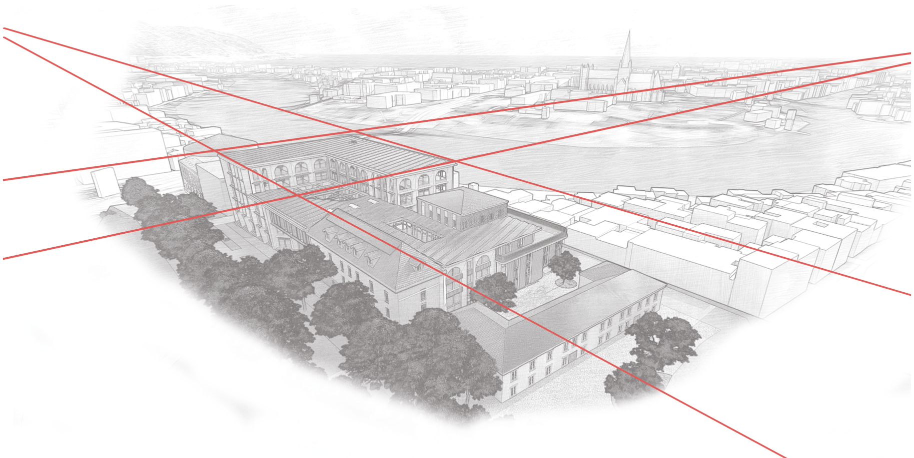
Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Architecture and Technology

Sebastian Ulloa-Thompson

KAMD –Develop a project on the triangular site right north of Grensen

Master's thesis in Sustainable Architecture
Supervisor: Michael Gruner
May 2022



NTNU
Kunnskap for en bedre verden

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Abstract

The thesis project is that of a Zero emission University building located in the centre of Trondheim north of Grensen. The project consists of 12500m2 new construction and the refurbishment of 3000m2 of existing building area on the site. The design focuses on creating a design strategy that balances itself between flexibility and practicality of design and against emissions in reaching a ZEB target of ZEB÷OM-EQ. This being achieved through the optimisation of energy generation by photovoltaics, energy strategies and material choices to balance over the 60 year life expectancy at minimum for this project. This all aims to produce both a design and analysis of the possible strategies to employ in the future KAMD design strategy which will be planned for completion of construction by 2030. With a construction mainly compromising of CLT and glulam a reduction to material emissions was greatly gained. However, the total embodied emissions from A1-A3 + B4 are that of 1.32 kgCO2eq/m2/yr and where the operational energy emissions are of 4.96 kgCO2eq/m2/yr. Due to PV optimisation a reduction of 5.40 kgCO2eq/m2/yr totalling a balance of **0.88** kgCO2eq/m2/yr which in turn did not reach a goal of ZEB÷OM-EQ. However, this was still able to reach ZEB÷O-EQ at **-0.44** kgCO2eq/m2/yr. This was not the aimed for outcome yet an understanding of how to reach higher goals without greater dependency on PV's suggested reducing the total floor area and reducing material emissions and use of concrete by reducing or removing the basement could aid this.

Concept for KAMD logo

Sebastian Ulloa-Thompson
MSc Sustainable Architecture

Summary

The project of KAMD coordinated by Statsbyge and NTNU is part of the larger unified campus project to unite NTNU under one central campus of Gløshaugen. Such an undertaking is extremely challenging regarding the logistics of moving existing departments and working with the proposed sites with its aim of finishing by 2030. Where a majority of sites contain historically important existing buildings or work with compromising topography and context for such large scale projects. KAMD itself is a sub development of this unified campus aimed to contain the four departments of Art, Architecture, Music and Design where three proposed sites directly north of NTNU's Main building and parallel to the student society building are proposed. Currently brief plans have been proposed to contain zoning through mass planing yet a more detailed understanding of construction and energy is yet to be documented.

For this thesis an investigation into one of these sites has been taken in order to develop a design and construction plan with set goals in mind. The Aims of the project are to assess possible development strategies while taking into account the current requirements of the site and to assess what scope of ZEB would be most relevant and feasible for the projected site where ZEB÷OM-EQ is aimed for.

In terms of design the aim of the project is integrating aspects of all faculties to create passive connections for interaction with students from al instead of separating faculties by sites. This hopefully benefiting the students in enabling them to share work though open study spaces, gallery exhibits and performance spaces centred around circulation spaces. Additionally integrating aspects of the public of greater Trondheim through partnered sharing of space with NRK and public venues of a restaurant, galleries and performance spaces to greater integrate the project with the city itself.

Goal and Scope

The goal is to reach an ambition level of ZEB÷OM-EQ yet finding which ambition level is most suitable for the scale of the project will be found through the design process based on its requirements set. The design process aims to find a balance between reaching emission ambition levels with functional flexible design and find a compromise between the two.

Methodology

For this thesis the methodology consists of analysing the existing site context and generating concepts for design based on iterating on simulations at concept stage to be based on form to further improve energy design and improving the efficiency of PV placement until a realistic ambition level can be reached.

Tools Utilised

The software used for this project were that of Revit for 3D modelling, Simien for simulating energy performance, Rhino and Autodesk simulations for daylight and emissions for materials and construction where taken from OneCLick LCA.

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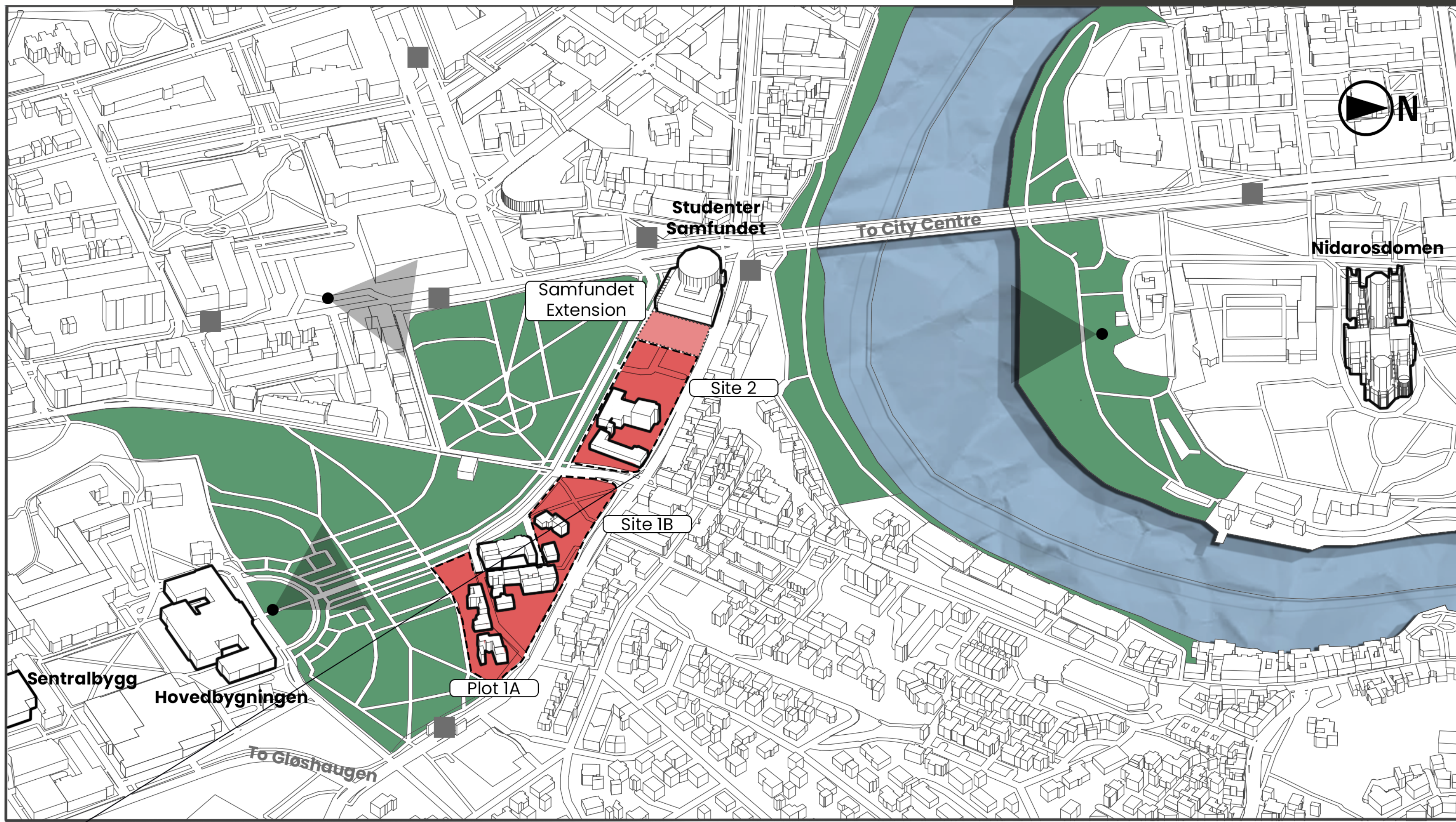
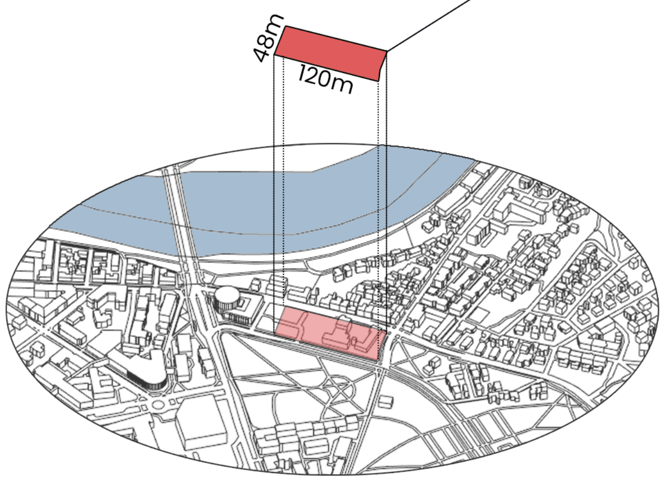
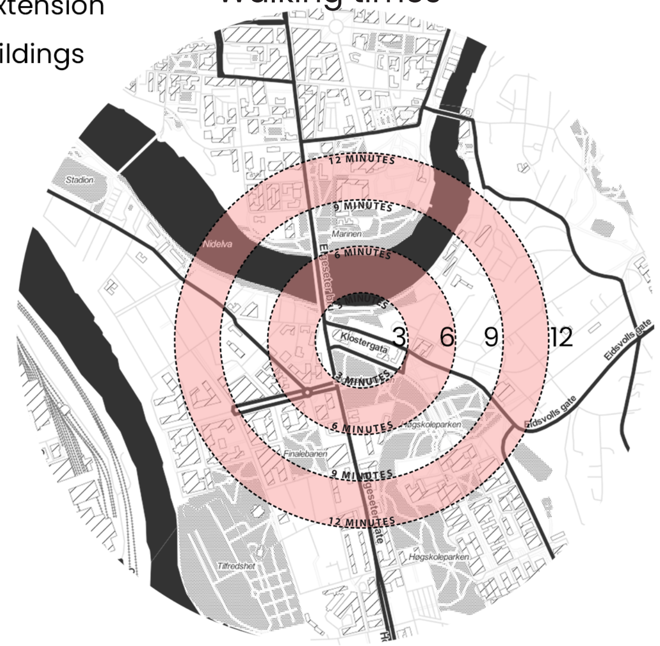
View from western approach on Høgskoleveien of southern facade



