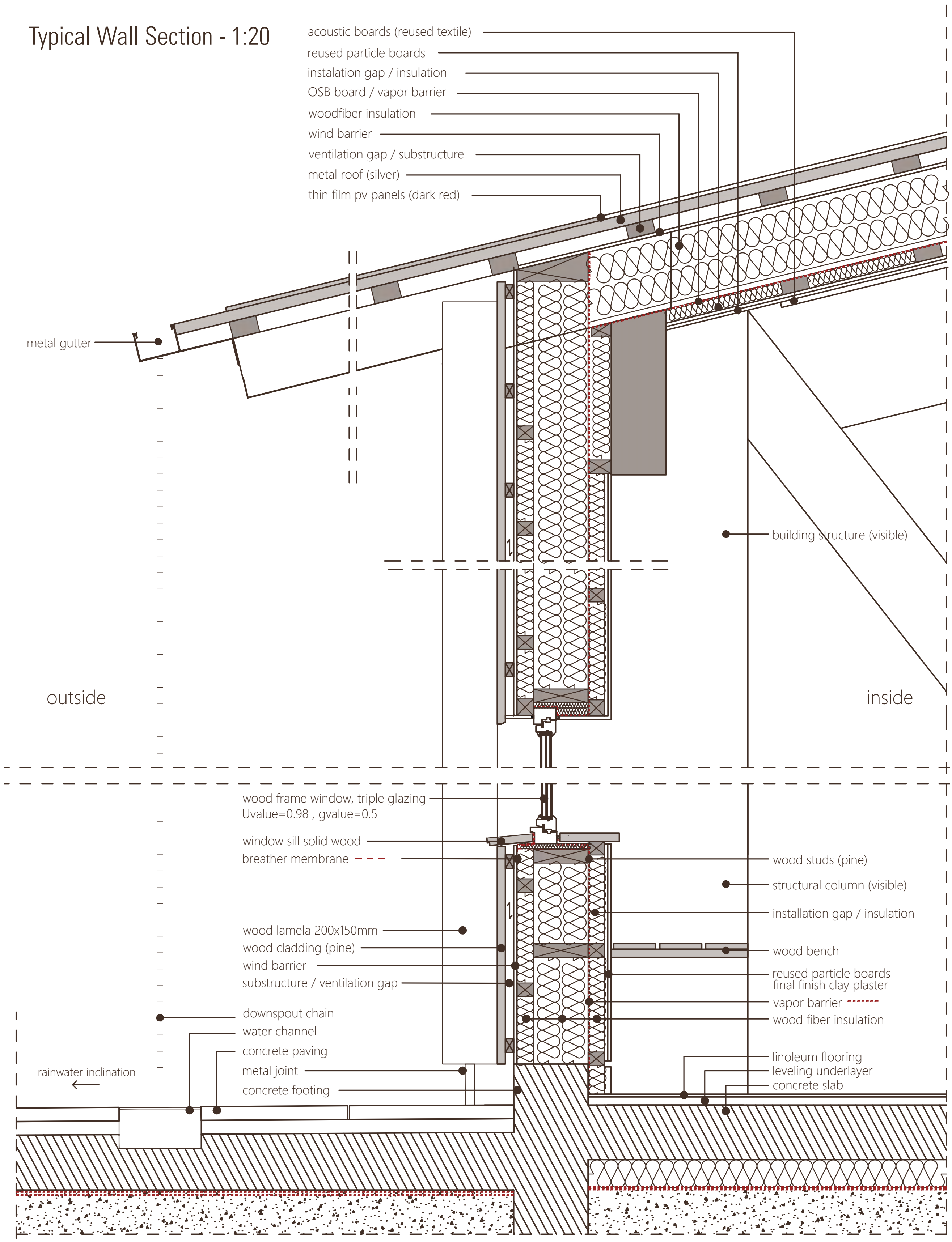
Sedum Roof - 1:20

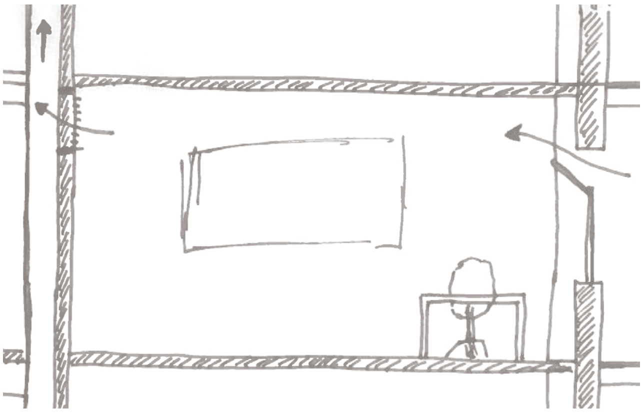


Typical Wall in Plan - 1:20

Some key points include that the wall width is 42cm with a U value of 0.13 W/m²K. In plan, studs in the insulation layers are rotated to reduce thermal bridges. Columns are left exposed to the interior to be visible to students. Their depth is lined up with integrated furniture such as benches and material storage shelves. The roof thickness and weight of the sedum roof makes its supporting beams deeper.

Typical Wall Section - 1:20





VENTILATION STRATEGIES

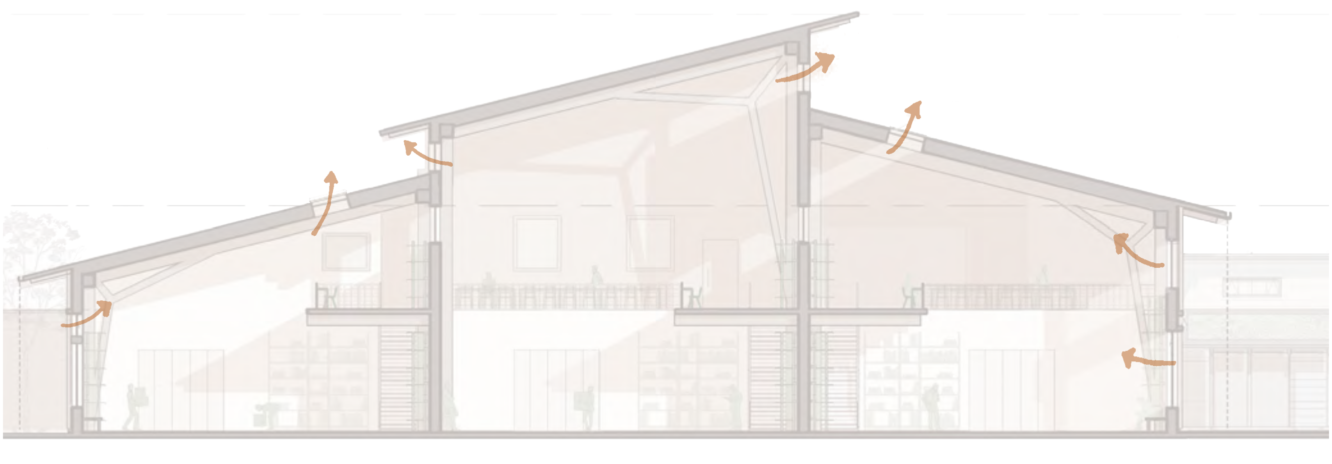
A hybrid ventilation strategy was chosen for the building combining both natural and mechanical ventilation. Mechanical ventilation was applied throughout the heating season, to minimize heat losses. In addition to this window were carefully designed to ensure small window openings were also available. This is, very useful for getting in some fresh air during winter without a large cold shock.

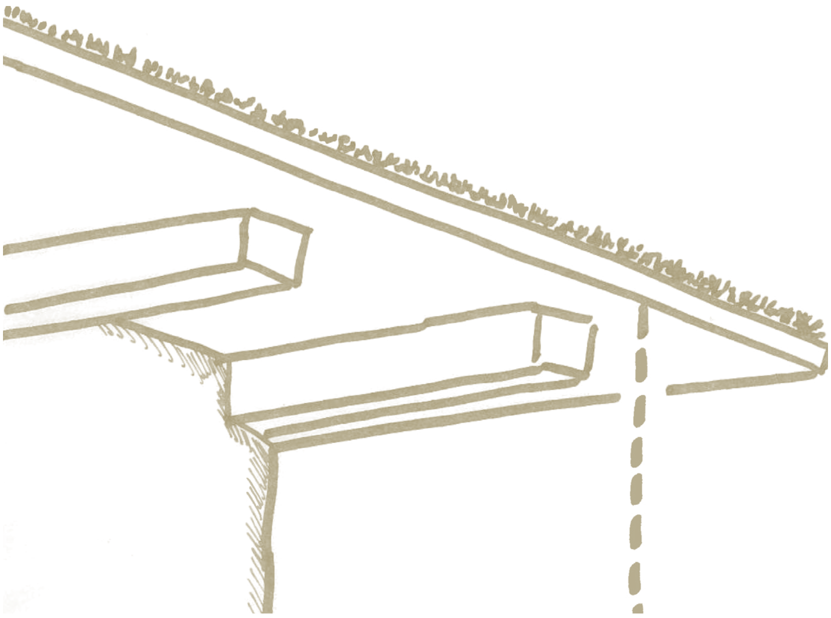
In contrast, natural ventilation is employed during the warmer months to ensure indoor air quality. In addition, natural ventilation has also been used to avoid overheating and minimize the hours above 26°C, thereby eliminating the need for mechanical cooling.

The sketchs demonstrate that most of the building areas can utilize cross-natural ventilation strategies by incorporating openings on two different sides of the building. Furthermore, the double-height spaces allow for a combination of stack and cross ventilation, achieved by placing openings at higher elevations.

The only areas where cross-ventilation strategies were not feasible were the classrooms on the ground and first floors. While an interior ventilation opening towards the corridors could have been an effective solution, it was avoided due to acoustic concerns. Consequently, solar ventilation chimneys were added to each classroom to enhance air movement within the space.

Finally, the machine workshop areas use mechanical ventilation to ensure the appropriate environment for the equipment.



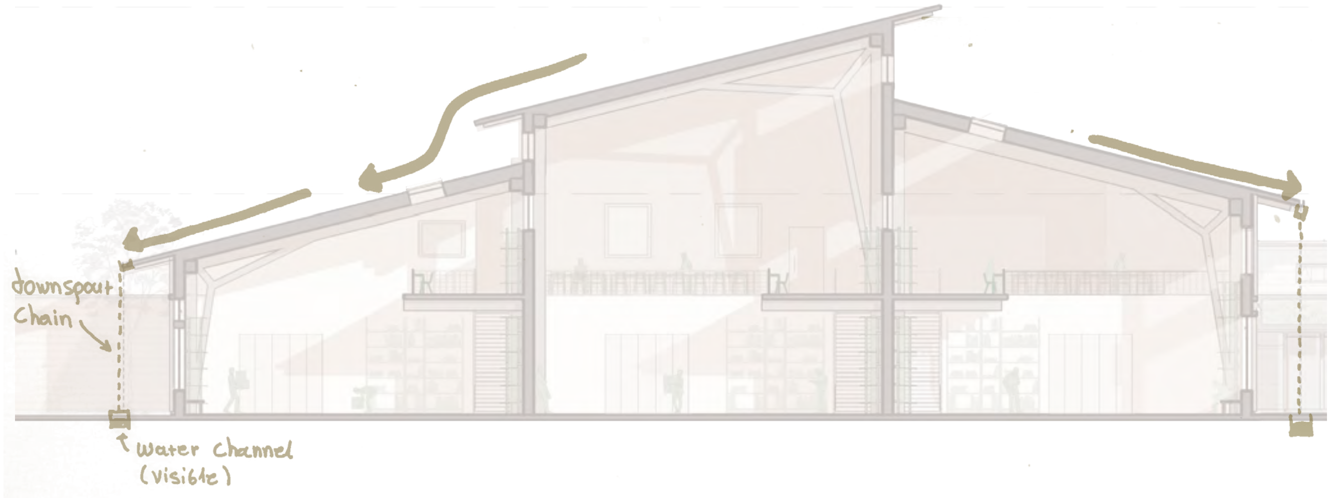


RAINWATER

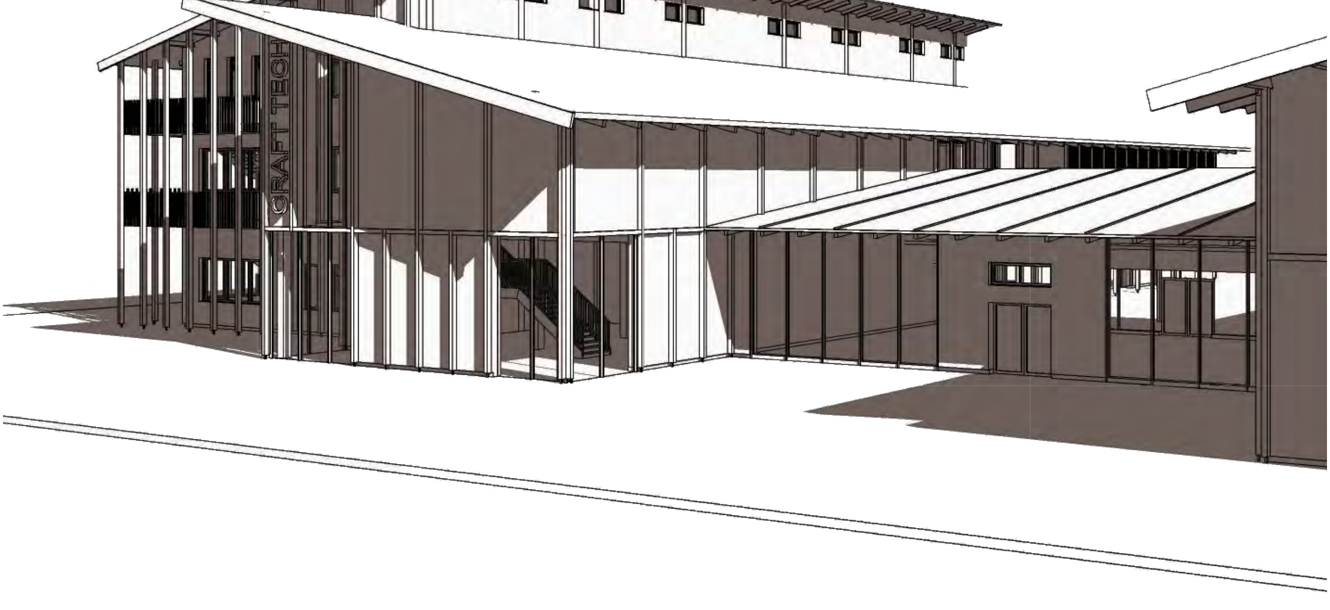
It is undeniable that rain is a dominant feature of the Danish climate. From the beginning of the project, the goal was to design a building that maintains its appeal and functionality in both sunny and rainy weather. To address the challenges posed by rain, a mono-pitched roof was selected. This design choice helps prevent the formation of inaccessible gutters between roofs, thereby enhancing the building's durability and ease of maintenance.

Big eaves with a depth of 2m are also protecting a big part of the facade, while at the same time, all of the entrances are also protected by the rain by small or bigger overhangs. Those overhangs provide a buffer zone for users as they enter or exit the building.

Furthermore, the rainwater drainage system has been designed as an integral and visible feature of the building. Instead of traveling through enclosed pipes, rainwater flows along an exposed route from the roof to the ground and into a storage system. Starting from the roof, a chain replaces the traditional downspout, guiding water into an open channel at ground level. This design allows students to observe and engage with the natural movement of water. The channels then direct the water into two ponds - one to the west and one to the south - which serve as rainwater storage. This approach helps prevent overloading the community rainwater system while providing an aesthetic quality to the landscape.


downspout
Chain
water channel
(visible)


downspout
Chain
water channel
(visible)
downspout
closed pipe
water channel
visible
(leading to the pond)


CRAFT TECH

PROCESS

The following pages present the process through which the final conclusions in the previous chapter were drawn.

VALUES DEFINED ON THE PROGRAM TABLE

An important addition to the building program spaces were the desirable values for a good quality indoor environment which were set by using the Danish standards regulations.

Indoor air quality (IAQ): The required ventilation rates were calculated using the following formula from the DS 15251_2007:

qtot= n*qp + A*qB

qtot = total ventilation rate of the room (l/s)

n= number of persons

qp = ventilation rate per person l/s per pers. The values for Category II (level of satisfaction) so 7.

A: room floor area

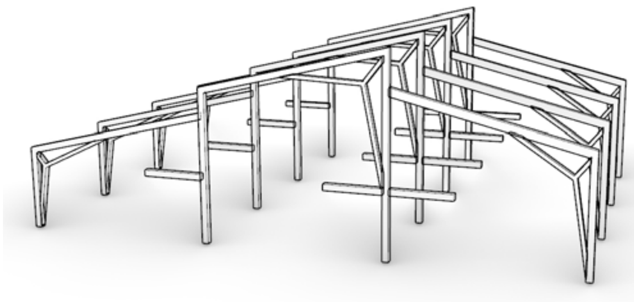
qB : ventilation rate for emission from the building l/s per m2. The values for Category II (level of satisfaction) were used 0.7 factor (low polluting) for most of the building and 1.4 (non-low polluting) for the workshops, the assembly studios, and the kitchen.

The desirable daylight levels in lux, were set by consulting the DS/ EN 12464-1:2021. According to this standard in the section devoted to schools, the levels of light for the classrooms and workshops is proposed relatively high at 500 lux. And this is the threshold that was set in all the simulations of this thesis.