KEY: ● Key view point to site | Green Space | Samfundet extension
Bus stops | KAMD whole sites | Important buildings



Walking times

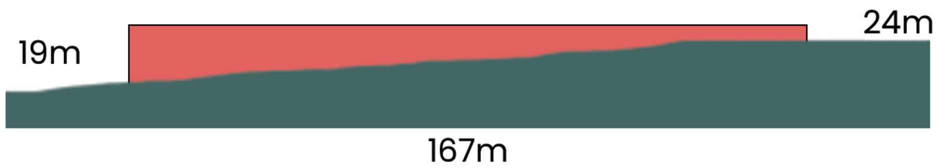


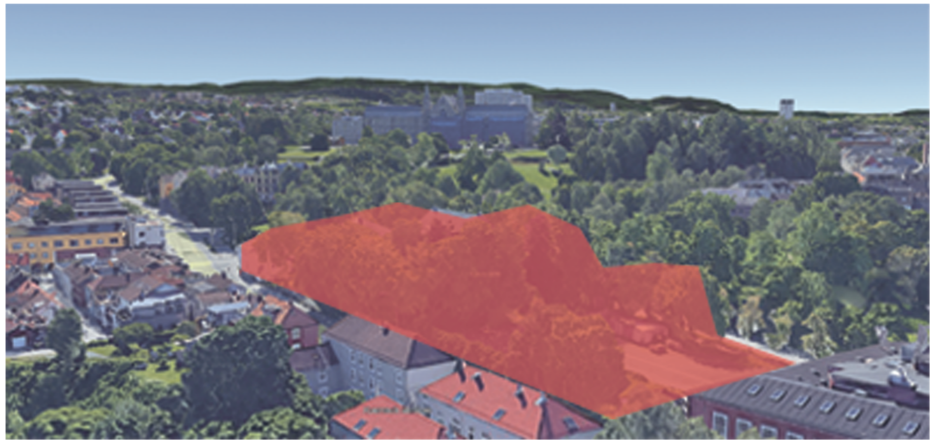
Site Analysis

The site is Located the Centre of Trondheim just outside the city Centre across the Elgesenter bridge and directly behind the Studentersamfundet (The Student Society). This placing itself at the gateway between Gløshaugen and the city Centre. With easy direct access by all means of transport with multiple bus stops within five minutes walk and direct cycles paths on either side of the site allows for direct means of approach. Key factors of green space encompass the site and direct views onto the Nidaros cathedral and the main building pose important site lines for visual interaction.

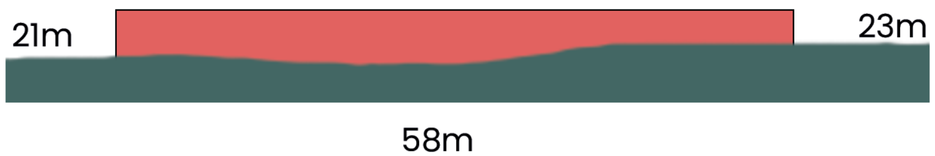
PROJECT CONTEXT

1 Section North View

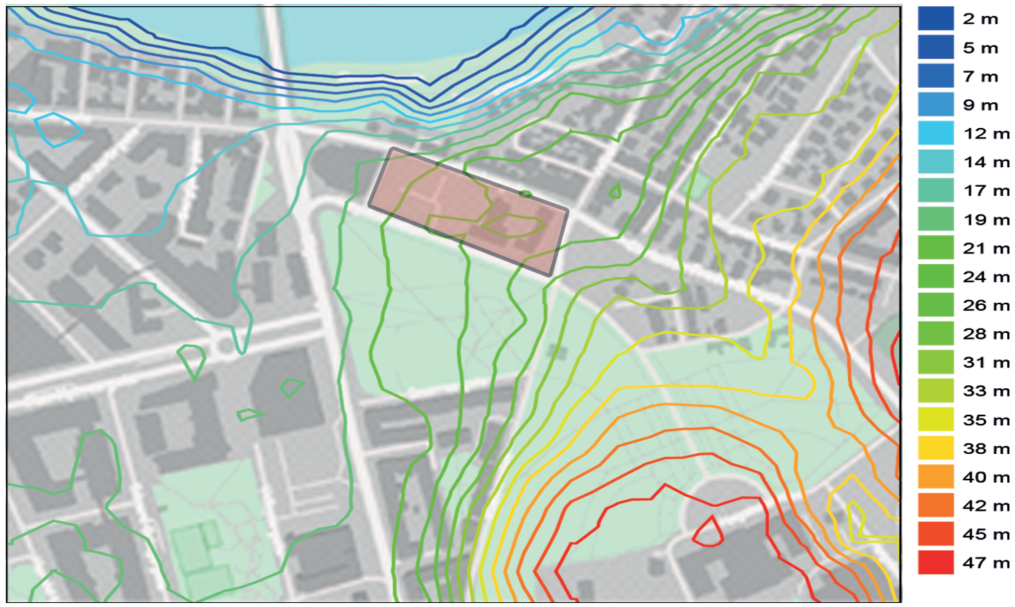


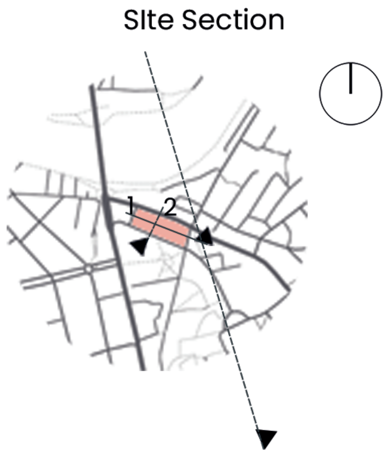


2. Section South View



The site elevation poses little threat as is fairly even with only a slight easterly incline at +4m maximum.





SWOT Analysis

Strengths:

- Strong connection to campus and city acting as a threshold to Gløshaugen
- Ease of access to and through site from all modes of transport
- Access to green space and open surrounding views

Weaknesses:

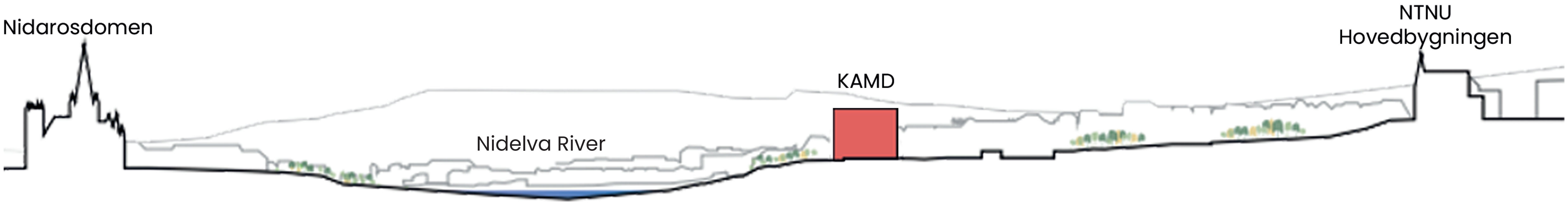
- Historical importance of existing buildings need preservation where appropriate
- New extension of samfundet reduces daylight and views out for north west facade

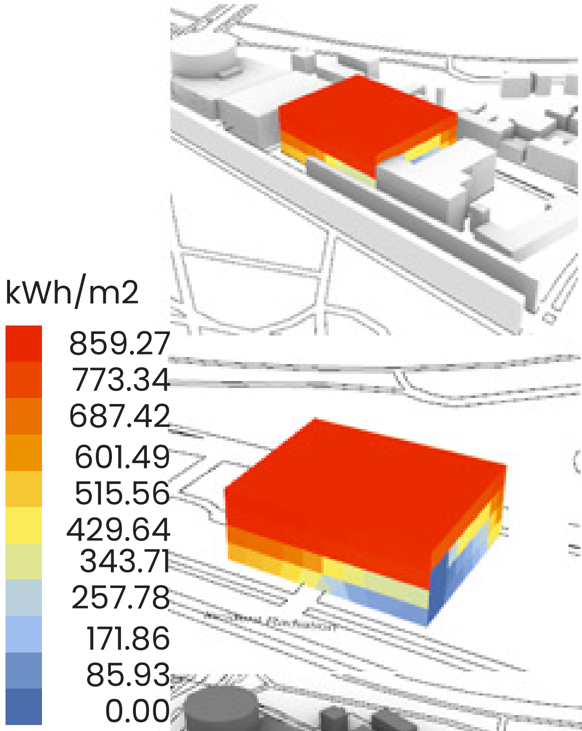
Opportunities:

- Cross sharing of space and facilities with samfundet for events

Threats:

- Elevation limited by neighbouring context to not exceed 24m
- Compromise in space when partnered with NRK for the high demand in m2



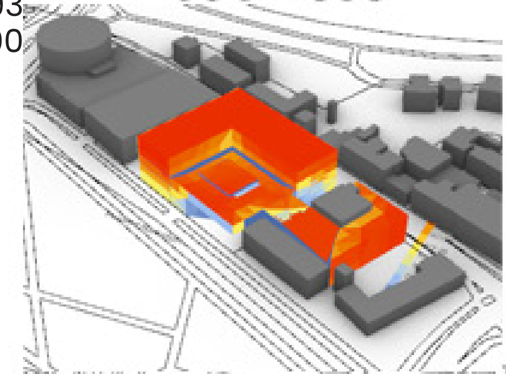


Climate Analysis

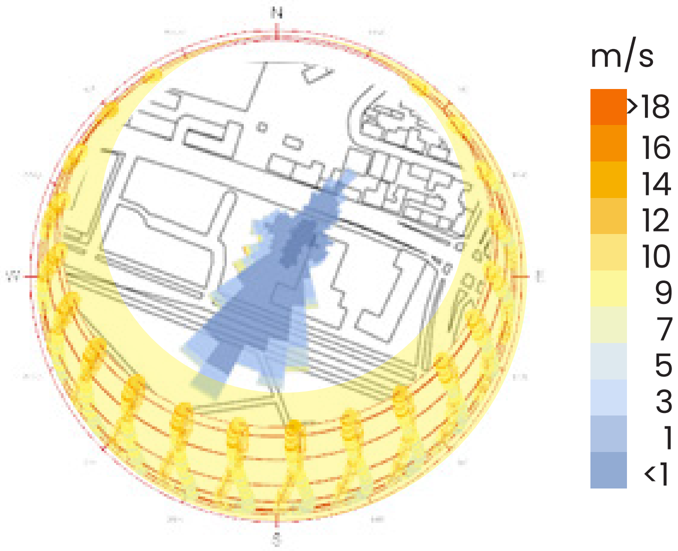
There is high annual temperature variation with the highest recorded temperature is 31.1°C during July and the lowest at -26.1°C during January. Average temperature of the coldest month (January) is of -1.9 °C, that of the warmest month (July) is of 15 °C. The average annual rainfall in Trondheim is 856 mm. Predominant winds are usually south westerly at around 6 m/s and the lowest is approx. 1 m/s from north. The southern predominant wind allows for natural ventilation possibilities to aid in summer loads.

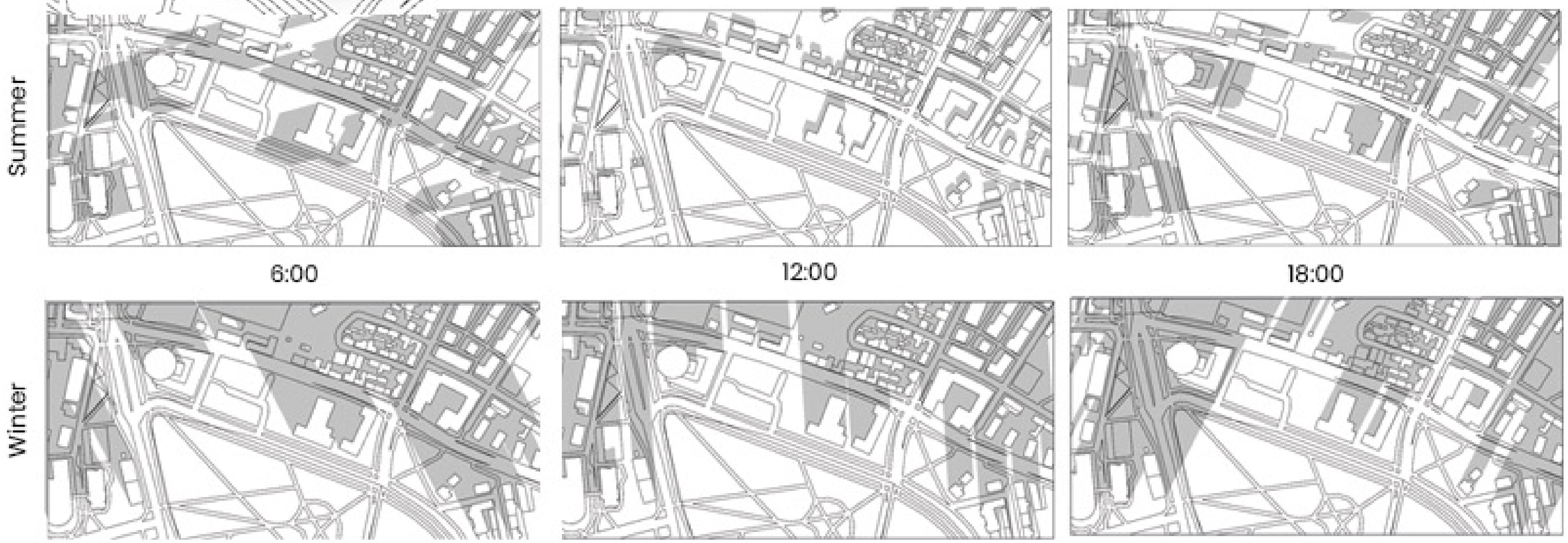
Radiation analysis found maximum direct radiation at 850 kWh/m2 leading to if PV efficiency is at 22% the maximum production value should produce 188.98 kWh/m2 yet this will be further reduced by greater variations.

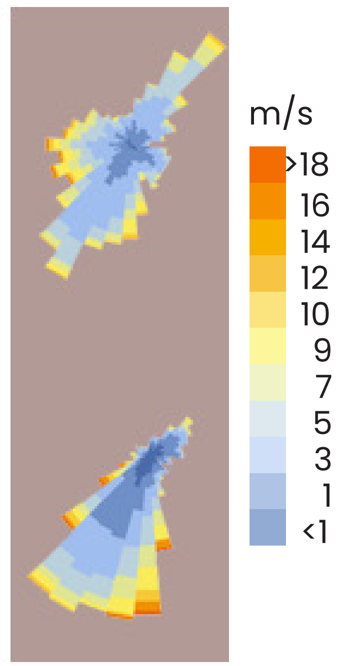
Shadow analysis provided information regarding possible PV placement for maximum solar radiation capture without interference and daylight capabilities in constructing next to adjacent existing buildings.



Yearly wind and sun direction





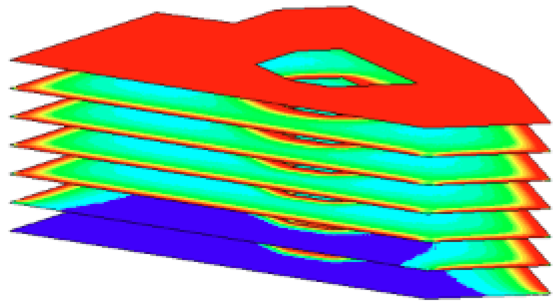


PROJECT CONTEXT

Initial change of site and recommendations

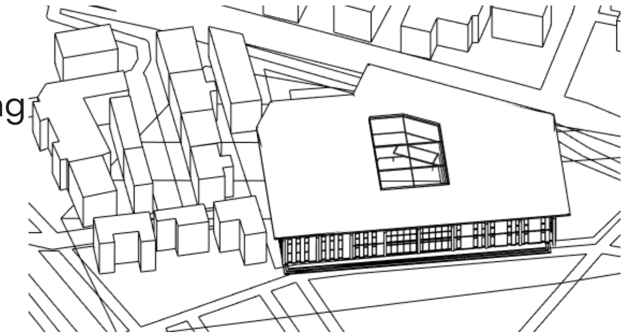
The Initial site provided was that of site 1A directly north of Grensen yet after a long investigation and analysis the ultimate conclusion was to change the site chosen to site 2. This did set the design stage planning back by half of the planned development time yet what was learnt and taken from site 1A aided transition to site 2.