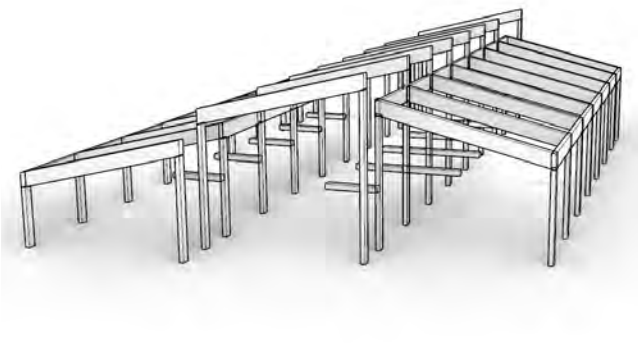
Finally for the operative temperature, according to the Danish standard DS 447:2021, the classroom should have a heating temperature of 20° and a cooling temperature of 26°. These are the temperatures also set for most of this project areas. Nonetheless, this temperature corresponds to a sedentary activity level of 1.2 met. Taking into consideration that vocational schools have also a more active part held at the assembly studios and machine workshop with a higher activity level (1.5 met) a different temperature for heating should be set. After the research process in various Danish standards, no specific heating temperatures were found for workshop areas. However, a temperature of 16° was proposed for areas with standing walking activity like department stores (DS_EN 15251:2007). This is the temperature set for the areas of the project with higher levels of activity.

STRUCTURE ITERATIONS

As mentioned in previous chapters the building structure is exposed and visible towards the inside. Since the intention for the craftsmanship volume was to cover the big span of 15m without any columns in between, various structure forms were made to ensure efficiency, functionality, and visual harmony. Below you can see some of the iterations that were rejected before the final choice of the structure presented in the presentation chapter.

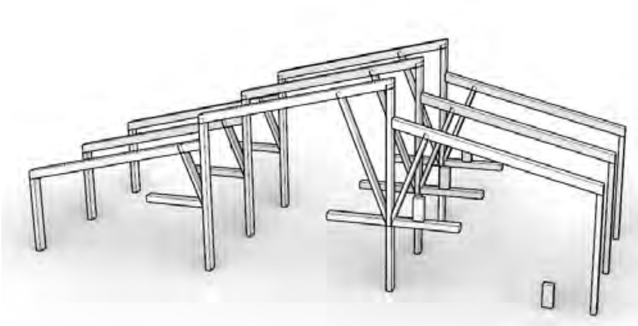


Final iteration: Breaking the span with a triangular truss

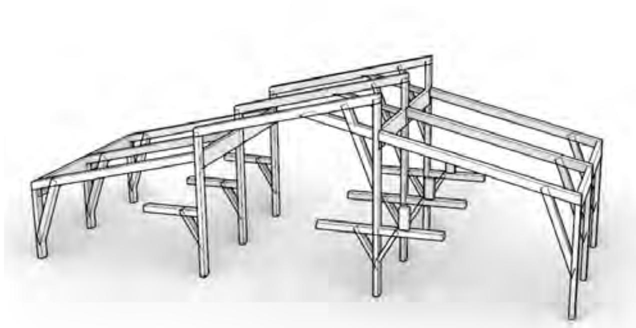


Structure iteration 1: Singular big height beam

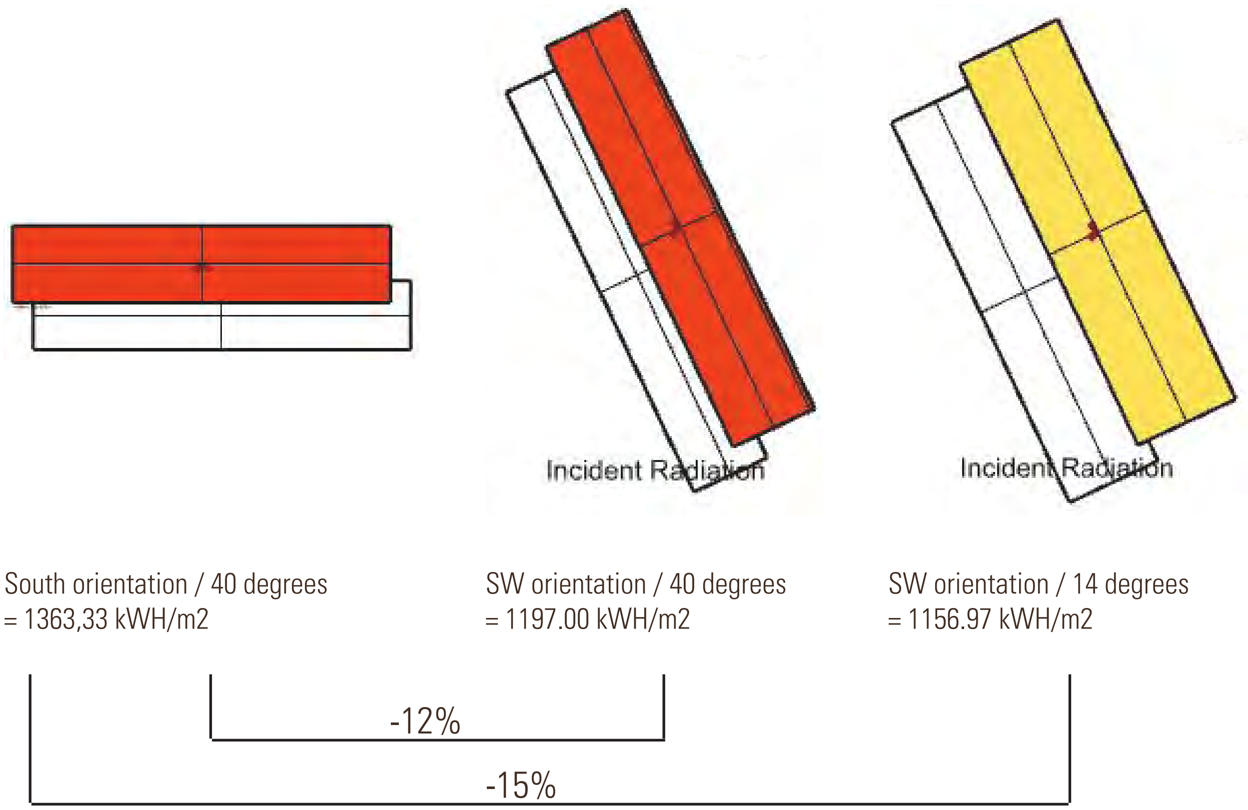
Structure iteration 2: Truss beam



Structure iteration 3: Breaking the span with a diagonal beam



Structure iteration 3: Breaking the span with an X truss



PV PANEL INVESTIGATION

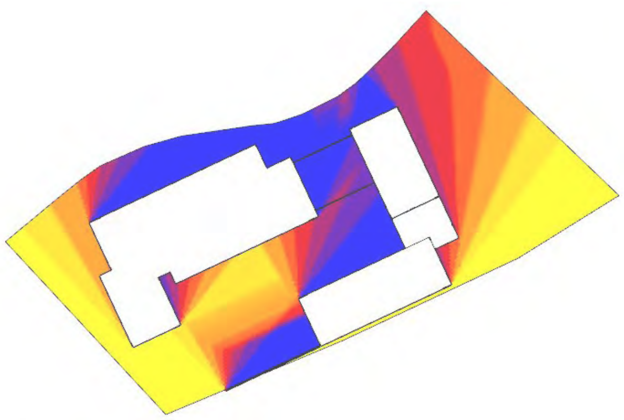
The extensive span of the project volumes and the decision to avoid pitched roofs to prevent rainwater accumulation and difficult-to-reach gutter areas resulted in the design of mono-pitched roofs. These roofs have a relatively low angle of 14° to prevent a significant increase in the building height.

Before deciding whether to add PV panels to the roof, an investigation was conducted to determine how much efficiency would be lost if the panels were not in the ideal orientation and slope. The program Grasshopper was used to calculate the incident solar radiation per square meter for three different scenarios.

According to the results, the project's PV panels will have 15% less efficiency than the ideal scenario. However, this reduction was not considered prohibitive for the decision to add the PV panels.

DIRECT SUN HOURS ANALYSIS

The direct sun simulations have been a considerations for this project from the early beginning of the concept stage. It was one of the main parameters that affected the design and the final choice of one massing concept from the different options created. Below an illustration shows a previous version of the final concept, in contrast with a alternate concept that was rejected due to its poor sun hours during winter. In the final concept, the main orientation of the building is Southwest and Northeast. This orientation allows both building volumes east and west of the lobby to receive direct sun hours. The same goes for the large courtyard yard between them that receives a big amount of direct sun hours both during summer and winter.

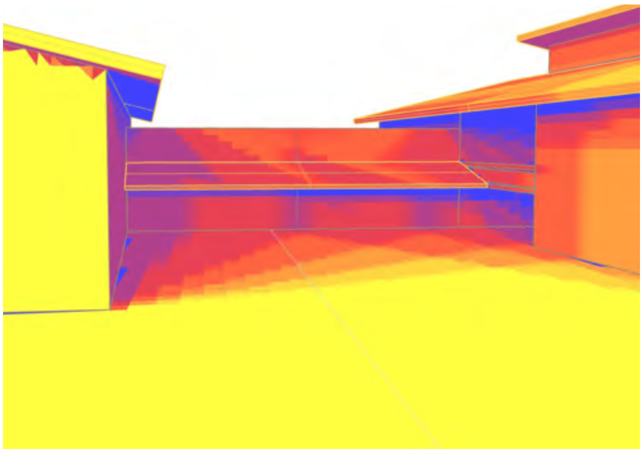


Rejected Design Concept: Direct hours during December

Final Conceptual Exterior Space - Direct Sun Hours During December

At a later stage of conceptual design, further considerations in terms of direct sun hours were investigated from three key areas outside the building: The canopy in front of the lobby, the small yard created by the building niche on the east building volume, and the balconies on the east facade.

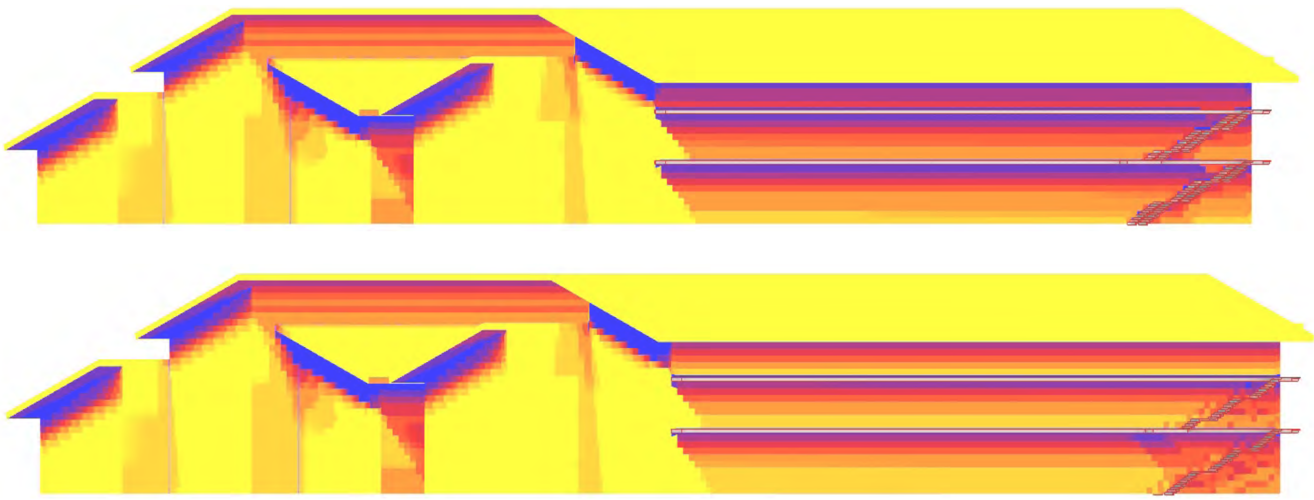
Concerning the canopy in front of the lobby, it was initially designed to be 6m deep. This depth serves the purpose of creating a protected area, highlights the lobby entrance, and creates a profile proportional to the rest of the volumes. However, there was a concern whether it was too deep and might prevent solar gains in the lobby during winter. According to the sun analysis, this concern was proved incorrect since the windows are completely shaded during July but receive a large amount of direct sun hours during winter (an average 60 hours during December). In addition, even if the canopy was 3m instead of 6m the direct hours during December would increase only 13% making a minor difference at the final results. Furthermore, the addition of an overhang in the lobby roof helped windows avoid direct sun during summer.



Lobby South Elevation Overhang - Direct Hours During December

Concerning the recess in the east volume, an investigation was conducted whether the addition of an exterior glass skylight would improve the sun conditions in this building area or not. According to the simulation in the exterior area ground created from the recess, the direct sun hours during the winter remain the same in both options since the sun position is very low, while during July the direct sun hours are doubled. As a result instead of adding a glass partition, it was decided to lower the recess depth from 7.5 m to 5 meters which also doubled the direct sun hours for the winter months.

Finally, on the northeast facade, decreasing the depth of the balconies and the roof overhang was tested going from from 3.5 to 2m. According to the results the direct sun hours on the elevation during December were increased by 10% while during July by 30%. This increase important for this facade



Direct Sun Hours in July - Before & After the Reduction of the Balcony Depth

SIMULATING THE INDOOR ENVIRONMENT

Standards

Depending on a room's occupancy, use and activity levels there are different requirements that need to be achieved. As per the program table 500lux needs to be achieved in 50% of the area for 50% of the time, along with a daylight factor of at least 2 percent. In addition to this a hybrid ventilation system should be able to achieve an IAQ of 175 l/s or 3.04 air changes per hour in the classrooms. Lastly the temperature shouldn't exceed 26 °C for more than 100 hours.

To produce an integrated design simulating building performance is a necessary part of the process. To understand the indoor environmental quality of key spaces within the building Grasshopper was used to answer following key questions:

1. Do spaces receive proper amounts of natural light?

2. Is it possible to cool the building solely through natural ventilation and still have comfortable indoor temperatures?

3. Is it possible to achieve proper air quality results in the summer from natural ventilation?

The key spaces were chosen by identifying the critical areas of the building where achieving favorable results would be most difficult and which spaces were most critical for everyday use. By designing these spaces to meet building requirements it is logically possible to do the same in less challenging spaces. The two main areas explored thorough building simulations are:

The Classrooms:

The classrooms on the North-East facade are one of the most used rooms in the building, with students coming in and out through the entire day. The main challenges they face are due to orientation, deep overhangs, and limited exterior frontage. Having only a single exterior facade makes using natural ventilation more challenging. Additionally, each level contends with a balcony or roof that casts large amounts of shade reducing already limited solar access. The specific classroom modeled in the simulations is in the middle of the second floor, with the largest overhangs.

The Assembly Studios:

A direct counterpart to the academic classrooms, the assembly spaces are equally important. They have large openings along their southern faces, especially at grade. Being double and triple height spaces the openings further up on their facades effect the same spaces. The amount of gazing makes controlling light conditions an area of particular interest.

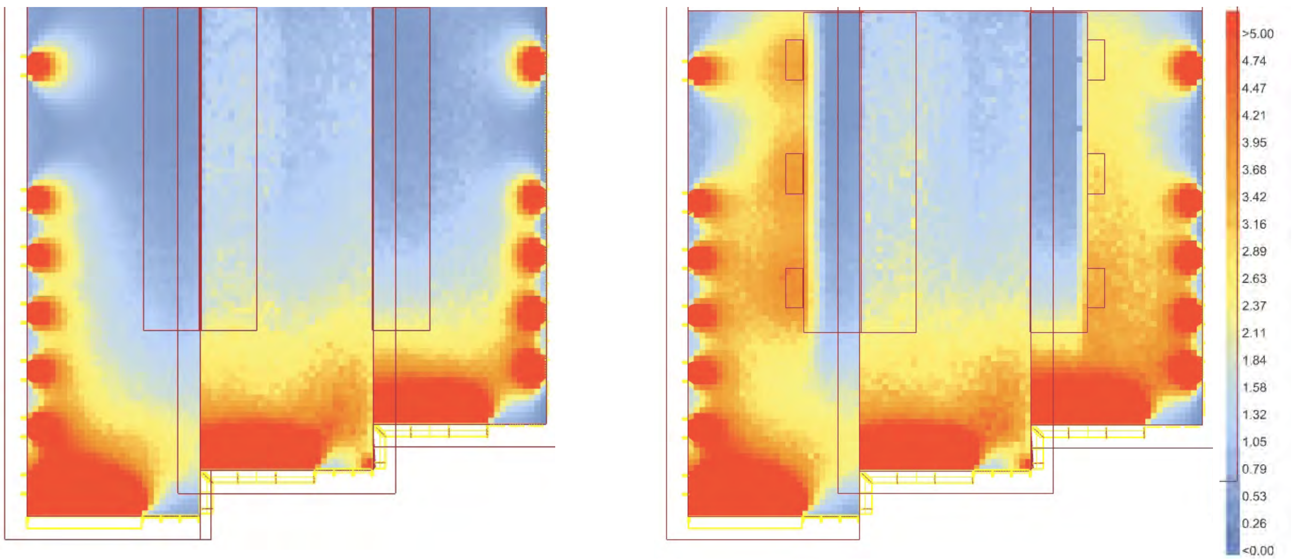
ASSEMBLY STUDIO INTERIOR ENVIRONMENT

Daylight Analysis

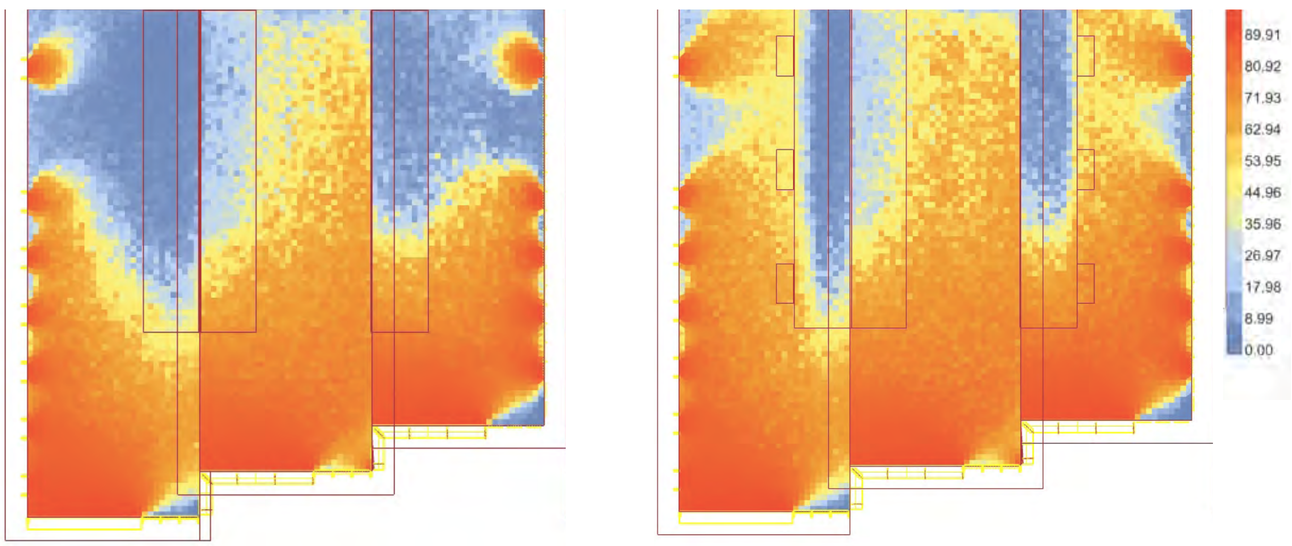
The three assembly studios were simulated to ensure that the goal of 500 lux for 50% of the time for 50% of the space was achieved. The middle assembly studio, despite having only one open elevation, achieves it's target thresholds without any iterations. This is due to the windows along the length and top of the walls, very high up in the space.