A brief explanation to this decision is depicted as to hopefully aid the decision for the future project development as currently there appears to be a lack of certainty if whether the site is to be removed from budget entirely or as several complaints from the surrounding neighbours of Plot 2 if oversized and interferes with the samfundet extension then shall be re-evaluated instead of considering site 2.



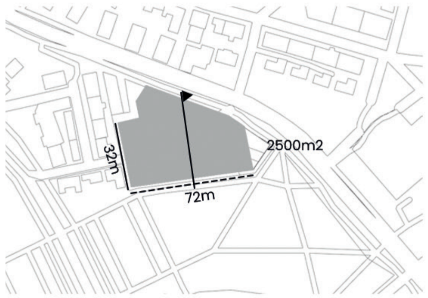
The initial concerns and challenges with site 1A:

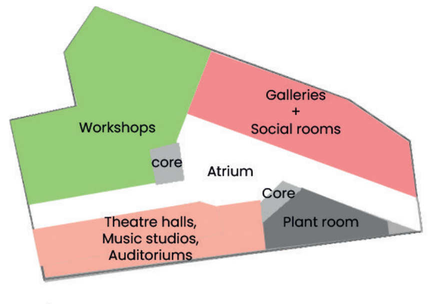
- In order to reach required footprint moving of historic buildings is proposed yet seems impractical
- Site dimensions and location hard to access and limit daylight penetration due to varied site topography and existing tree coverage on the entire southern side.
- The site shape must be maximised and left with a bulk mass with awkward spacing for proposed programme.

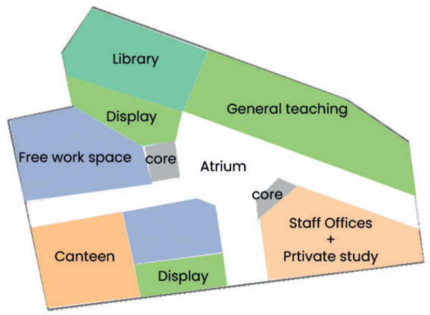


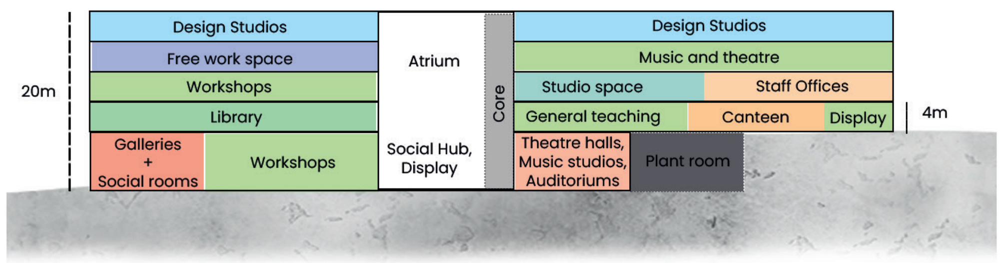
This example is summarised and not comprehensive of the study as to progress to the new site and design with the limited time frame that remained after yet the conclusions from this brief example were the benefits from changing site were greater than resolving the issues through compromise.

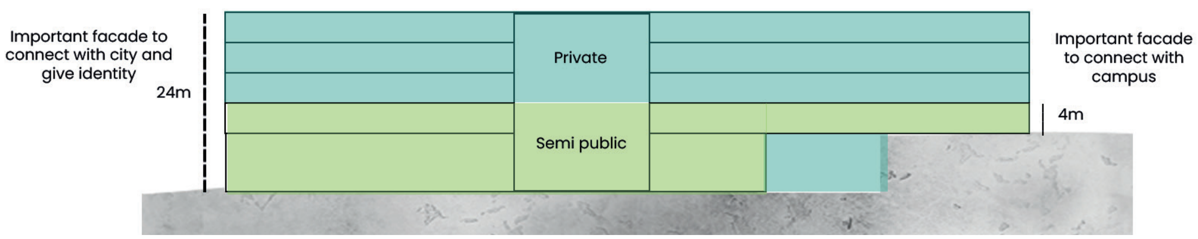
Preliminary site 1A assessment of context and concept massing

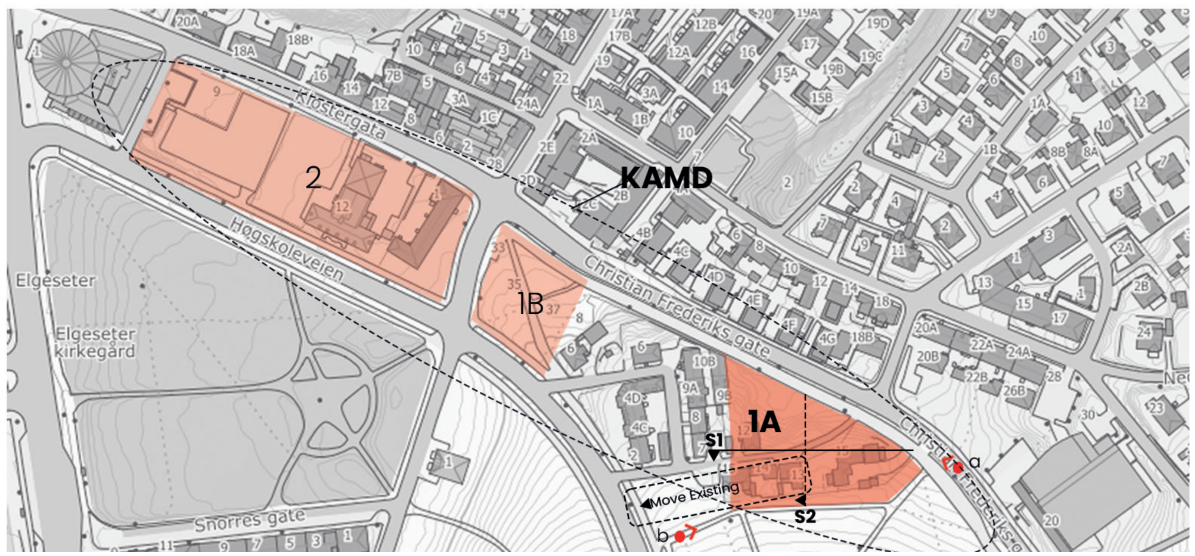










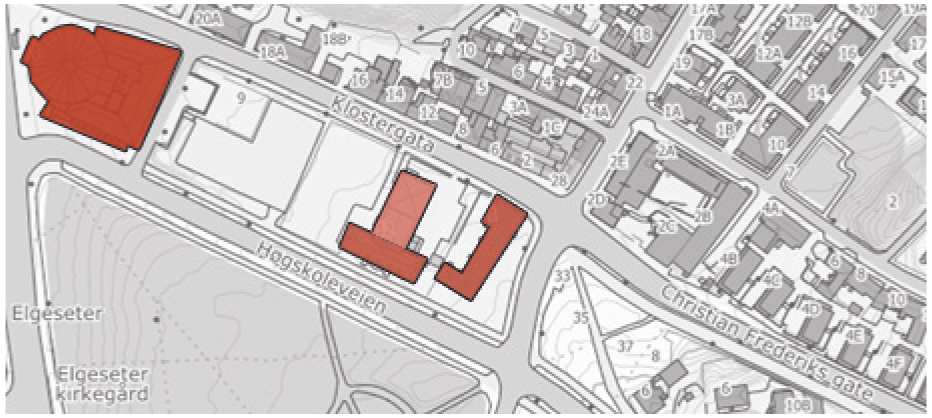


Existing buildings and historical context
The site of plot 2 has existing buildings of historical preservation value which must be taken into consideration when accommodating the requirements for both the new build and extension planned and will ultimately influence the design in working symbiotically with these. Such buildings contained within the site or direct proximity are that of the old state archive (Det gamle statsarkivet), Vollan farm (Hovedbygningen på Vollan gård) and the student society building (studentersamfundet). The key aspects of consideration for each of these are as follows:

Class Protected
- Samfundet - preserve visual relevance from main access points and allow access to the building. Additionally respect the proposed extention plan behind this building as marked on the site plan in fig

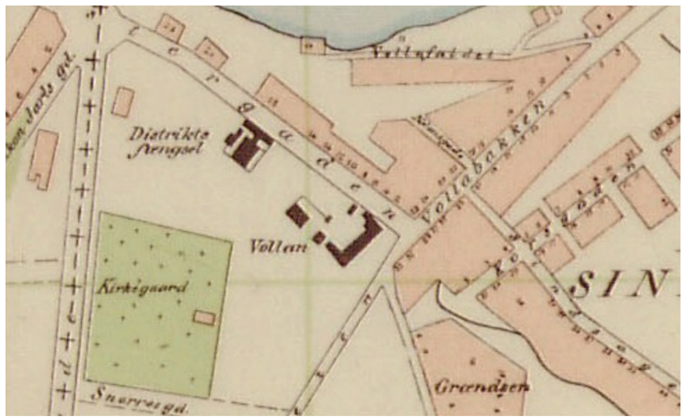
Class B High antiquarian value
- Vollan Farm - Existing structure must be preserved yet internals can be refurbished as seen fit.
- The old state archive - the southern facade must be preserved yet internals and the magazine section of the building can be altered entirely.

Such important matters of historical preservation are taken into account in the design phase of this project.



Historical Value:

- Class B - High antiquarian value
- Protected Building
- Demolishable



Elgeseter gamle kirkegård
Kartutsnitt, 1902

Flyfoto 1937
Norgeibilder.no

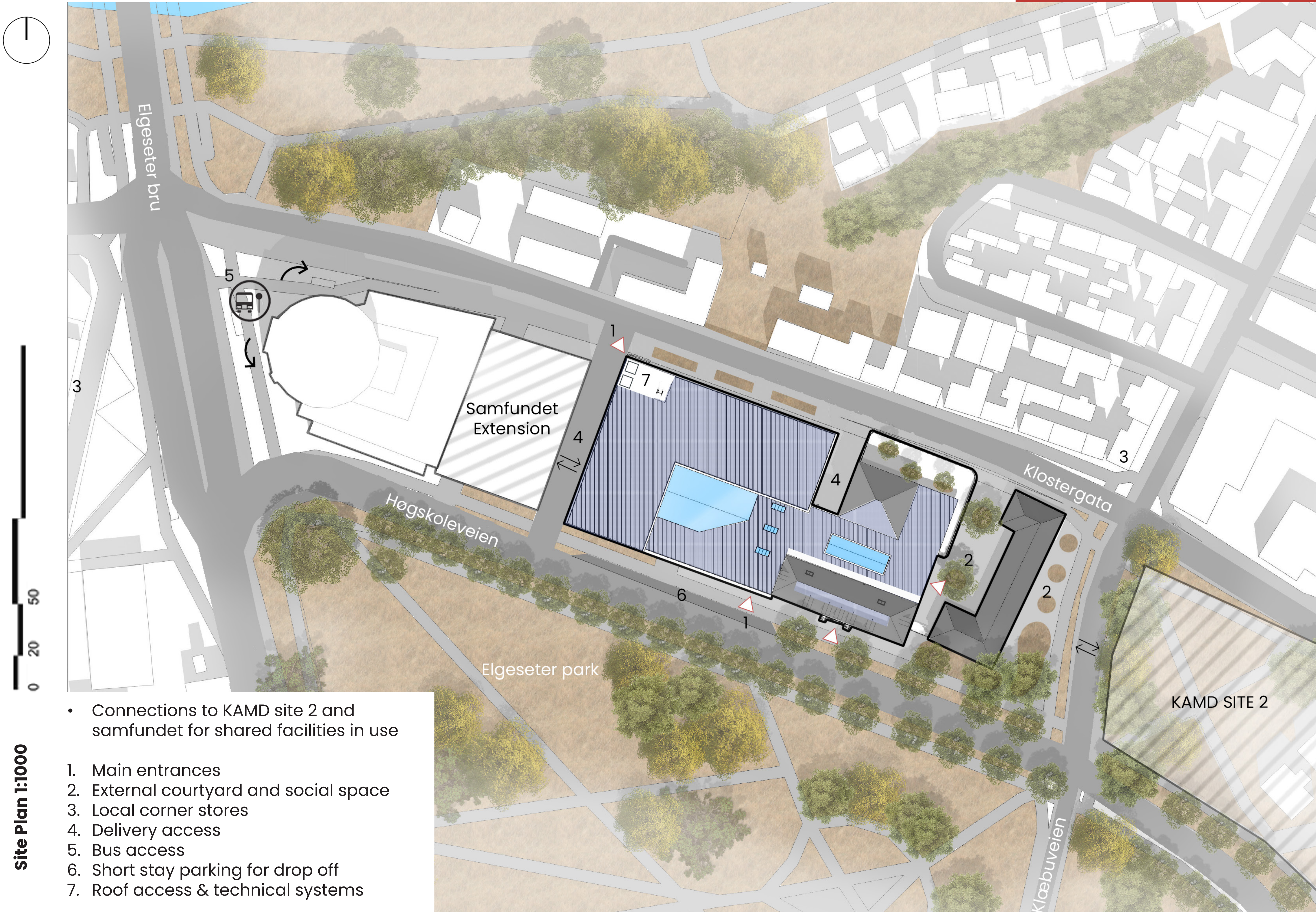
Views of Elgeseter park, site and samfundet

Views of The old state archive

Views of Vollan Farm

(Trondheim Kommune, 2013)

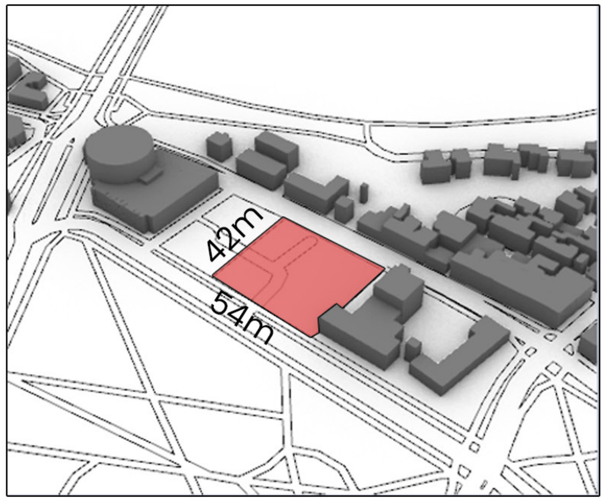
View of North Elevation and main entrance at early morning from Klostergata approaching from the west.



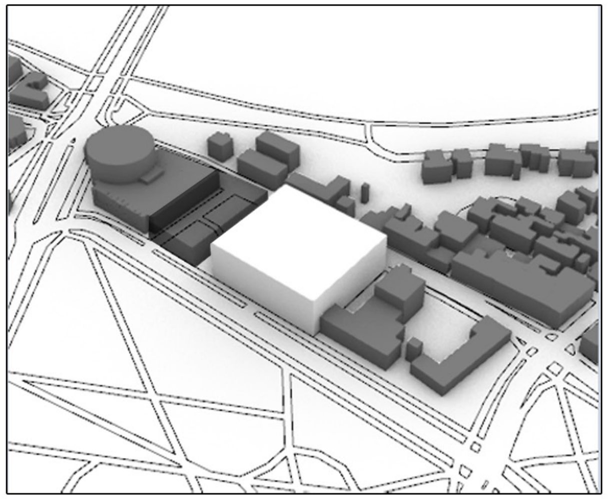
Site Plan 1:1000

- Connections to KAMD site 2 and samfundet for shared facilities in use

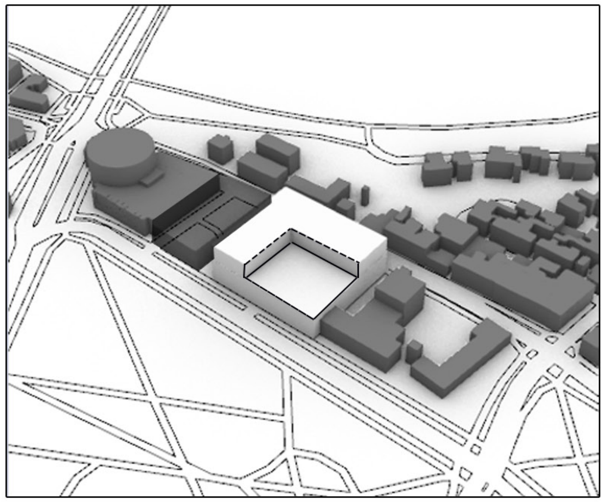
1. Main entrances
2. External courtyard and social space
3. Local corner stores
4. Delivery access
5. Bus access
6. Short stay parking for drop off
7. Roof access & technical systems