However, the west and east assembly studios, despite their extensive southern facades with adequate window openings, exhibited areas with insufficient lighting. To address this issue, three strategically placed skylights were added to each studio, ensuring a uniformly lit interior.

When considering the three studios as a general area, the daylight factor was increased from **2.5% to 3.07%** after introducing skylights into the space. The percentage of the area with the target lux for 50% or more of the time was increased from **54% to 69%.**



Daylight factor before and after the addition of skylights



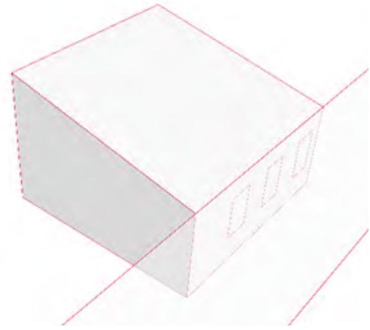
The amount of time (%) that the area receives >500lux Before & After the Addition of the skylights

CLASSROOMS
INTERIOR ENVIRONMENT

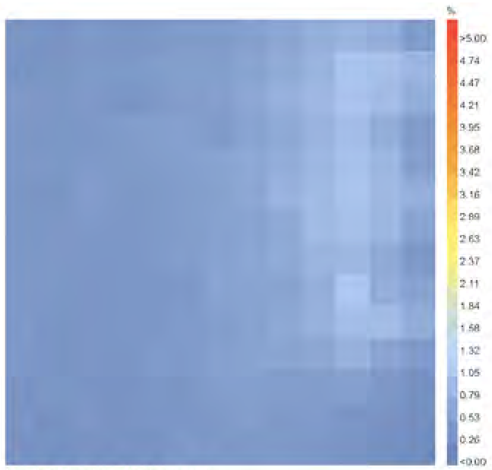
Do Spaces Receive Proper Amounts of Natural Light?

Scenario 1:

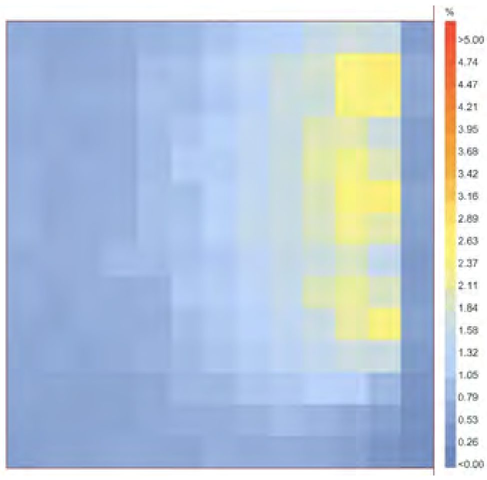
Orientation:	North East
Shading:	3m
Windows:	3 at 1.1m x 2m



As mentioned previously a minimum daylight factor of 2% is required to comfortably be able to complete classroom related tasks. As the graph below shows, the average level in this scenario is only on the top floor **0.4%** and only slightly higher on lower levels at **0.9%**. The reason for the difference is that the balcony is orthogonal to the building facade unlike the roof that is angled downwards in front of it, blocking more of the light. This shows that the design needed to be changed to order let the minimum amour of light inside, before being able to examine indoor temperature and air quality.



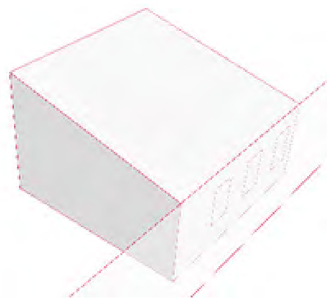
Daylight Factor at the Second Floor Classroom



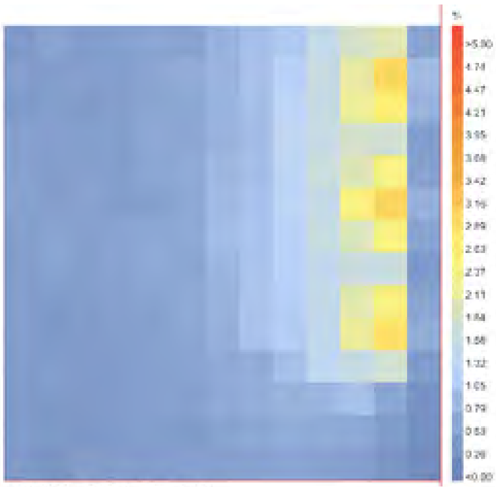
Daylight Factor at the First Floor Classroom

Scenario 2:

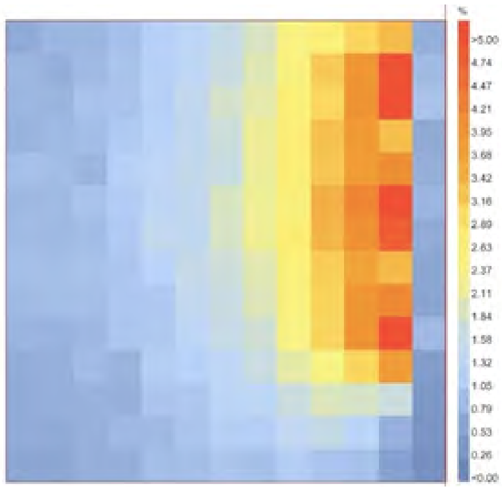
Orientation:	North East
Shading:	2m
Windows:	3 at 1.1m x 2m



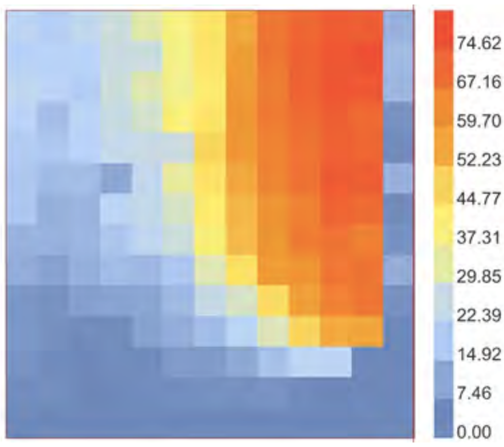
This scenario reduces the overhang by 1.5 meters by removing the exterior balcony stairs out from under it's shelter. While the reduction of the shading improves the situation, with the average DF increasing to **0.77%** and **2.5%** respectively the outcome is still not satisfactory. Wile the lower classrooms reach the minimum daylight factor Only **26%**of the space achieves 500 lux half the time. This is largely due to only having light aces from one side of the room. Further improvements were necessary to the base lighting conditions in both types of classroom before progressing further in the simulations.



Daylight Factor at the Second Floor Classroom



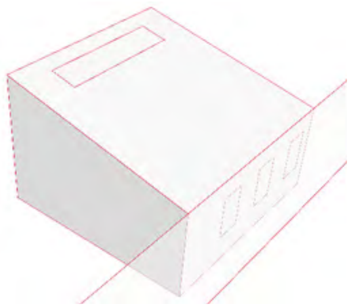
Daylight Factor at the First Floor Classroom



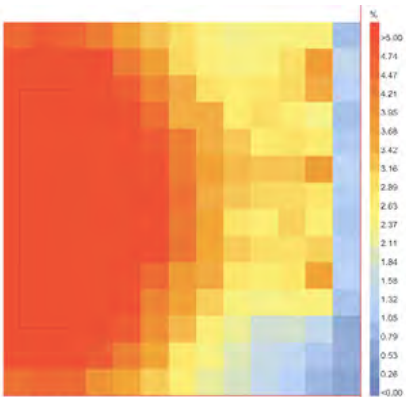
Lux Leves for the First Floor Classroom

Scenario 3:

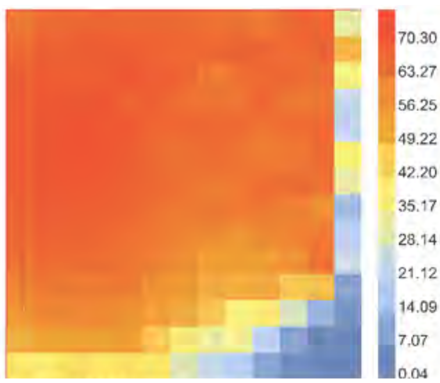
Orientation: North East
Shading: 3m
Windows: 3 at 1.1m x 2m
Skylights/Int. Windows: 1 at 1.1m x 4m



In the top floor classroom a skylight was added to allow more light to enter the room, greatly improving the interior lighting conditions. An average daylight factor of **5.8%** was achieved and **75%** of the space achieved 500lux over 50% of the time. Some problems still persist, such as the uneven distribution of the light.

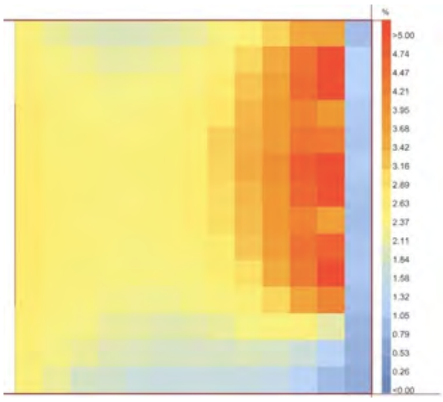


Daylight Factor - Second Floor Classroom

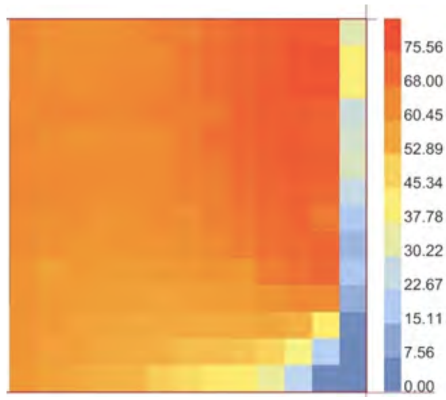


Lux Leves - Second Floor Classroom

Adding a skylight was not possible on any of the lower floors therefore the lack of light was addressed through the addition of an interior clerestory window facing the corridor. This created very nice interior conditions with an even distribution of light throughout the space. The average daylight factor achieved was **2.55%** with **84%** of the area meeting the lux requirements.



Daylight Factor - First Floor Classroom



Lux Leves - First Floor Classroom

Having achieved the desired light conditions in the space it is necessary to check if these design solutions solve one problem while causing others. The current window placements could be causing overheating or be insufficient for the ventilation needs of the space. Therefore, it is necessary to evaluate;

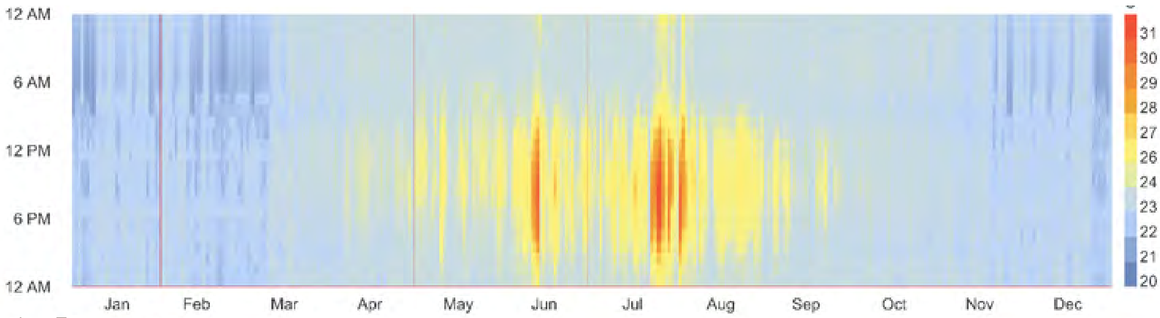
Is it possible to cool the building solely through natural ventilation and still have comfortable indoor temperatures and sufficient ACH values?

Orientation:	North East
Window U Value:	0.98 W/m²K
Window g Value:	0.5
Skylight U Value:	0.98 W/m²K
Skylight g Value:	0.5
Wall U Value:	0.13 W/m²K
Nat. Vent. Set Point:	24˚C
Operable Area:	70%

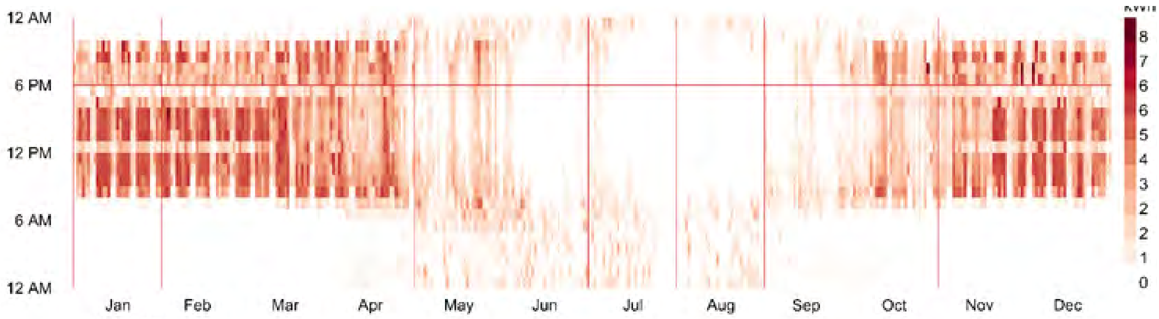
The strategy for ventilation and temperature control evaluated below is a hybrid ventilation system. In the classrooms one of the biggest challenges is the solitary exterior face making cross ventilation difficult. To address this issue stack ventilation is introduced in the lower floors in the form of a solar chimney, while the topmost level utilizes an operable skylight.

To explore the aforementioned questions a Honeybee script was constructed whose logic and embedded information can be seen in the appendix. The key values parameters of the evaluated assembly are listed above.

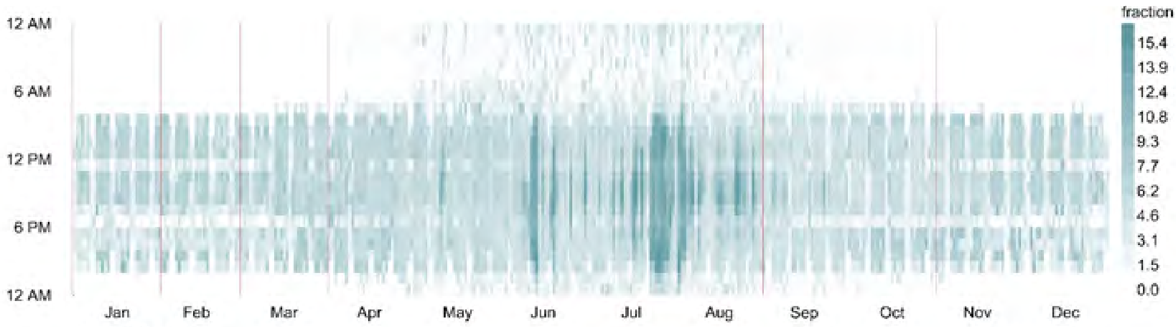
The space used for the following modeling exercise is the uppermost classroom.



Indoor Temperature



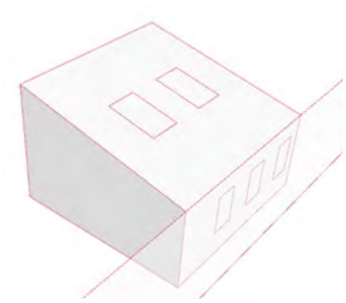
Heating Energy in KW/h



Hourly Plot of the Air Change Rate Per Hour

The first graph shows the indoor operative temperature for the entire year. While October to March all fall within comfortable indoor temperature ranges there is some overheating in June and July which needs to be investigated. The second graph shows when the heating system activates. Overall, within a year it uses **191.7 kWh/m^2**, which is quite high. The reason can be seen in the third graph – windows are being fully opened in the colder months as the people load drives the temperature above 24˚C, rapidly over-cooling the space and causing the heating system to activate. In the summer the cooling from natural ventilation is activating appropriately, although it seems the heating system is activating overnight when there are no people present and equipment is turned off. This is an issue as the area should be heated in the warmer months. The ACH is usually around **3.1** throughout the year, with the hottest days causing some visible spikes as the need for ventilation increases. In this scenario the building has **162 hours** above 26˚C and **107** above 27˚C.

Overall, with the current widow placement and operability sufficient light and Air Changes are achieved, but the requirements for indoor temperature are not satisfied and the lighting conditions are quite uneven.

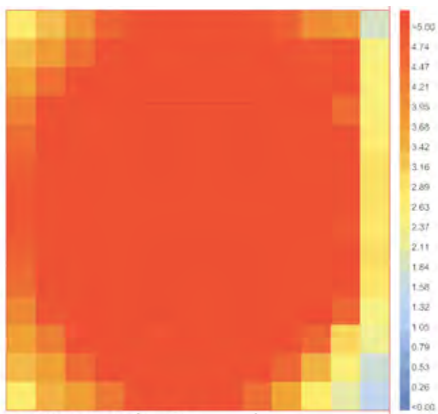


Scenario 4:

Orientation:	North East
Shading:	3m
Windows:	3 at 1.1m x 2m
Skylights/Int. Windows:	2 at 1.1m x 1.8m

To address the unevenness of the light conditions in the previous scenario the skylight placement was moved to the center of the room. The overall glazed area was also reduced to help with overheating. The use of two rectangular skylights also aligns more with the window design on the facade.

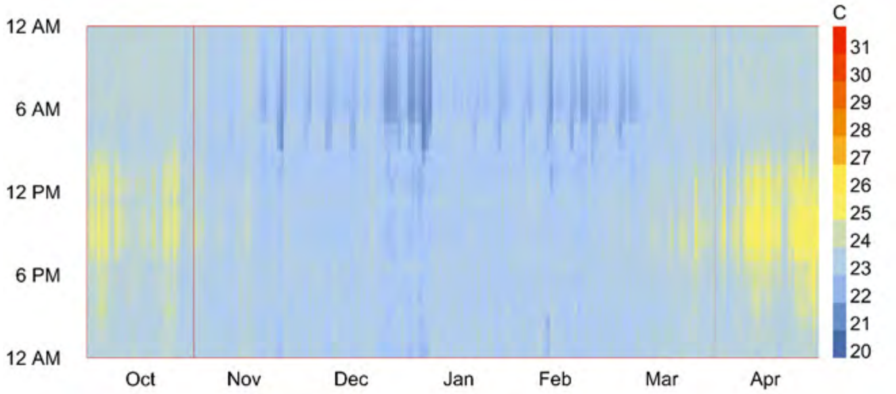
As intended moving the skylight and splitting it into two improves the lighting parameters for the space. The previous average daylight factor went from **5.8%** to **6.2%**. Similarly more of the space achieved 500 lux over 50% of the time, rising to **84%**. The placement of the window within the space had a major effect in the environment within it.



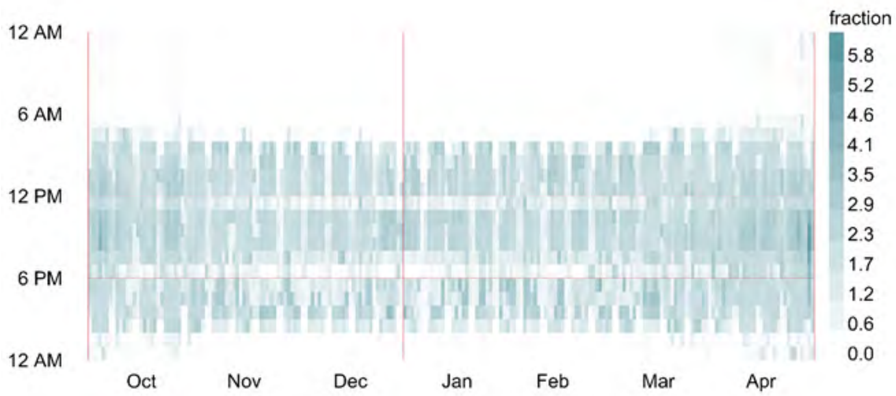
Daylight Factor - Second Floor Classroom

In this scenario, to address the over-cooling issues in the winter months we modified the design of our windows to allow for smaller openings in the winter. Therefore, the simulation was run twice, once from October through to April, and another from May to September. In the former simulation the operable area of the windows on the simulation was reduced to **20%**, and in the other months was kept at **70%**. This allows for a greater degree of flexibility within the system and how the hybrid ventilation is configured.

Heating Months:



Indoor Temperature

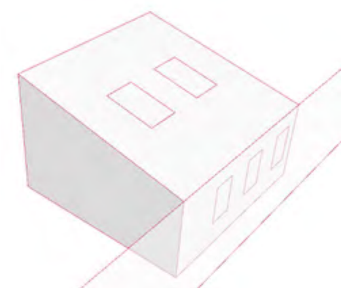


Hourly Plot of the Air Change Rate Per Hour

These are the months ranging from October to April, where the heating system is working with a set point of **21˚C**. As the space is conditioned the temperatures remain acceptable and never exceed 26˚C. The most important thing is that introducing smaller windows drastically reduced the amount of heating energy needed to **26 kWh/m^2** from **191.7 kWh/m^2**. So while the windows are opening when the temperature is increasing above 24 ˚C they are not causing a cold shock to the room. This opening is achieving a ACH of around **3**, during the day when the building is in operation, although this could be more efficiently achieved through mechanical ventilation which wouldn't be suppling causing any temperature fluctuations and would be even more energy efficient. In this case opening the widows would only be necessary if someone wanted fresh air, preferably using one of the smaller operable openings.

Cooling Months:

The new skylights slightly improve the situation in terms of overheating while the ventilation ACH remains virtually unchanged. The hours over 26˚C went down by 8 hours and need to be further reduced.

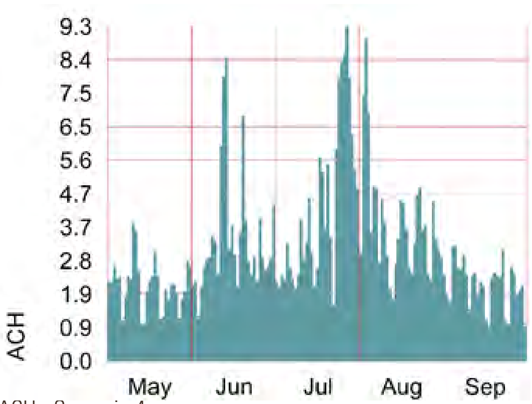


Scenario 5:

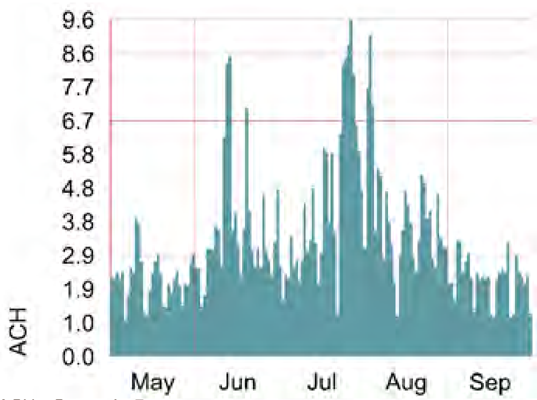
Orientation:	North East
Shading:	3m
Windows:	3 at 1.1m x 2m
Skylights/Int. Windows:	2 at 1.2m x 2.0m

The following scenarios aim to optimize the cooling months condition, particularly in regard to overheating hours. The major change in this scenario was lowering the SHGC from 0.5 to **0.23**. This means that the thermal energy from the sun has a much lower effect on the space, while not impacting the conditions relating to visual spectrum.

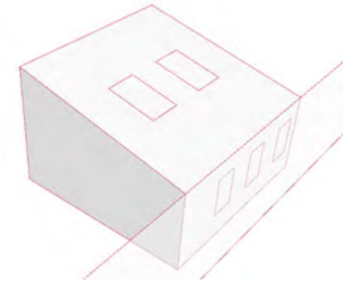
This change had a dramatic effect, causing the overheating hours to drop significantly. The hours above 26˚C went down to **110 hours** with **68 hours above 27˚C and 32 hours over 28 ˚C.** However since the natural ventilation was set to open when the temperature rose above 24 ˚C, and this happened less often, there was a lower air change rate as seen below. This is an issue since ideally the required ACH should be achieved solely through natural ventilation.



ACH - Scenario 4



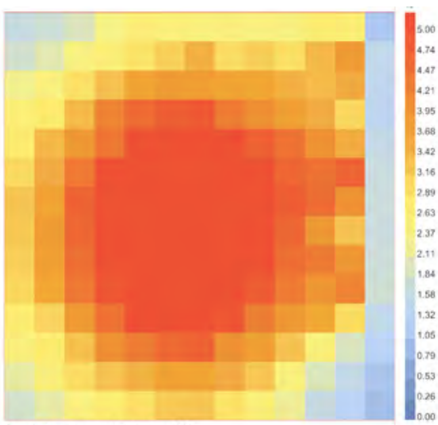
ACH - Scenario 5



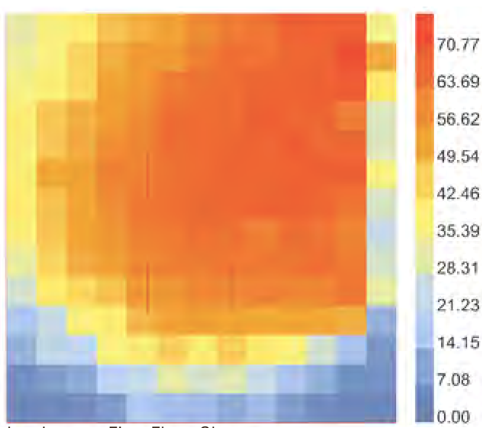
Scenario 6:

Orientation:	North East
Shading:	3m
Windows:	3 at 1.1m x 2m
Skylights/Int. Windows:	2 at 0.9m x 1.3m

In this scenario two final optimizations were made. Firstly, the skylight size was reduced to 0.9mx1.5m from 1.3mx2m. Secondly the natural ventilation set point was set to 22 ˚C. With such a drastic change it was necessary to review the lighting conditions to ensure they were still sufficient.



Daylight Factor - First Floor Classroom

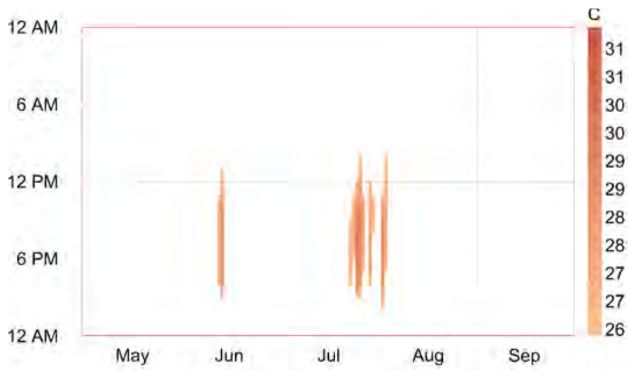


Lux Leves - First Floor Classroom

The change did reduce the amount of natural light, however all requirements in terms of the minimum Daylight Factor and time over 500lux are still being met. The current values are an average Daylight factor of **3.6 %** and **51%** of the spaces receiving over 500lux 50% of the time. The requirements of 2% and 50% are based on the Danish standard which guarantees a better indoor quality than other worldwide standards. For example, the worldwide standard usually guarantees 300lux not the 500 specified for classrooms in the Danish standard. Therefore, meeting these goals ensures that the indoor environmental quality remains excellent

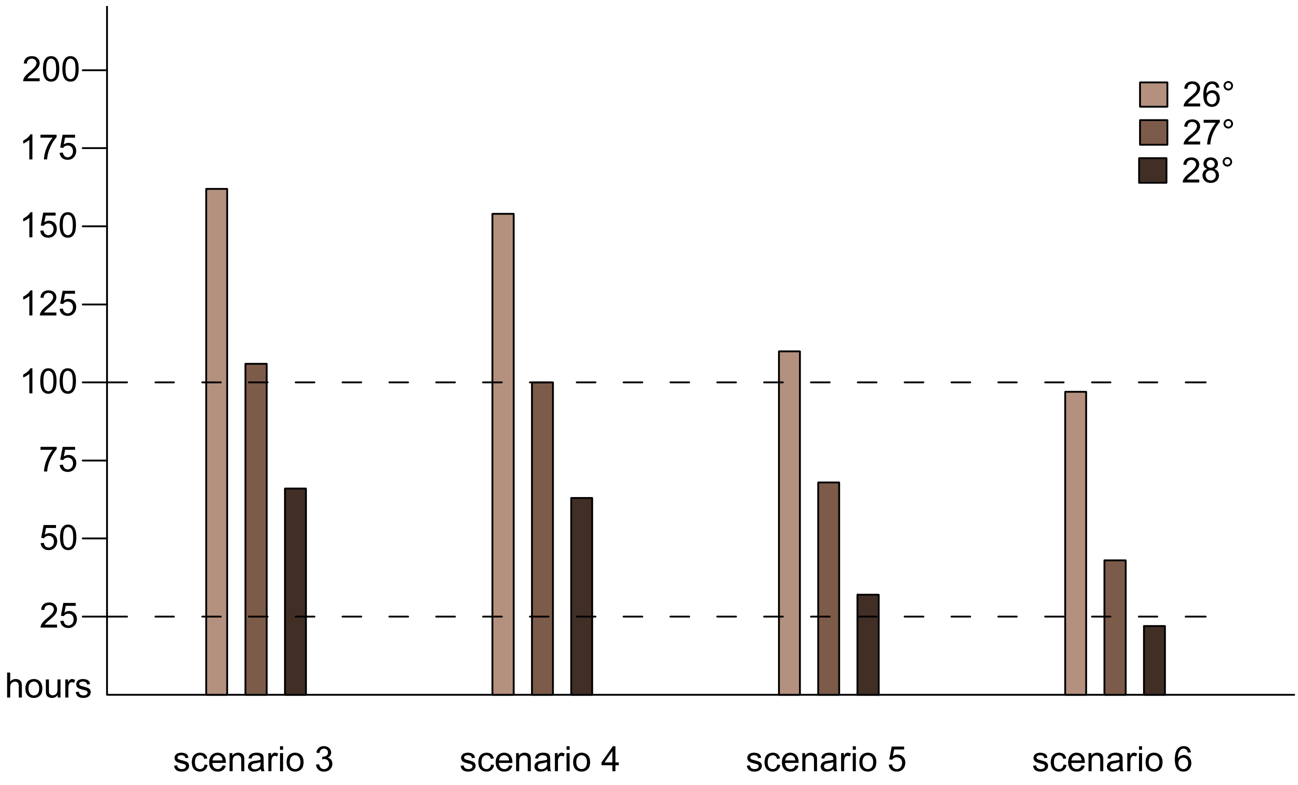
Indoor Temperature and Ventilation Rate

These changes allowed the space to reduce its hours over 26˚C to under 100 to **97 hours**, complying with Danish Standards without any need for a cooling system. The **hours over 27 ˚C** in this scenario are **43** and **22 hours over 28 ˚C**. Additionally, many of these hours occur after 6 pm when the building is either closed or at a lower occupancy level. As they also occur in the summer months it is possible to create a building schedule for summer classes that avoid taking place in the afternoon. Despite lowering the ventilation set point the indoor temperature remained comfortable throughout the other periods.



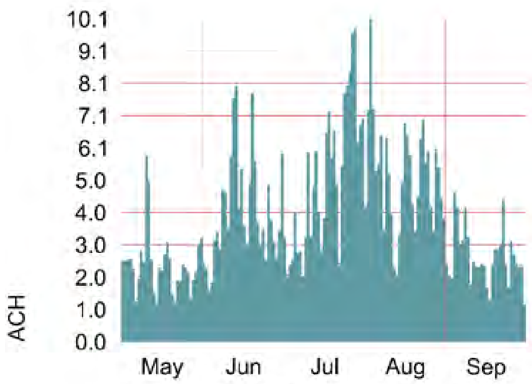
Yearly Distribution of the Hours over 26°C

The graph below illustrates the progression in optimizing the indoor environmental conditions of the classrooms when it comes to overheating. The goal of having less than 100 hours under 26 degrees within a year is met in the final scenario. Although the hours over 27 degrees do not drop below 25 per year the hours over 28 do. Therefore in this final scenario a slightly wider margin for adaptive comfort is asked of the building occupants as it allows the building to function soloey through low-tech methods of cooling.