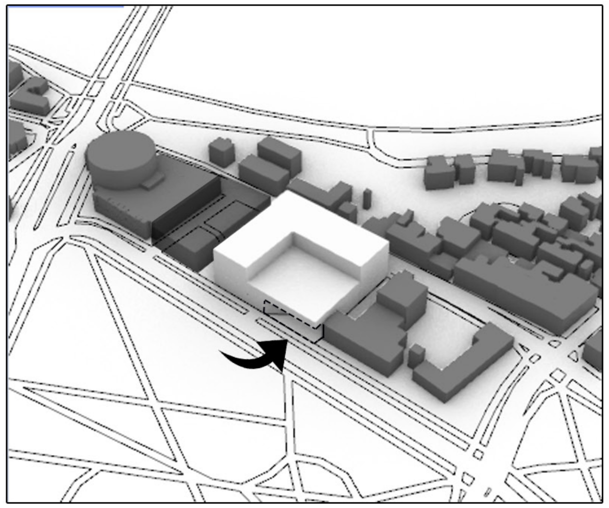
1. Define site perimeter



2. Find volume from area



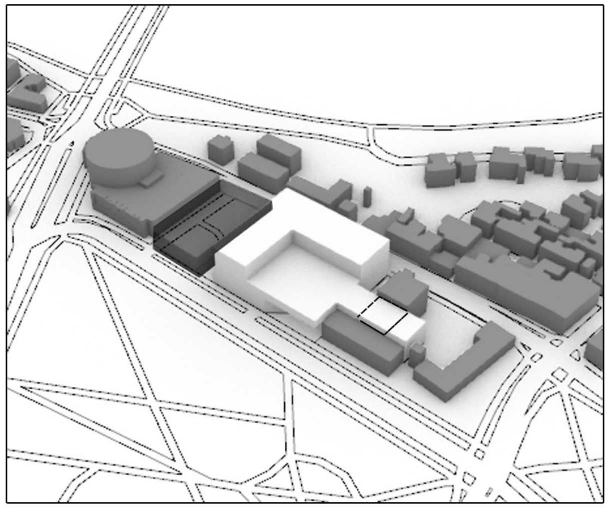
3. Reduce volume yet keep roof area



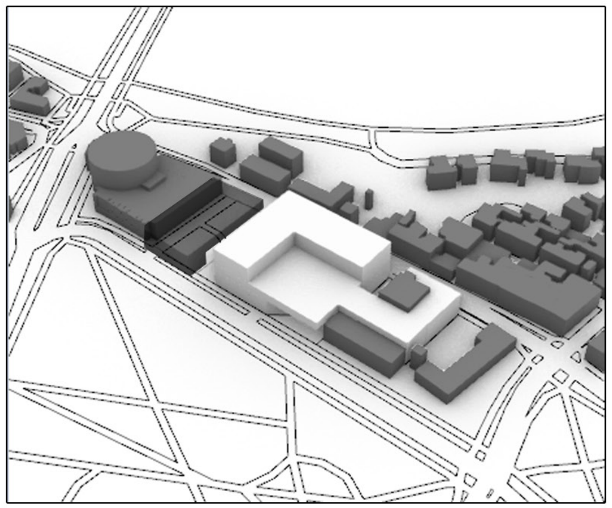
4. Open entrance and allow for light

Development

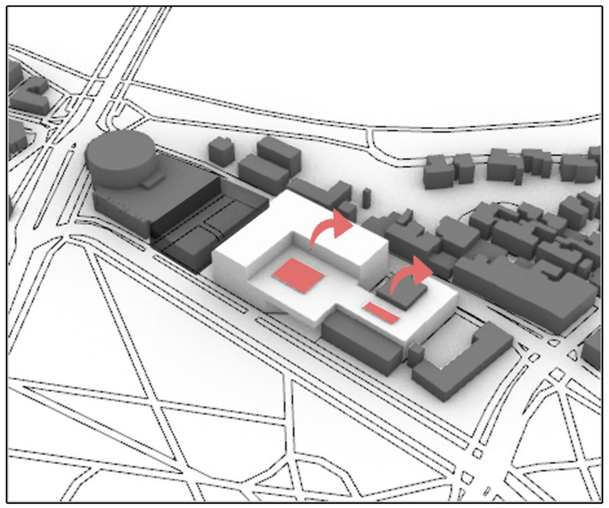
1. The first step of design was to set the site boundary for the new construction to the maximum footprint area without conflicting with the existing historical buildings. This followed a 6x6 metre grid to aid flexibility in design and for future changes.
2. The maximum hight in relation to the context was 24m as to not obstruct views and cause visual conflict with the surrounding context in which was found to not provide adequate floor area. Additionally daylight would be limited in which reductions must be made first or the use of a central atrium would be considered.
3. Following this an initial reduction to the to the volume on the southern face to prevent shadows cast onto roof PV's if reversed. The decision use a flat roof centred around the use of PV's as from provided documents and testing found would provide the highest output of energy.
4. An additional cut to show visual identification and guidance to the entrance and allow for light to still access the existing state archive as this central building was to remain.
5. As the "Magazine" section of the state archive as new than the original main building allowed for demolition or change this space has been expanded into in order to better integrate the new with existing and create a larger volume to fit the required programme.
6. Further extension to wrap around the remaining section of the state archive as to preserve yet maximise site usage was added.
7. The placement of two atriums after daylight analysis provided sufficient light levels for both the new and extension additions to the site. This additionally aiding ventilation as exhaust points.
8. Although tested from the start of design to ensure maximum benefits to PV energy generation a placement of PV on the new build and extension were placed. Additionally roof access for views across the city was added.



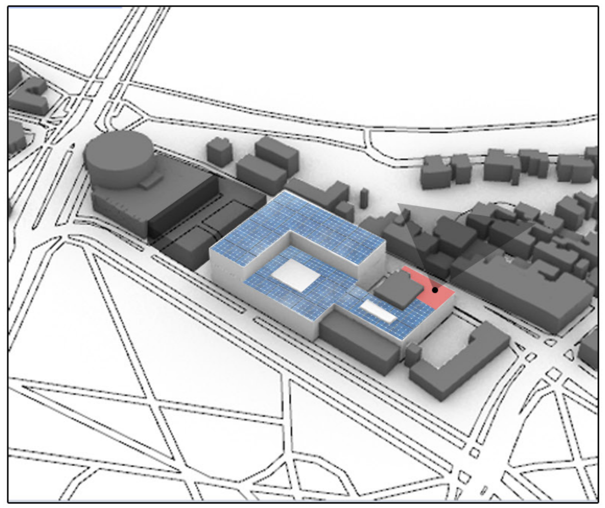
5. Extend into existing building



6. Maximise usable site



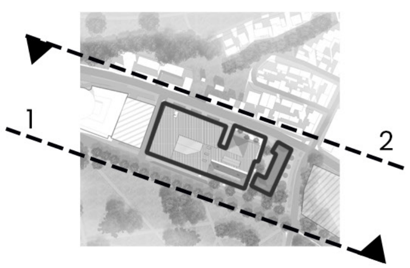
7. Atrium placement for lighting



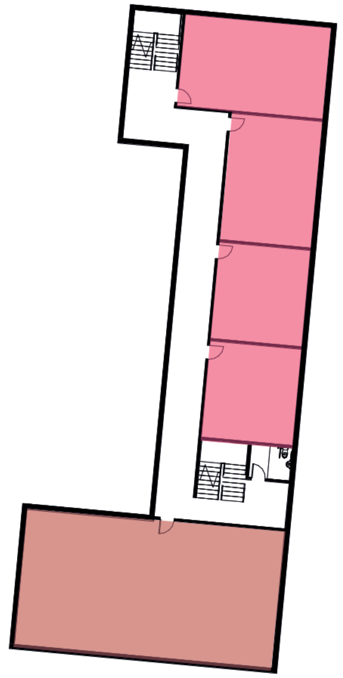
8. Find efficient PV placement

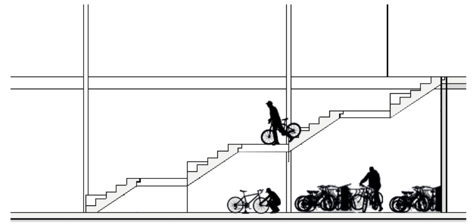
1. South Elevation

2. North Elevation



Elevations 1:500





(SARIS, 2022)

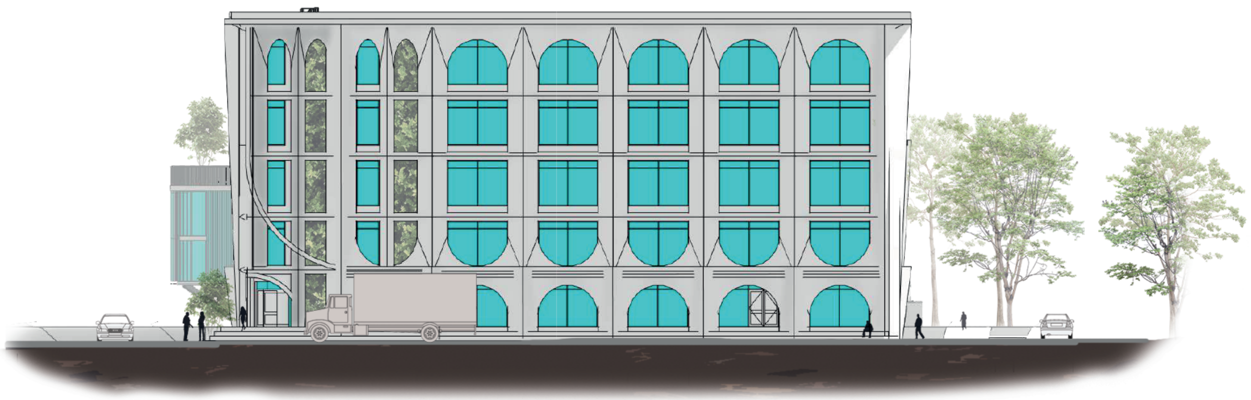
As required bicycle storage was for 400 bikes at an estimated 300m2 in the provided planning documentation the only feasible location was in the basement yet to reach this location internal access through stair guided bike access will be provided though a side entrance. Yet to make use of this space the storage will continue under said stairs and parallel to these will be staggered study platforms.

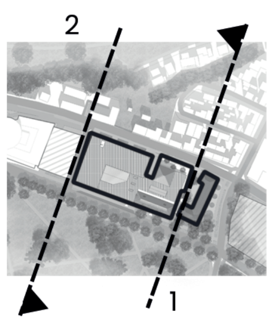
External bicycle storage racks are located on the northern side of the site below the library in which was raised to maintain this external space for ease as directly parallel to the cycle path. Additionally, temporary parking for ease of pick up and drop-off are located on the opposing side as of less traffic amounts for less congestion between parking and leaving.

The social courtyard acts as a buffer-zone between existing buildings yet connects them through direct circulation and active use of the space.