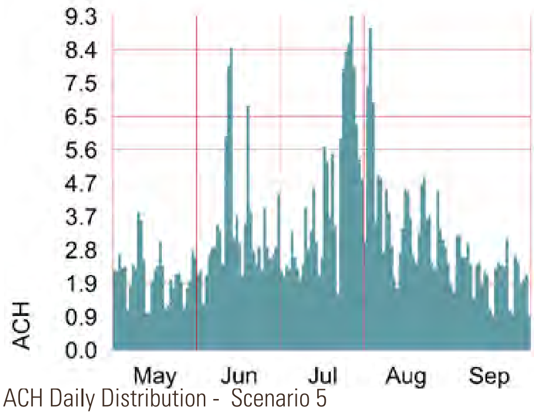


Comparison of hours at 28, 27 & 26°C Between the Scenarios

Lowering the set-point had the intended effect of increasing the ACH to previous levels that meet the 3.04 average as seen below.

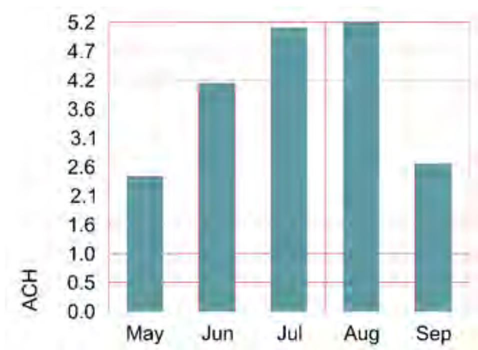


ACH Daily Distribution - Scenario 6

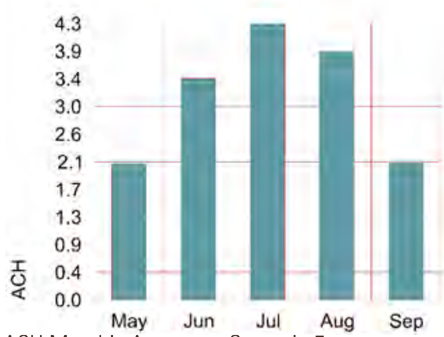


ACH Daily Distribution - Scenario 5

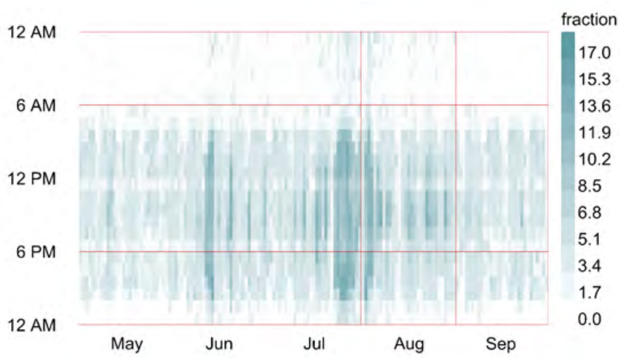
The average values for each month can be seen here as well however are slightly misleading as the ventilation doesn't open when the building is unoccupied as often, of course changing the air less often as well. The hourly plot shows this quite nicely with the most common ACH between 6 and 22 being between 3-5.



ACH Monthly Average - Scenario 6



ACH Monthly Average - Scenario 5



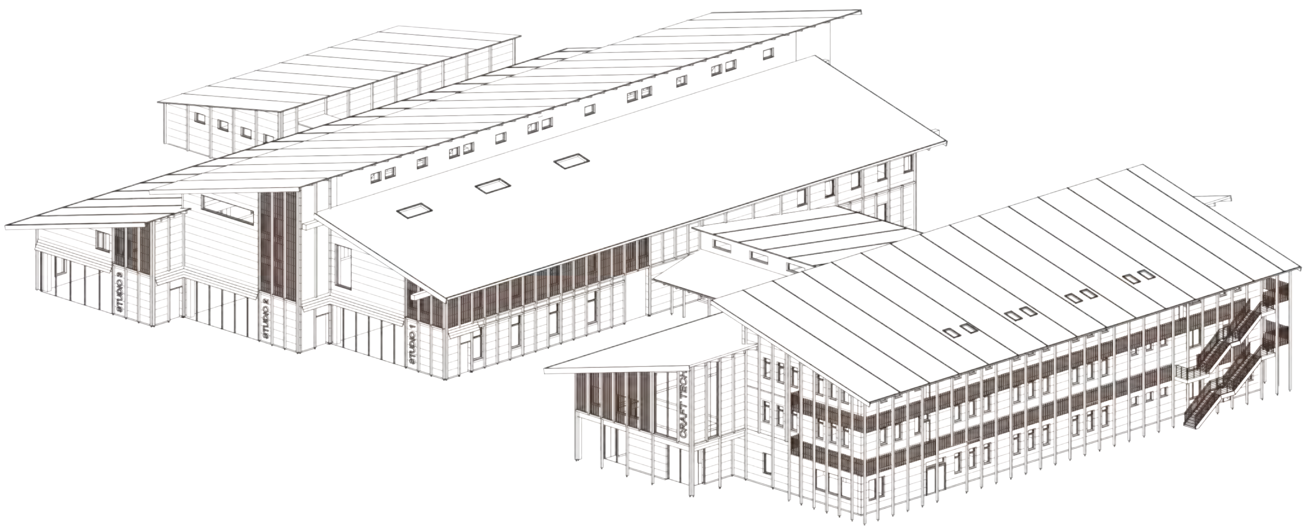
ACH Hourly Distribution - Scenario 6

OUTRO

This thesis began by asking how to create a building that promotes vocational education in Denmark through its program and design. The three educational paths of carpentry, digital fabrication and sustainable construction provide an example of how attractive new programs can be situated in the same location as more traditional vocational education. The decision to implement collaborative projects increases student connection with the school and the nature of this collaboration subsequently ties the school into the community.

The building itself is designed in such a way as to enhance these programmatic intentions. Interwoven flexible multi-purpose spaces allow the building to expand and contract to accommodate it's users. Depending on the time of year areas such as the lobby can draw the public in to exhibitions that educate them about the trades or be occupied by students working on year end projects. The structure itself is also designed to serve as an educational tool, with a natural material structure left exposed for students to see.

Ultimately, this thesis demonstrates the importance of creating educational environments that are not only functional but also inspirational, sustainable, and reflective of the importance of craftsmanship in the modern world.


STUDIO 3
STUDIO 2
STUDIO 1
CRAFT TECH

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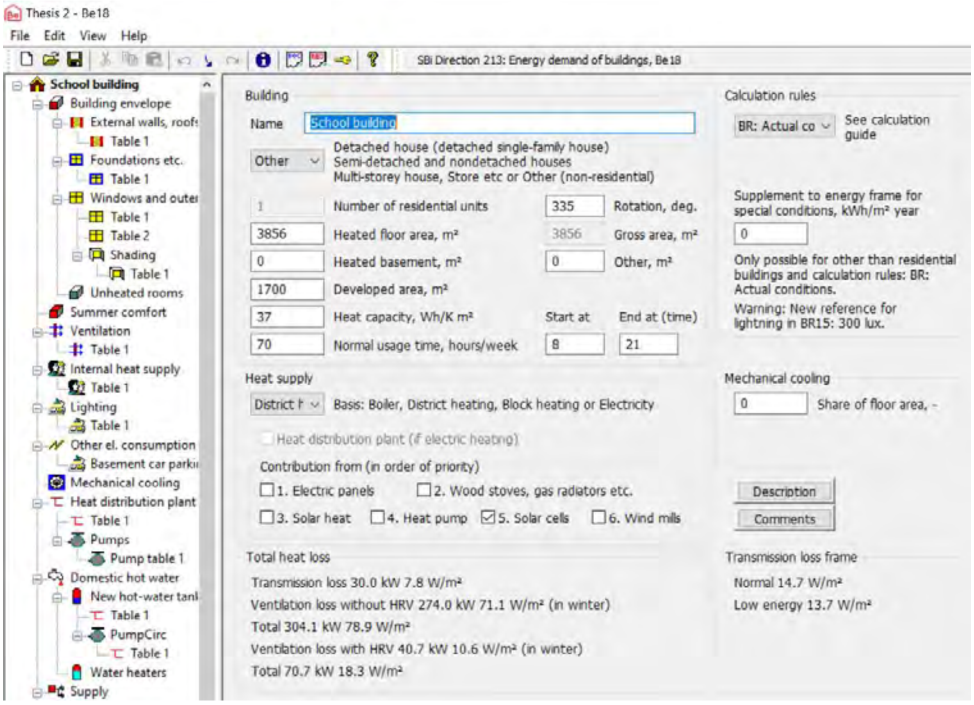
APPENDIX

BE18



	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Inside (C)	Dim.Outside (C)	Loss (W)
		4825.76		CtrlClick	614.129			14343.9
+1	Canteen ground floor	112.55	0.13	1.00	14.6315	20	-12	468.208
2	Wall West V1rest	193.1	0.13	1.00	25.103	20	-12	803.296
3	canteen/study 2nd floor	273.95	0.13	1.00	35.6135	20	-12	1139.63
4	Library north	138.42	0.13	1.00	17.9946	20	-12	575.827
5	Classroom north	203.75	0.13	1.00	26.4875	20	-12	847.6
6	Classroom east	551.84	0.13	1.00	71.7392	20	-12	2295.65
7	Classroom south	207.55	0.13	1.00	26.9815	20	-12	863.408
8	Classroom roof	780	0.12	1.00	93.6	20	-12	2995.2
9	V1 Roof	542	0.12	1.00	65.04	20	-12	2081.28
10	Floor	1700	0.13	1.00	221	20	10	2210
11	V1 lobby	122.6	0.13	1.00	15.938	20	16	63.752

	Windows and outer doors	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ht (W/K)	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside	Dim.Outside	Loss (W)	Ext
		75			188.84		CtrlClick	185.063			CtrlClick				5922.02	0/1
+1	East classroom window 3rd floor	15	NE	90	1.35	0.98	1.00	19.845	0.65	0.5	east 3rd flo	1	20	-12	635.04	0
2	Balcony door	2	NE	90	4.7	0.98	1.00	9.212	0.65	0.5	east 3rd flo	1	20	-12	294.784	0
3	WC 3rd floor	3	NE	90	0.45	0.98	1.00	1.323	0.65	0.5	east 3rd flo	1	20	-12	42.336	0
4	Classroom 2nd floor	12	NE	90	1.8	0.98	1.00	21.168	0.65	0.5	east seconc	1	20	-12	677.376	0
5	Balcony 2nd floor	1	NE	90	5.64	0.98	1.00	5.5272	0.65	0.5	east seconc	1	20	-12	176.87	0
6	WC 2nd floor	3	NE	90	0.9	0.98	1.00	2.646	0.65	0.5	east seconc	1	20	-12	84.672	0
7	Classroom ground floor	9	NE	90	1.8	0.98	1.00	15.876	0.65	0.5	east grounc	1	20	-12	508.032	0
8	entrance ground floor	1	NE	90	11.4	0.98	1.00	11.172	0.65	0.5	east grounc	1	20	-12	357.504	0
9	WC ground floor	3	NE	90	0.9	0.98	1.00	2.646	0.65	0.5	east grounc	1	20	-12	84.672	0
10	Kitchen east	1	NE	90	7.6	0.98	1.00	7.448	0.65	0.5	east grounc	1	20	-12	238.336	0
11	Office 2nd floor	1	NE	90	8.5	0.98	1.00	8.33	0.65	0.5	east seconc	1	20	-12	266.56	0
12	Office ground floor	1	NE	90	8.5	0.98	1.00	8.33	0.65	0.5	east grounc	1	20	-12	266.56	0
13	Classroom south 3rd floor	6	SE	90	1.35	0.98	1.00	7.938	0.65	0.5	east 3rd flo	1	20	-12	254.016	0
14	Classroom south 2nd floor	6	SE	90	1.8	0.98	1.00	10.584	0.65	0.5	east seconc	1	20	-12	338.688	0
15	Kitchen south	1	SE	90	11.6	0.98	1.00	11.368	0.65	0.5	east grounc	1	20	-12	363.776	0
16	Classroom 3rd north	6	NW	90	1.35	0.98	1.00	7.938	0.65	0.5	east 3rd flo	1	20	-12	254.016	0
17	office 2nd north	2	NW	90	8.6	0.98	1.00	16.856	0.65	0.5	east seconc	1	20	-12	539.392	0
18	ofice ground north	2	NW	90	8.6	0.98	1.00	16.856	0.65	0.5	east grounc	1	20	-12	539.392	0
19																
20																

	Windows and outer doors	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ht (W/K)	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside	Dim.Outside	Loss (W)	Ext
		21			281.4		CtrlClick	275.772			CtrlClick				8824.7	0/1
+1	Canteen south ground	1	SE	90	25.8	0.98	1.00	25.284	0.65	0.5	canteen sou	1	20	-12	809.088	0
2	Canteen east ground	1	NE	90	6.4	0.98	1.00	6.272	0.86	0.5	canteen sou	1	20	-12	200.704	0
3	Canteen west ground	1	SW	90	44.4	0.98	1.00	43.512	0.86	0.5	canteen grc	1	20	-12	1392.38	0
4	Canteen east 1st floor	1	NE	90	11.3	0.98	1.00	11.074	0.86	0.5	canteen sou	1	20	-12	354.368	0
5	Canteen south 1st floor	1	SE	90	29.3	0.98	1.00	28.714	0.86	0.5	canteen sou	0.76	20	-12	918.848	0
6	Study area	5	SW	90	6.4	0.98	1.00	31.36	0.65	0.5	study area	0.76	20	-12	1003.52	0
7	strair ground floor	1	SW	90	39.5	0.98	1.00	38.71	0.86	0.5	stair grounc	1	20	-12	1238.72	0
8	stair 1st floor	1	SW	90	21.1	0.98	1.00	20.678	0.86	0.5	stair upper	1	20	-12	661.696	0
9	windows outside library	1	SE	90	6.9	0.98	1.00	6.762	0.86	0.5	recess libra	1	20	-12	216.384	0
10	Windows outside library 1st floor	1	SE	90	3.7	0.98	1.00	3.626	0.65	0.5	recess libra	1	20	-12	116.032	0
11	study area north	1	NW	90	3.7	0.98	1.00	3.626	0.65	0.5	recess stud	1	20	-12	116.032	0
12	canteen north	1	NW	90	6.9	0.98	1.00	6.762	0.65	0.5	recess cant	1	20	-12	216.384	0
13	library west	2	SW	90	7.6	0.98	1.00	14.896	0.65	0.5	canteen grc	1	20	-12	476.672	0
14	library north 1st floor	1	NW	90	20	0.98	1.00	19.6	0.86	0.5	canteen sou	1	20	-12	627.2	0
15	Library north ground floor	2	NW	90	7.6	0.98	1.00	14.896	0.86	0.5	canteen sou	1	20	-12	476.672	0

Description: New solar cells

Solar cells

300	Panel areal, m²
0.15	Peak Power (RS), kW/m²
0.95	System efficiency (Rp), -

Orientation and shadows

SW	Orientation, S, SE, E, ...		
14	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °

Key numbers, kWh/m² year

	Without supplement	Supplement for special conditions	Total energy frame	Total energy requirement
Renovation class 2	95.6	0.0	95.6	24.8
Renovation class 1	71.7	0.0	71.7	24.8
Energy frame BR 2018	41.3	0.0	41.3	24.8
Energy frame low energy	33.0	0.0	33.0	24.8

Contribution to energy requirement	
Heat	29.2
El. for operation of bulding	-0.0
Excessive in rooms	0.0

Net requirement	
Room heating	22.5
Domestic hot water	6.6
Cooling	0.0

Selected electricity requirements	
Lighting	7.1
Heating of rooms	0.0
Heating of DHW	0.0
Heat pump	0.0
Ventilators	5.5
Pumps	0.0
Cooling	0.0
Total el. consumption	29.3

Heat loss from installations	
Room heating	0.0
Domestic hot water	1.4

Output from special sources	
Solar heat	0.0
Heat pump	0.0
Solar cells	12.6
Wind mills	0.0

Key numbers, kWh/m² year

	Without supplement	Supplement for special conditions	Total energy frame	Total energy requirement
Renovation class 2	95.6	0.0	95.6	48.8
Renovation class 1	71.7	0.0	71.7	48.8
Energy frame BR 2018	41.3	0.0	41.3	48.8
Energy frame low energy	33.0	0.0	33.0	48.8

Contribution to energy requirement	
Heat	29.2
El. for operation of bulding	12.6
Excessive in rooms	0.0

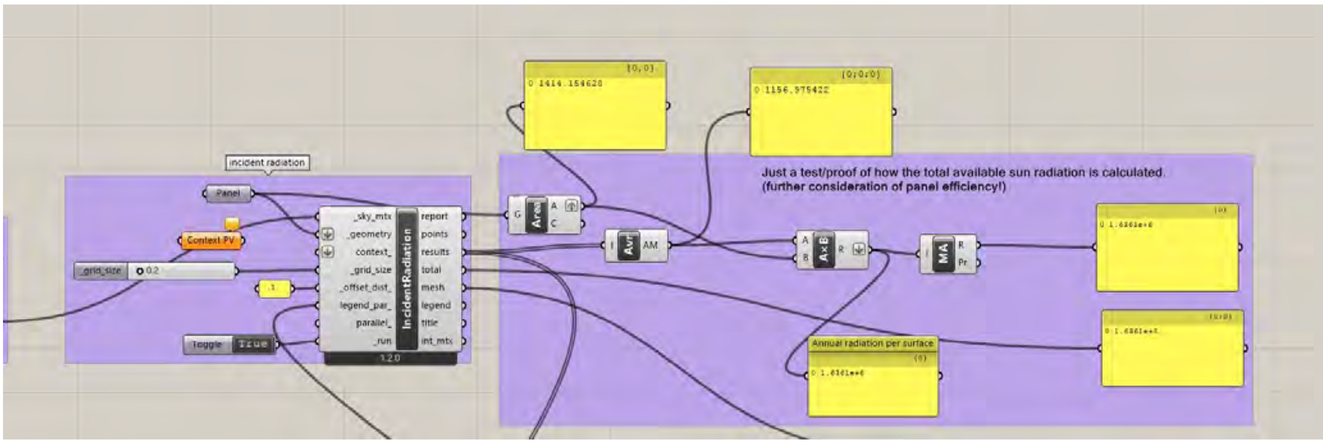
Net requirement	
Room heating	22.5
Domestic hot water	6.6
Cooling	0.0

Selected electricity requirements	
Lighting	7.1
Heating of rooms	0.0
Heating of DHW	0.0
Heat pump	0.0
Ventilators	5.5
Pumps	0.0
Cooling	0.0
Total el. consumption	29.3

Heat loss from installations	
Room heating	0.0
Domestic hot water	1.4

Output from special sources	
Solar heat	0.0
Heat pump	0.0
Solar cells	0.0
Wind mills	0.0

PV PANEL GRASSHOPPER SCRIPT



DANISH STANDARDS

EN 15251:2007 (E)

The ventilation rates (q_B) for the building emissions are:

	Very low polluting building	Low polluting building	Non low-polluting building
Category I:	0,5 l/s, m^2	1,0 l/s, m^2	2,0 l/s, m^2
Category II:	**0,35 l/s, m^2**	**0,7 l/s, m^2**	**1,4 l/s, m^2**
Category III:	0,3 l/s, m^2	0,4 l/s, m^2	0,8 l/s, m^2

Total ventilation rate for a room is calculated from the following formula

$$q_{tot} = n \cdot q_p + A \cdot q_B \qquad \text{(B.1)}$$

Where:

q_{tot}= total ventilation rate of the room, l/s

n = design value for the number of the persons in the room,-

q_p = ventilation rate for occupancy per person, l/s, pers

A= room floor area, m^2

q_B = ventilation rate for emissions from building, l/s,m^2

Examples of the total ventilation rates for non-industrial, non-residential buildings based on these values are calculated using Equation (B.1) with default occupancy densities indicated in Table B.2. The values in the table are based on complete mixing in the room (concentration of pollutants is equal in exhaust and in occupied zone). Ventilation rates can be adjusted according to the ventilation efficiency if the performance of air distribution differs from complete mixing, and can be reliably proven (EN 13779). The ventilation required for smoking is based on the assumption that 20 % of occupants are smokers smoking and smoke 1,2 cigarettes per hour. For higher rate of smoking the ventilation rates should be increased proportionally. Ventilation rates for smoking are based on comfort, not on health criteria.

Table B.3 — Examples of recommended ventilation rates for non-residential buildings for three categories of pollution from building itself. Rates are given per person or per m² floor area

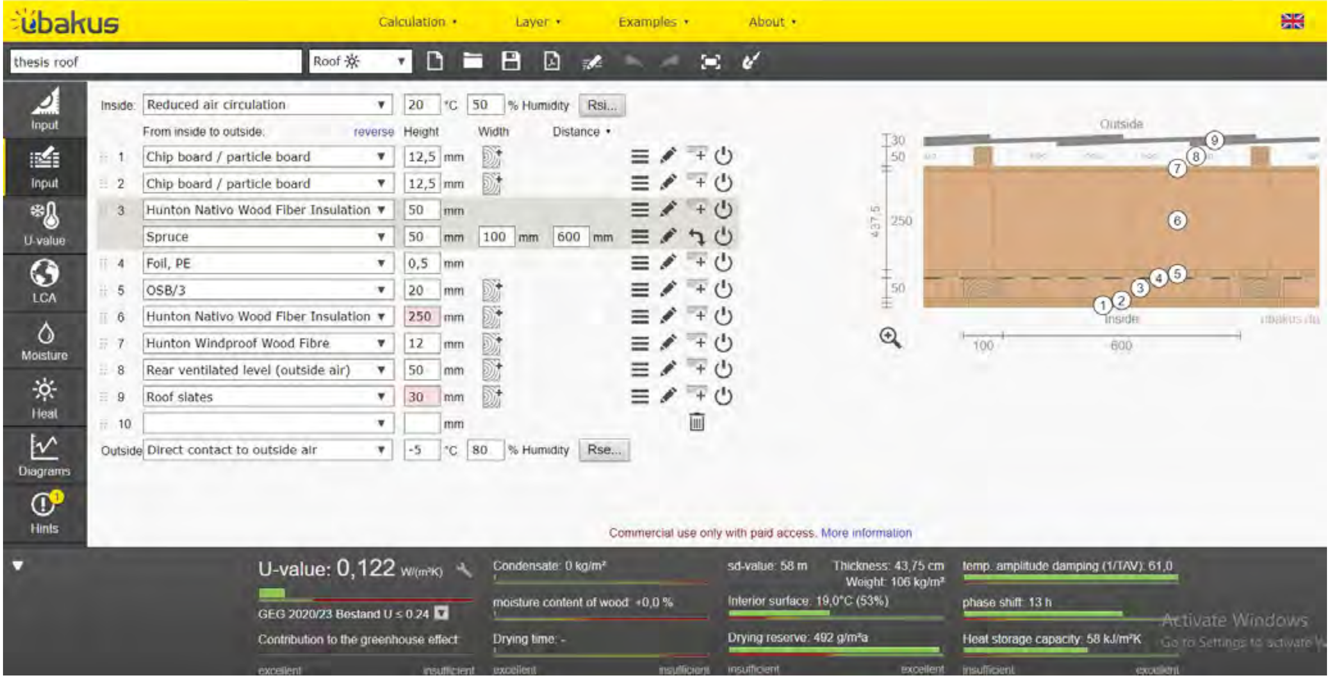
		Airflow for building emissions pollutions (l/s/m²)		
Category	Airflow per person l/s/pers	Very low polluting building	Low polluting building	Non low polluting building
I	1O	0,5	1	2
II	7	0,35	0,7	1,4
III	4	0,2	0,4	0,8

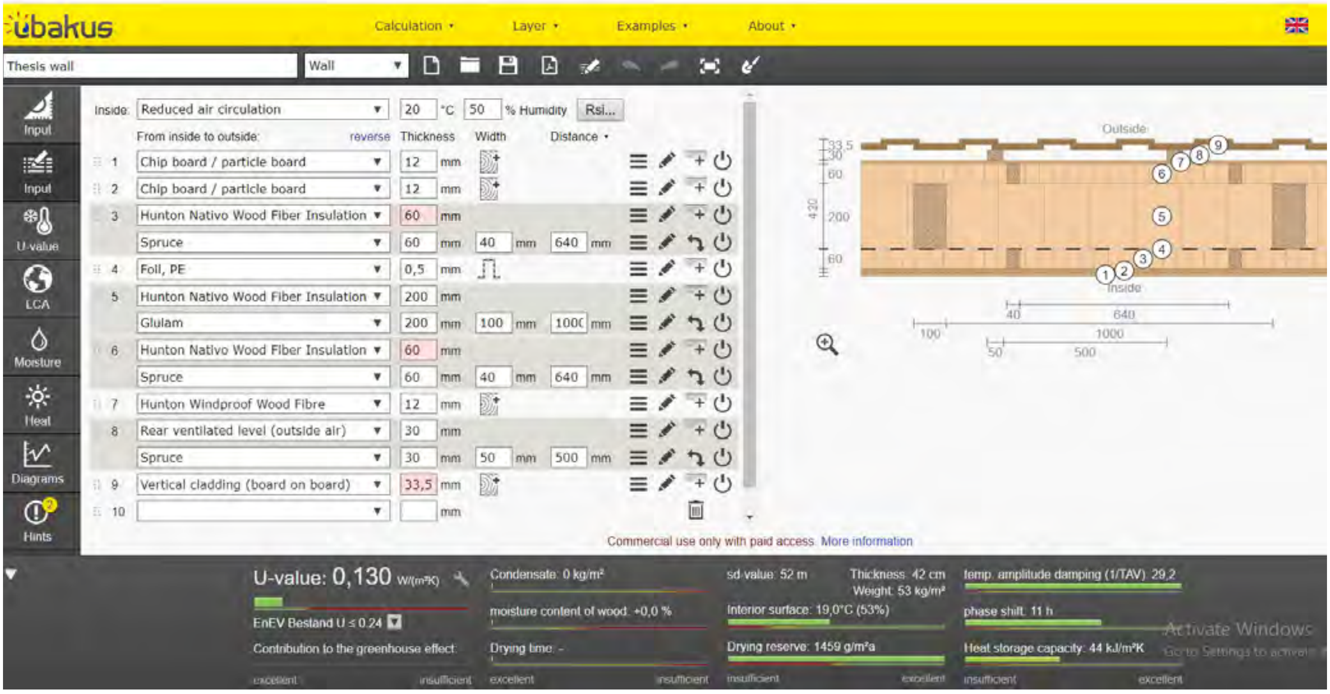
A.3 Recommended indoor temperatures for energy calculations

Table A.3 — Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

Type of building or space	Category	Temperature range for heating, °C Clothing ~ 1,0 clo	Temperature range for cooling, °C Clothing ~ 0,5 clo
Residential buildings, living spaces (bed room's living rooms etc.) Sedentary activity ~1,2 met	I	21,0 -25,0	23,5 - 25,5
	II	**20,0-25,0**	**23,0 - 26,0**
	III	18,0- 25,0	22,0 - 27,0
Residential buildings, other spaces (kitchens, storages etc.) Standing-walking activity ~1,5 met	I	18,0-25,0	
	II	**16,0-25,0**	
	III	14,0-25,0	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met	I	21,0 – 23,0	23,5 - 25,5
	II	**20,0 – 24,0**	**23,0 - 26,0**
	III	19,0 – 25,0	22,0 - 27,0
Kindergarten Standing-walking activity ~1,4 met	I	19,0 – 21,0	22,5 - 24,5
	II	**17,5 – 22,5**	**21,5 – 25,5**
	III	16,5 – 23,5	21,0 - 26,0
Department store Standing-walking activity ~1,6 met	I	17,5 – 20,5	22,0 - 24,0
	II	**16,0 – 22,0**	**21,0– 25,0**
	III	15,0 – 23,0	20,0 - 26,0