1. East Elevation

2 West Elevation

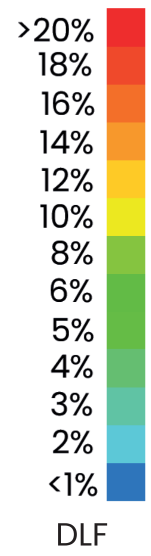


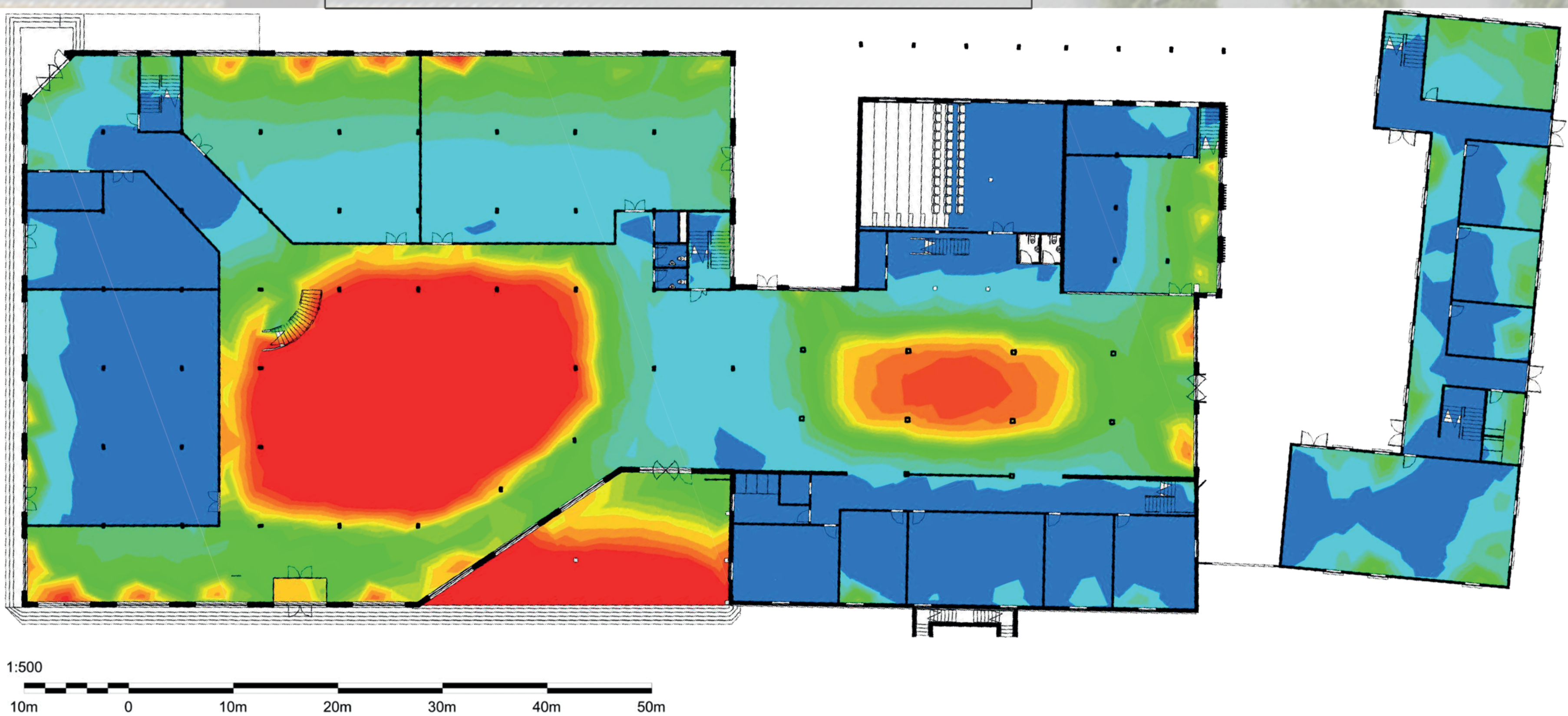


LEVEL -1 & Elevations

1:500

- Central circulation + Cores
- Music & Theatre hall
- Backstage and storage
- Lecture theatre
- Technical room
- NRK
- Bike storage
- Open study space
- Daylight labs
- Music rehearsal rooms
- Skibolig - Social facility