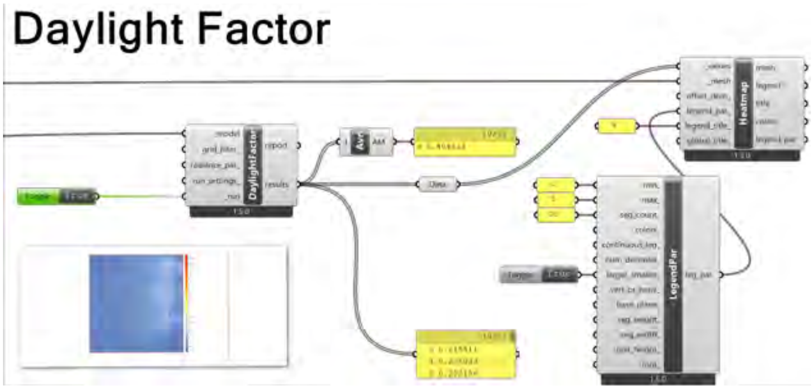
UBAKUS – WALL PERFORMANCE



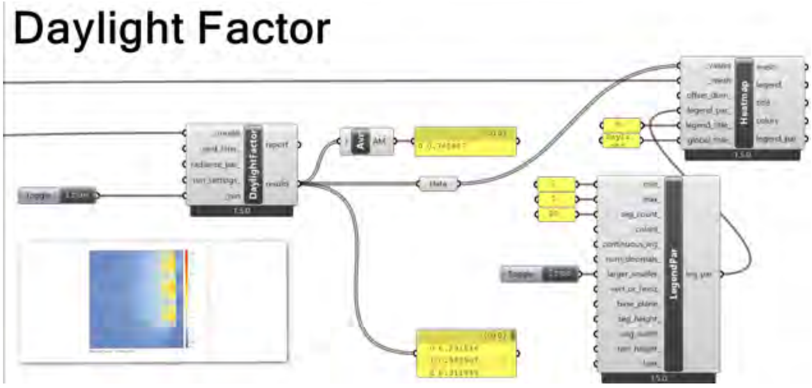


GRASSHOPPER – CLASSROOM SIMULATION RESULTS

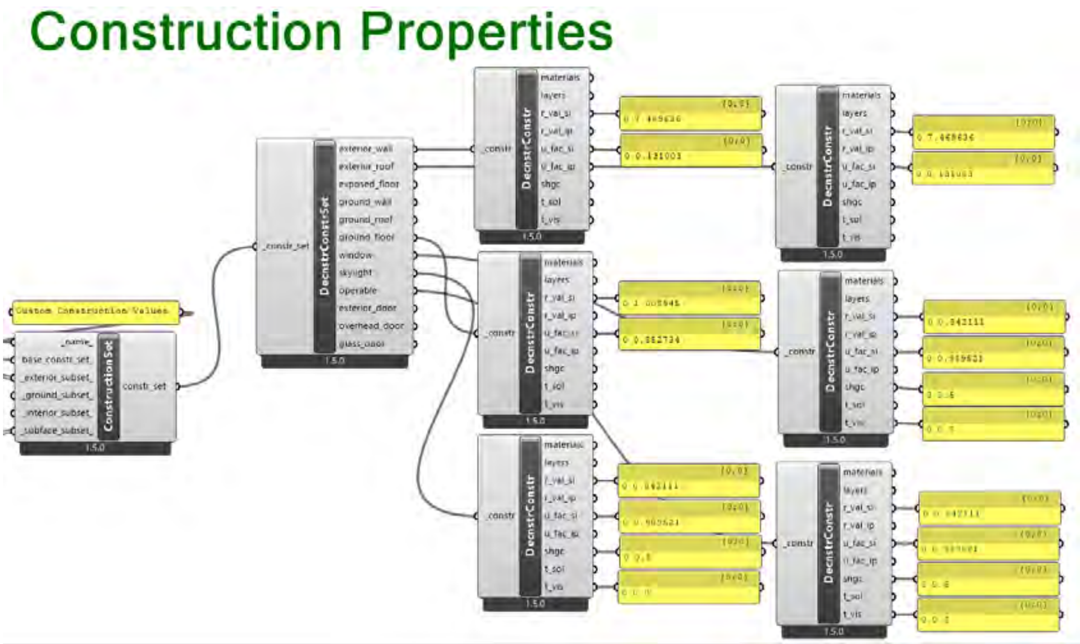
Scenario 1 - Large Overhang No Skylight

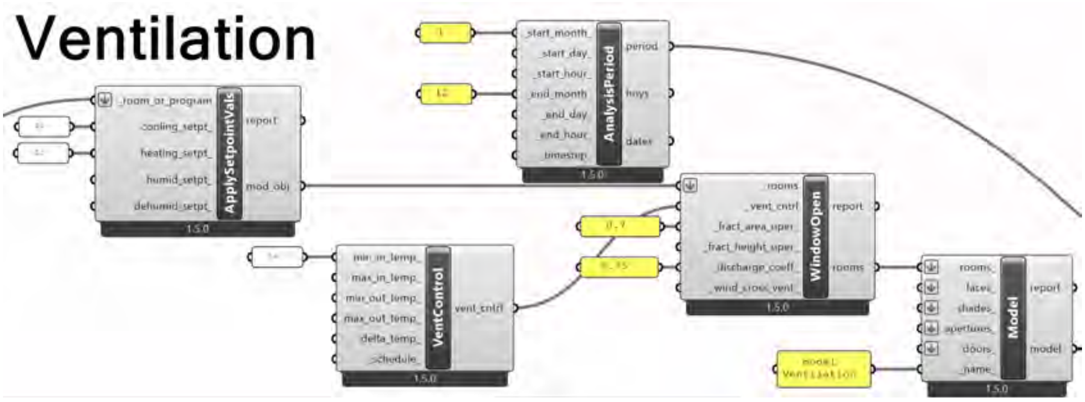


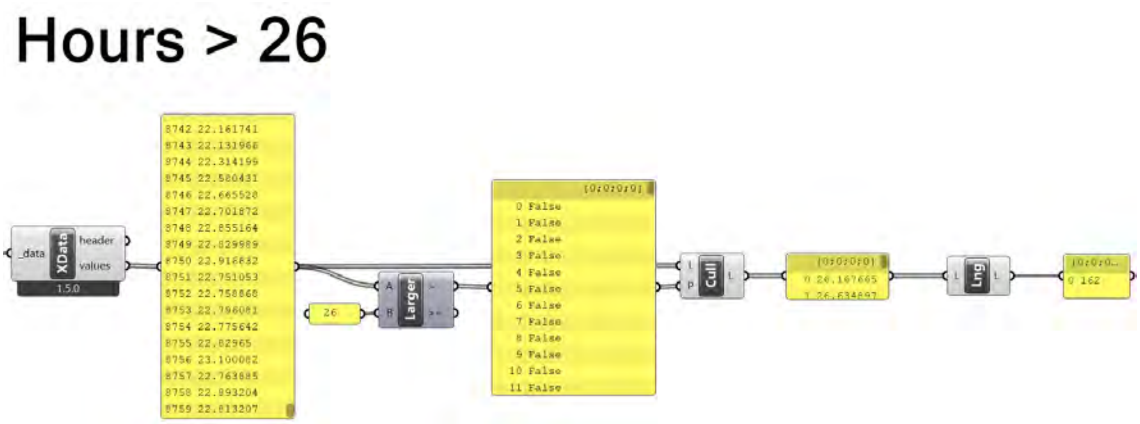
Scenario 2 - 2m Overhang No Skylight



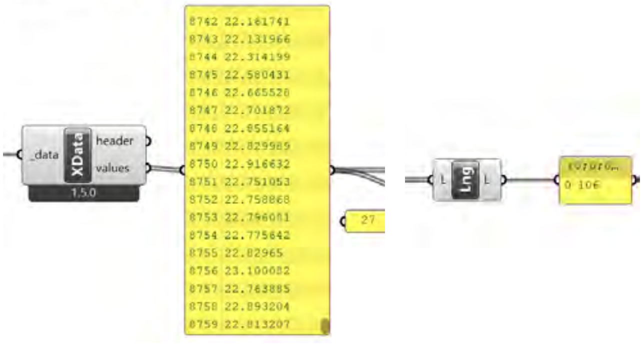
Scenario 3 - 2m Overhang Large Skylight



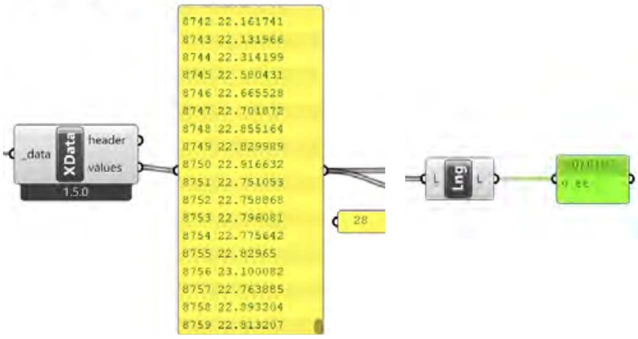




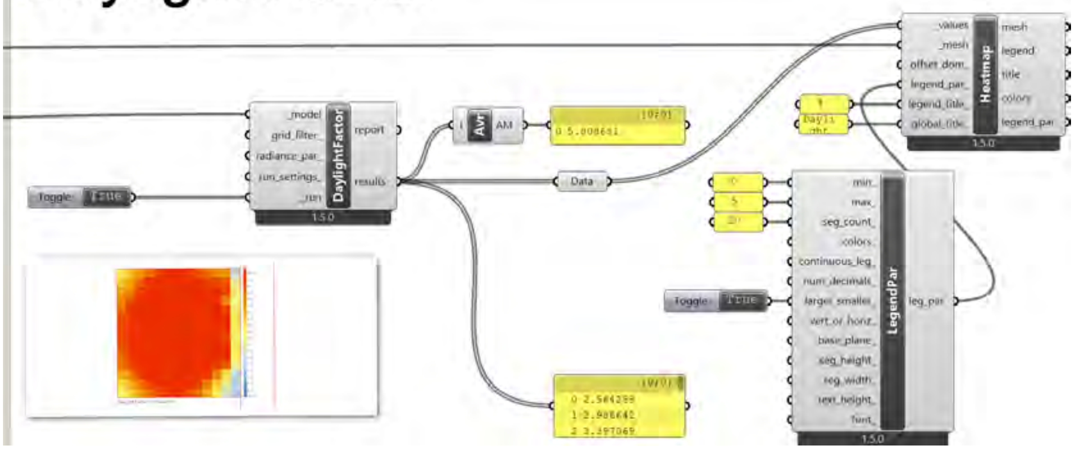
Hours > 27



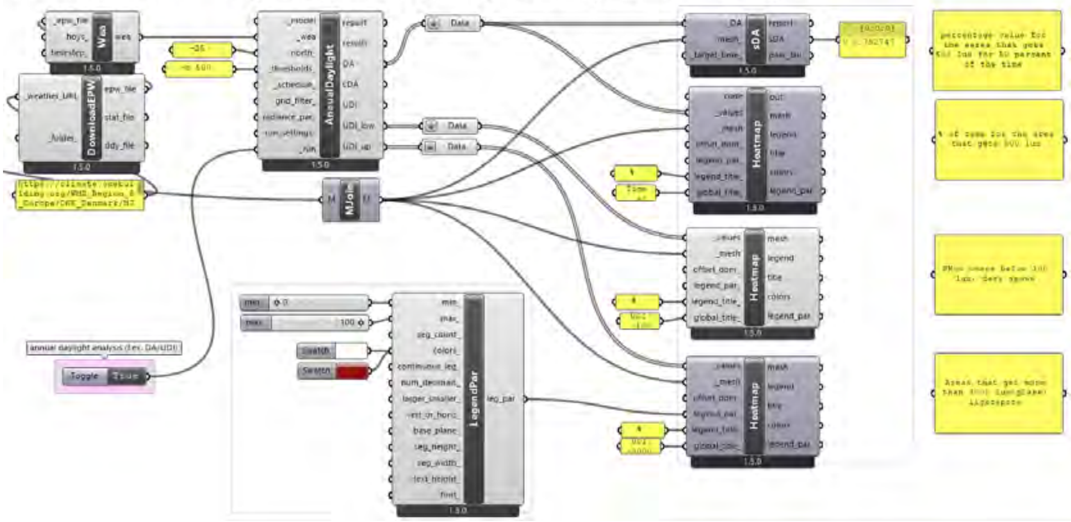
Hours > 28

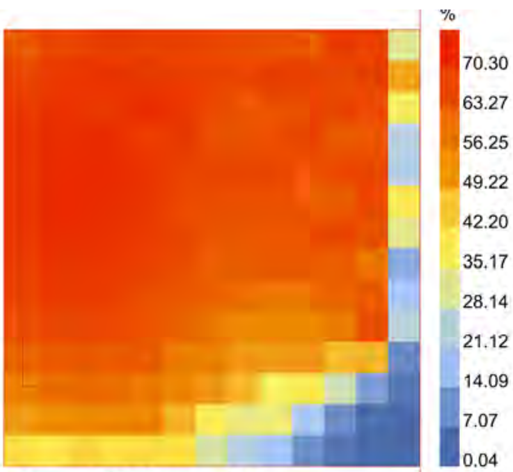


Daylight Factor

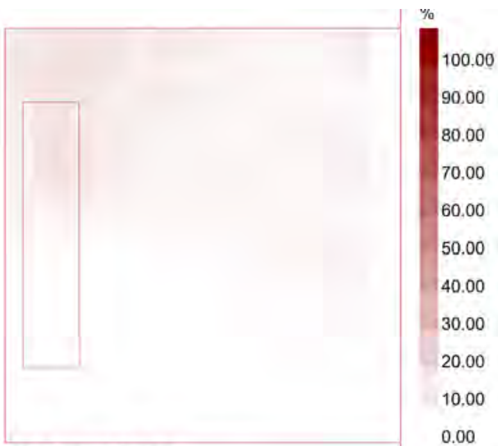


Annual Daylight Analysis (DA/UDI)





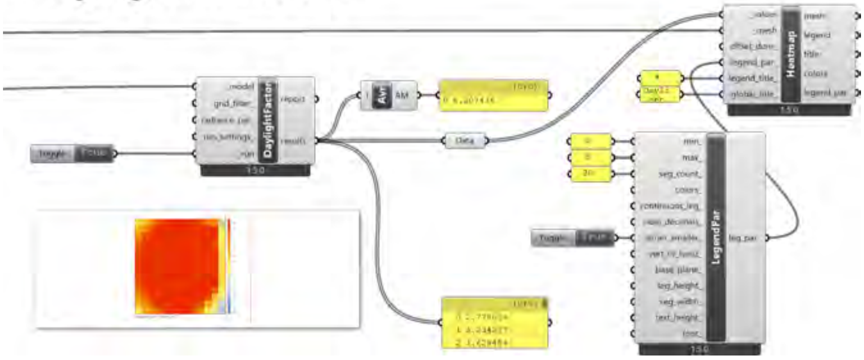
Time at 500lux or More

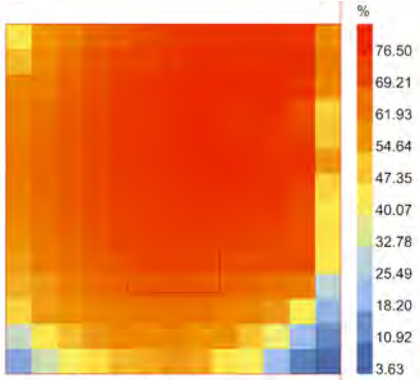


UDI: >3000 lux

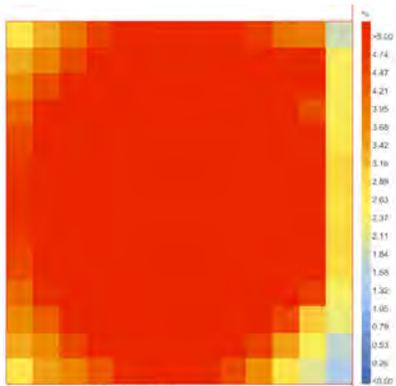
Scenario4 - 2m Overhang 2 Skylights

Daylight Factor

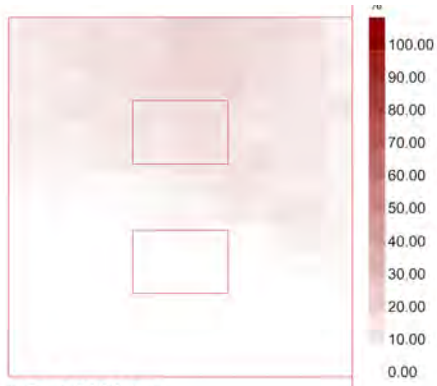




Time at 500lux or More

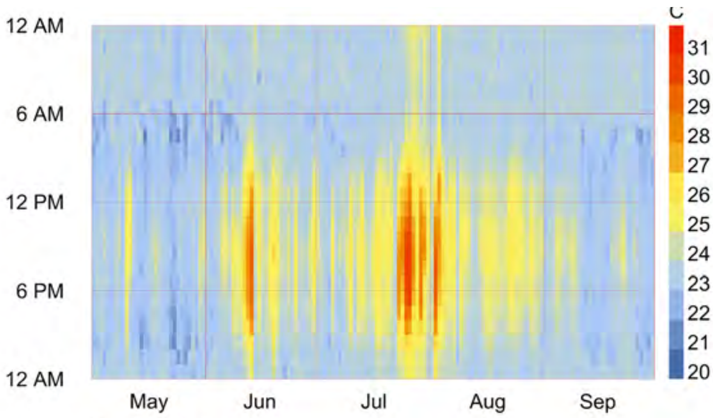


Daylight Factor - Minimum 2%

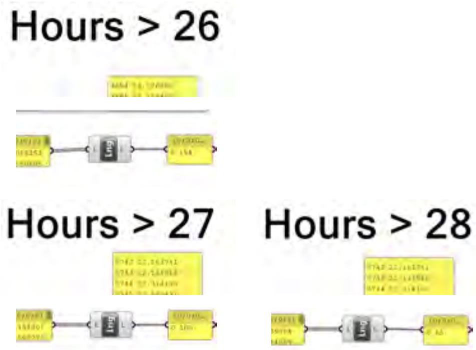


UDI: >3000 lux

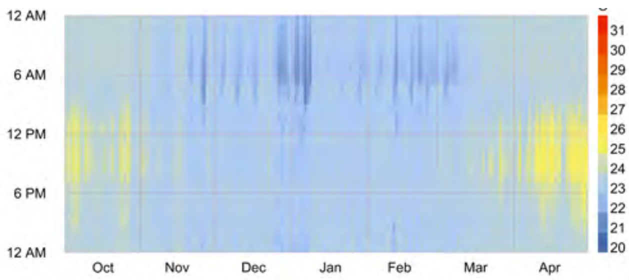
Heating months 5-9



Temperature (C)
5/1 to 9/30 between 0 and 23 @1
Zone: CLASS_4C8EC71A
type: Zone Operative Temperature

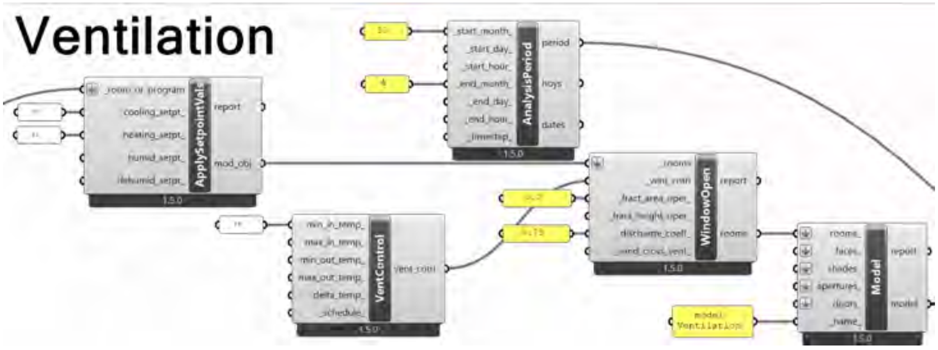


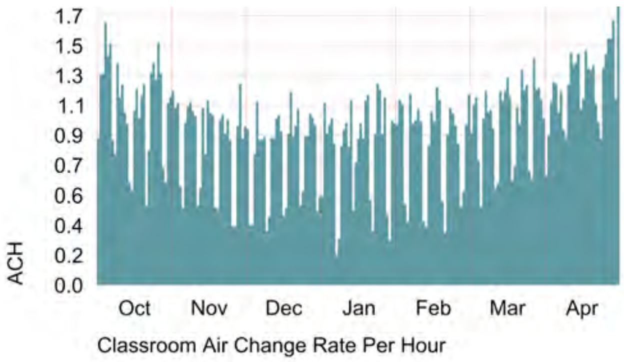
Cooling Months months 10-4

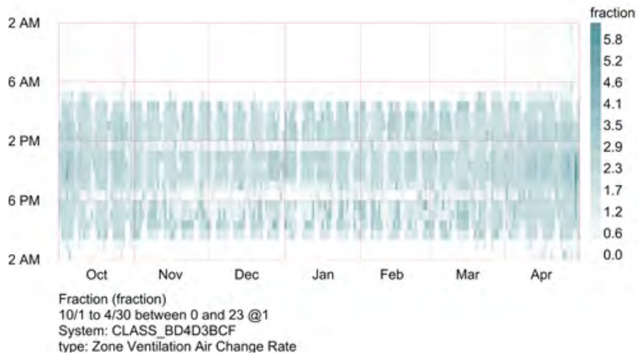


Temperature (C)
10/1 to 4/30 between 0 and 23 @1
Zone: CLASS_BD4D3BCF
type: Zone Operative Temperature

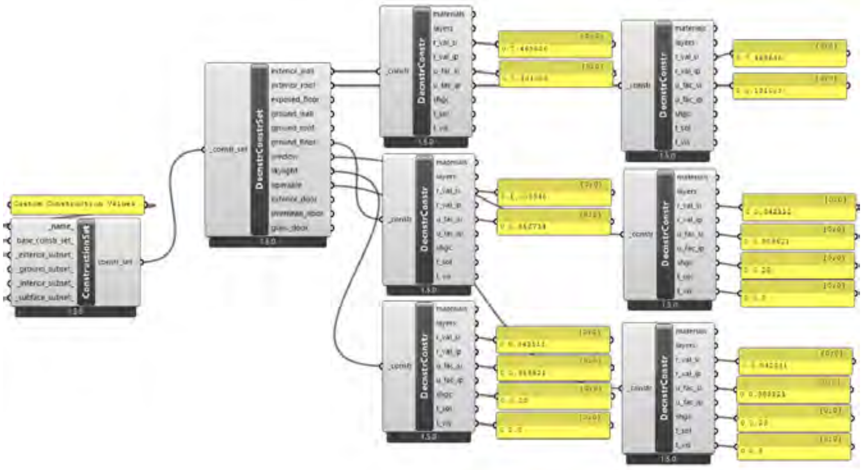
Energy (kWh)
10/1 to 4/30 between 0 and 23 @1
System: CLASS_BD4D3BCF IDEAL LOADS AIR SYSTEM
type: Zone Ideal Loads Supply Air Total Heating Energy

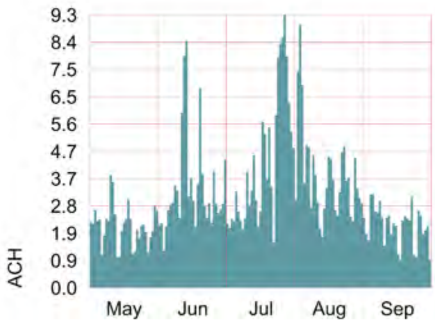


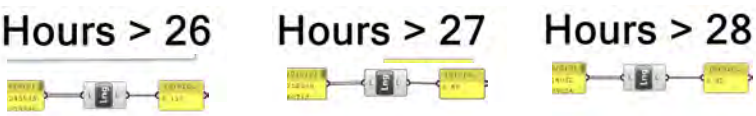


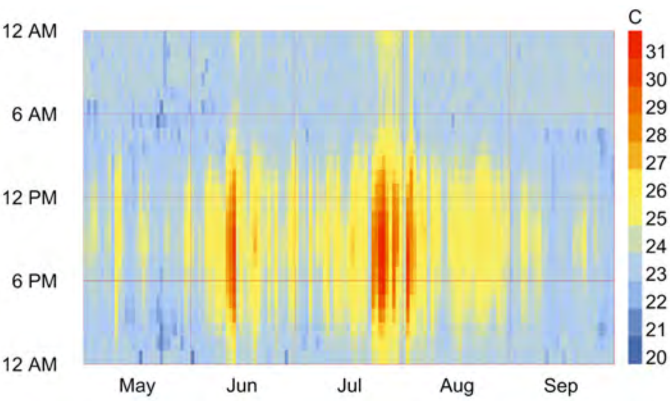


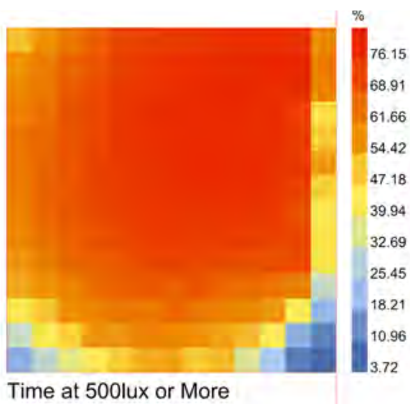
Scenario 5 - Better g



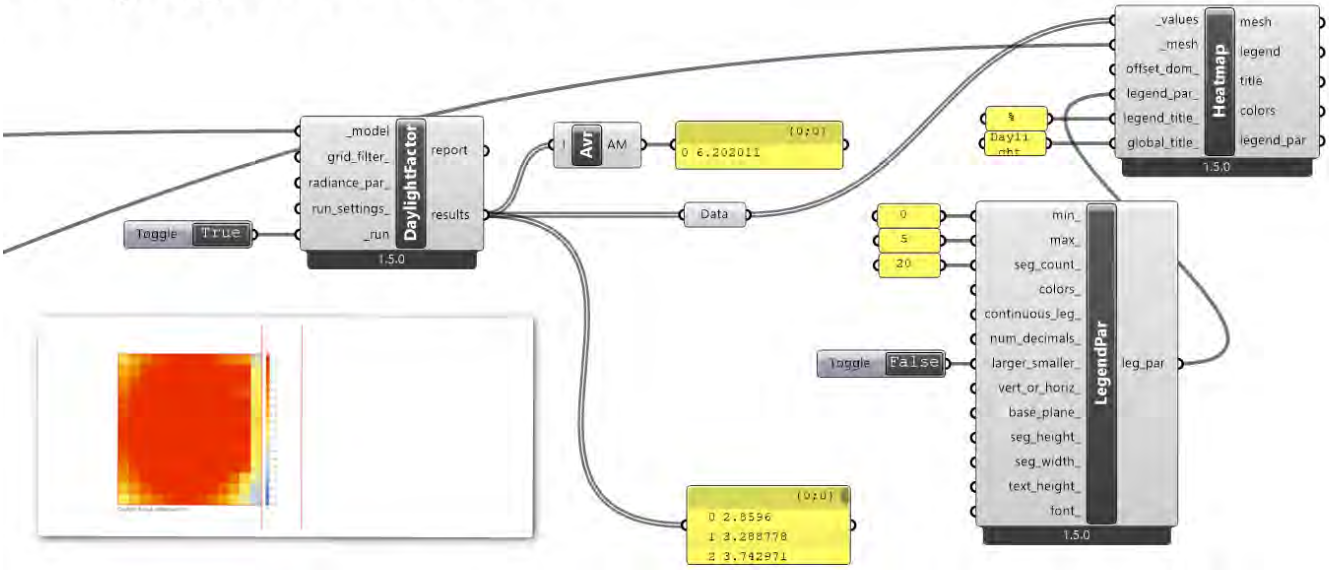






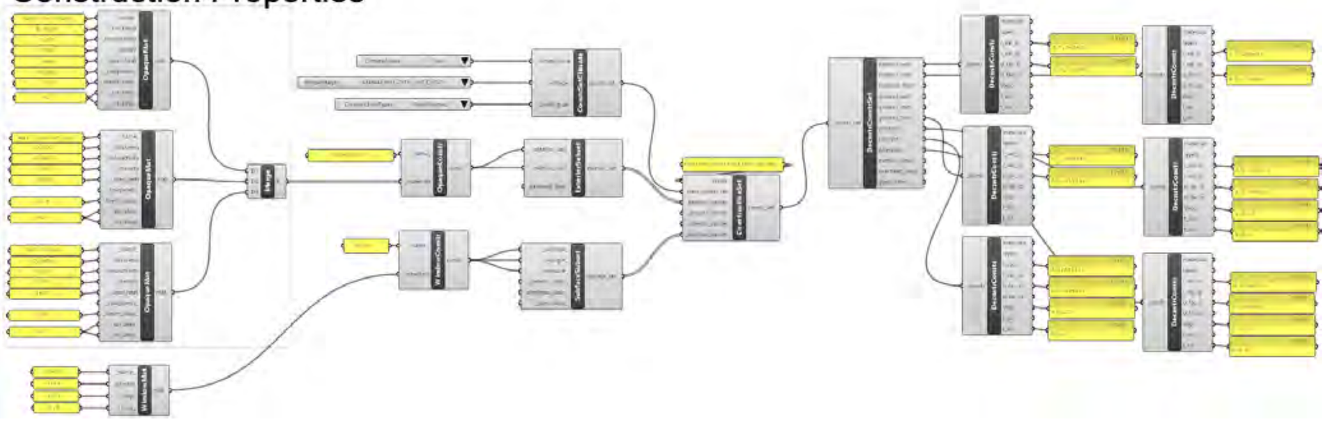


Daylight Factor



Scenario 6 - Better g smaller skylights

Construction Properties

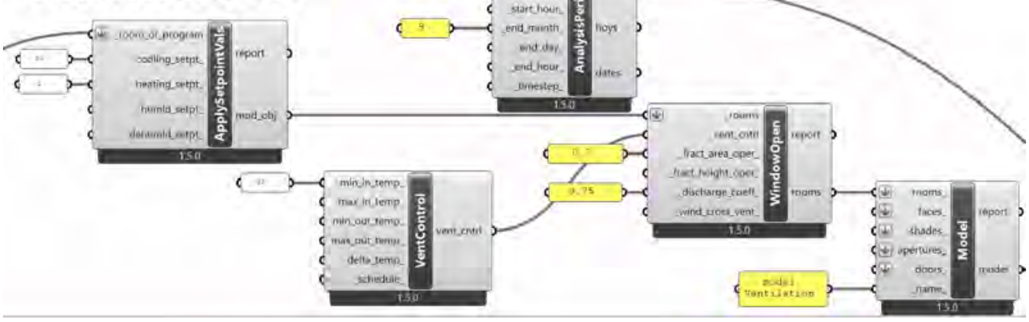


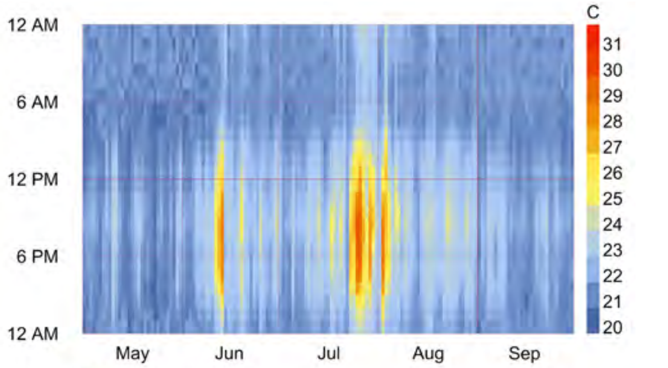
Hours > 26

Hours > 27

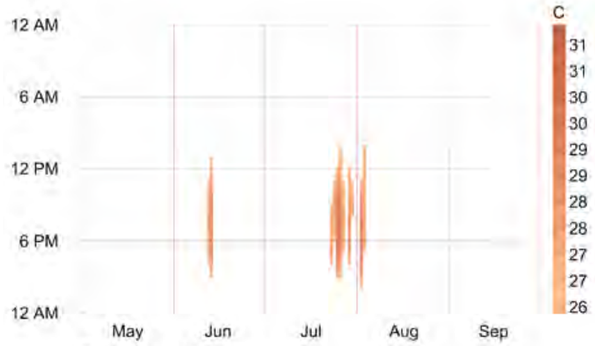
Hours > 28

Ventilation



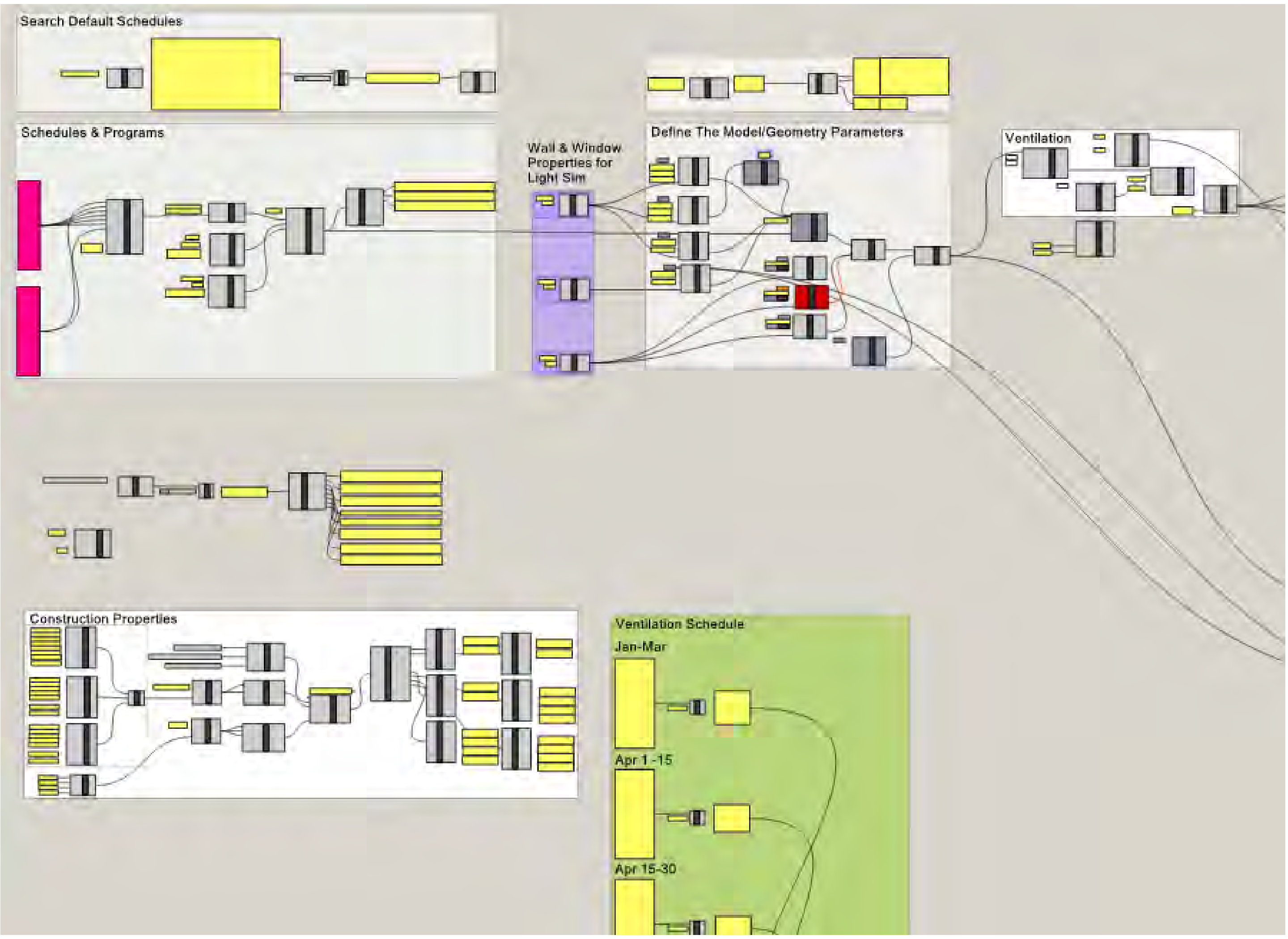


Temperature (C)
5/1 to 9/30 between 0 and 23 @1
Zone: CLASS_A56C0A28
type: Zone Operative Temperature



Temperature (C)
5/1 to 9/30 between 0 and 23 @1
Zone: CLASS_A56C0A28
type: Zone Operative Temperature

GRASSHOPPER – SCRIPT OVERVIEW



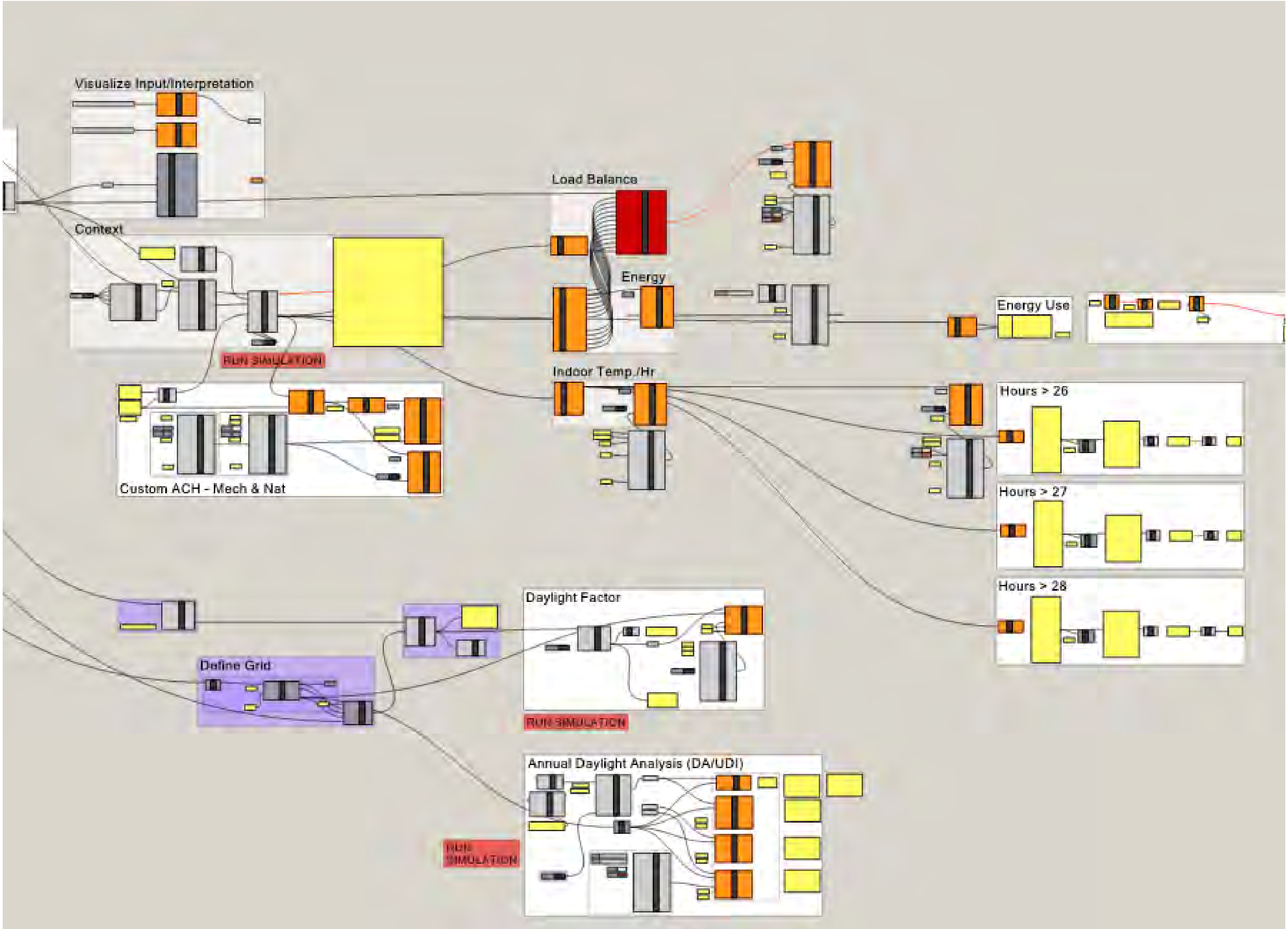
The process of using this script behind in the center with defining the model geometry. This defines the size of any apertures and the boundary conditions of the walls. Specific properties useful in daylight simulations can also be applied here such as transparency. This area is highlighted in purple.

Occupancy schedules are applied to this generated model, providing information about when the biding is in use. This is completely customizable. In this case since the occupancy of our building is atypical, with evening classes and events on weekends, custom values were set, though it is also possible to us e pre-made inbuilt schedules.

It is also possible to define when the ventilation functions as n=sen in the green schedule to the bottom. Beside it, all the construction properties of the walls and windows are defined to ensure accurate results.

Once all these model parameters are specified it the model is plugged into the ventilation type.

Results however cannot be accurate without being situated in a proper context with accurate orientation and weather data. Beyond this point the rest of the script is about extracting and visualizing and extracting the results generated by the imput simulation parameters.



Visualize Input/Interpretation
Context
Load Balance
Energy
Energy Use
RUN SIMULATION
Indoor Temp./Hr
Custom ACH - Mech & Nat
Hours > 26
Hours > 27
Hours > 28
Daylight Factor
Define Grid
RUN SIMULATION
Annual Daylight Analysis (DA/UDI)
RUN SIMULATION