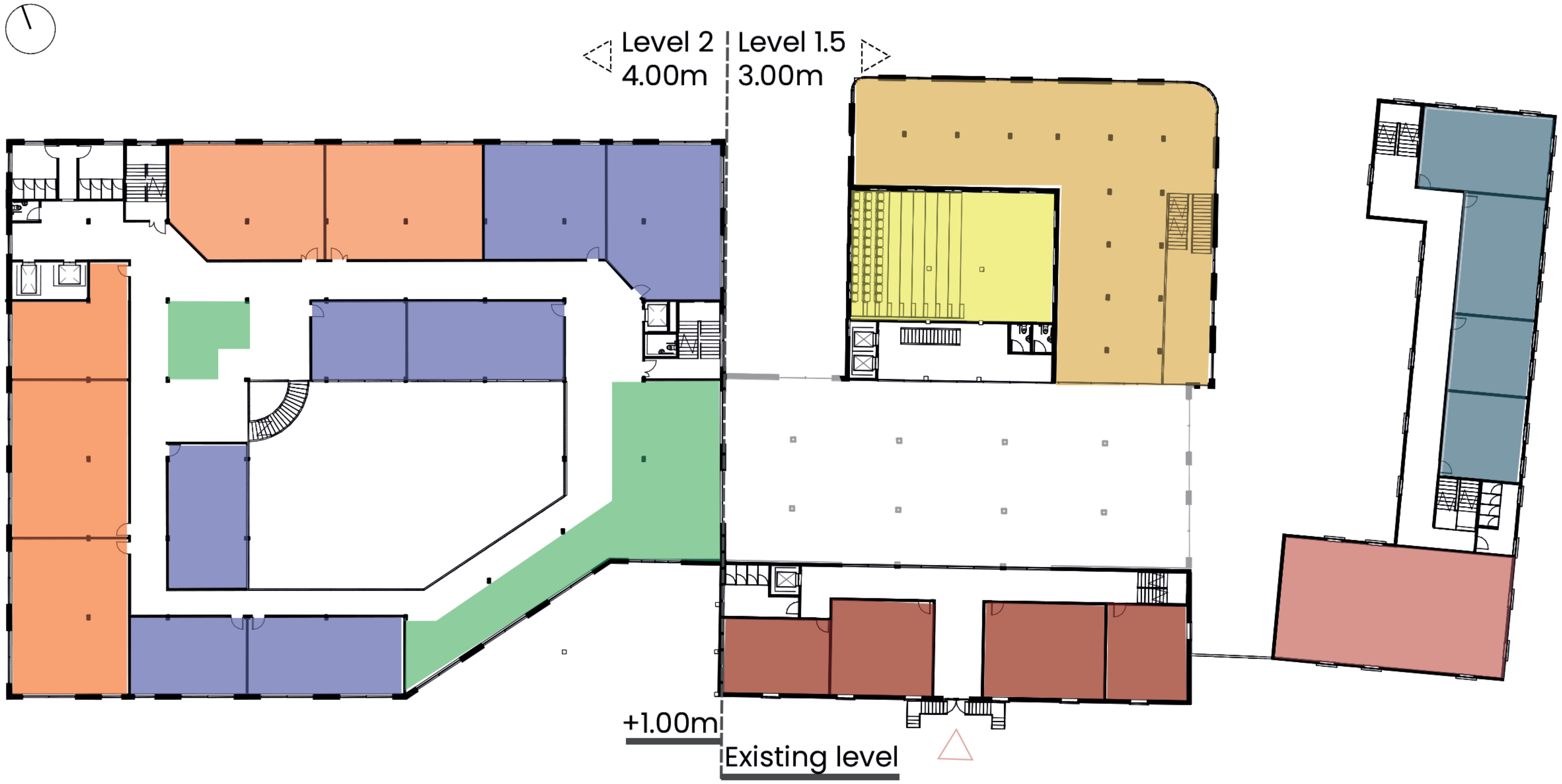




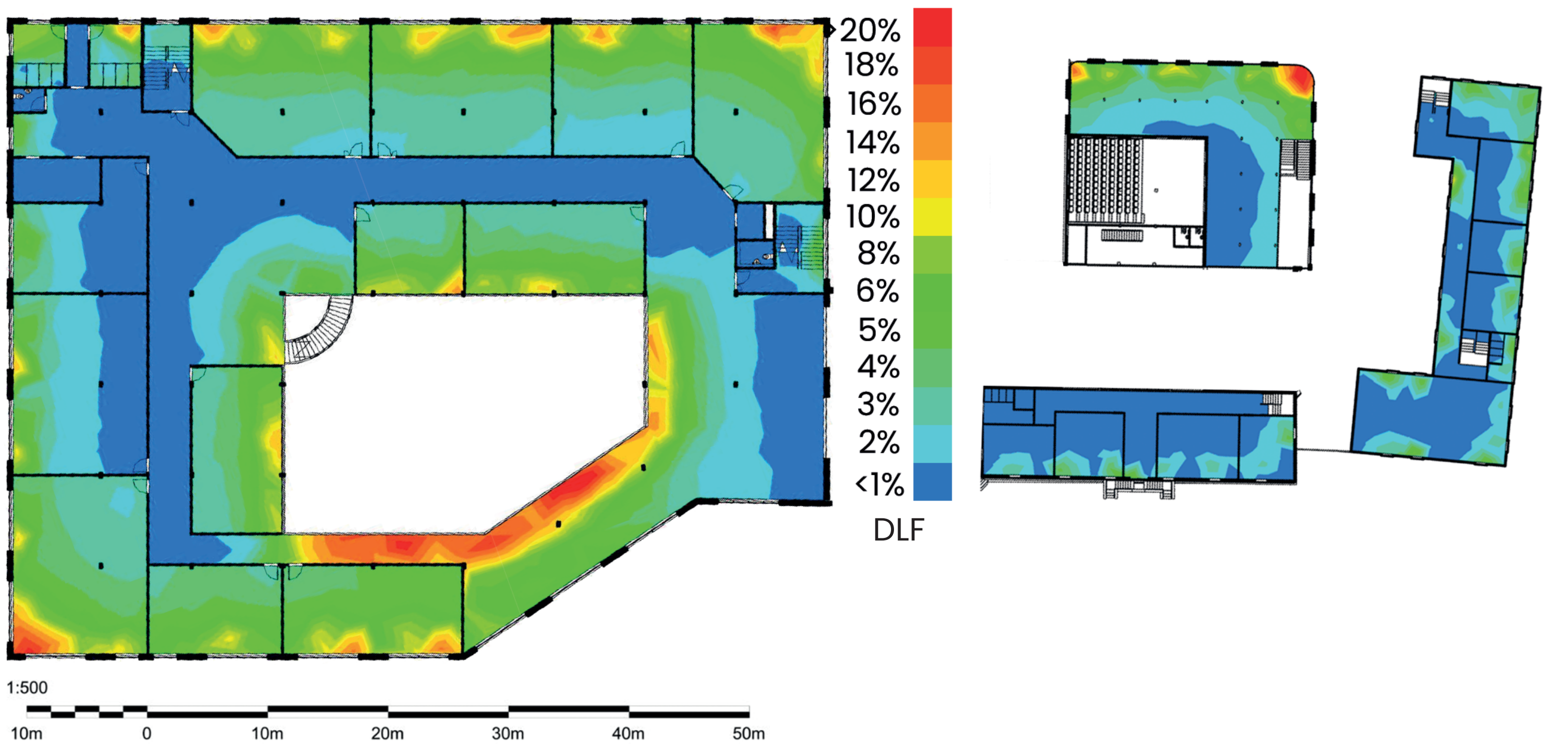
LEVEL 1

1:500

- Central circulation + Cores
- Open multi-use hall
- Workshops
- NRK
- Music & Theatre performance
- hall
- Open study space/Exhibition
- Hall
- Offices
- Display room
- Lecture theatre
- Skibolig social event space
- Cafe

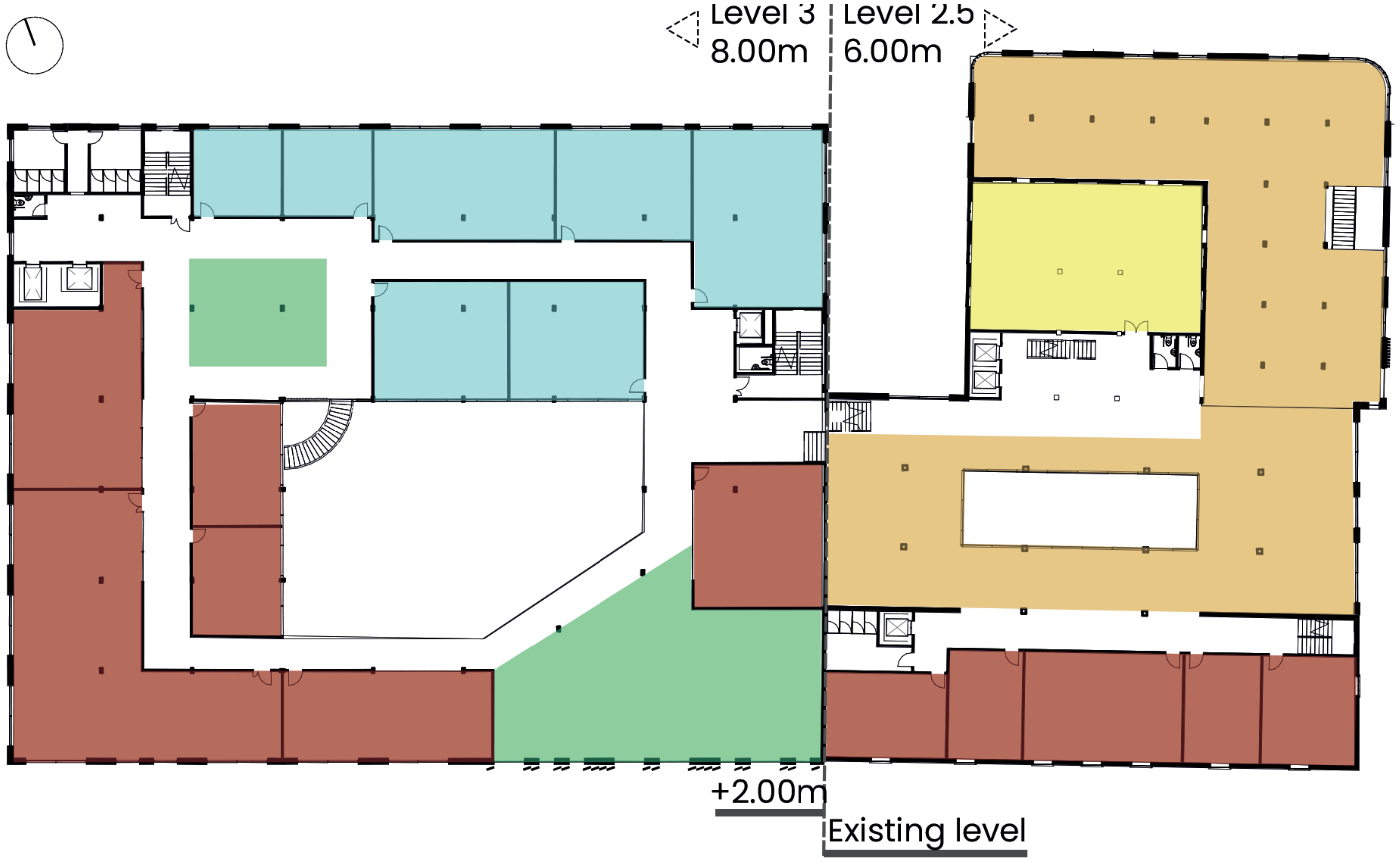


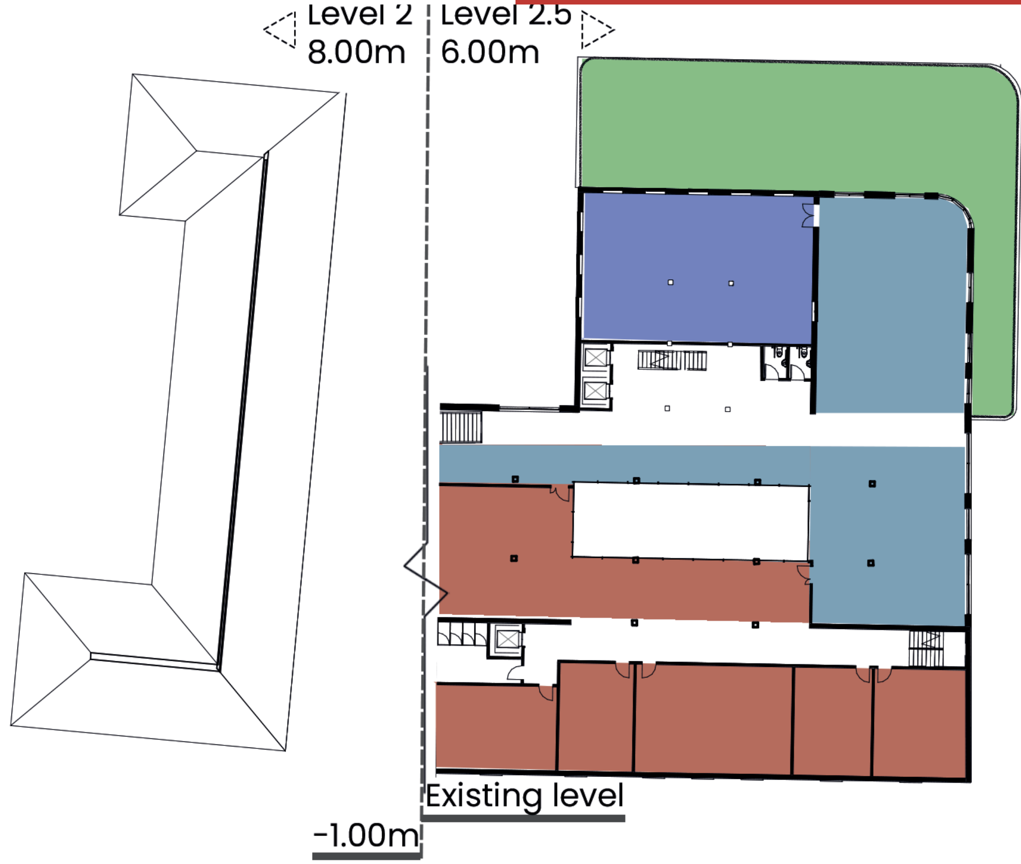
Day light for all levels has aimed to pass 2% in all usable rooms for study and work as to meet TEK17 standards which passes for the construction at around 95% excluding circulation space in which those rooms which cannot reach this will be supported by artificial light greater however this till greatly reduced lighting energy usage. However, the existing buildings were a challenge as with not being able to alter their façades improving daylight was challenging part from improving internal layouts and materials for improved light spread.

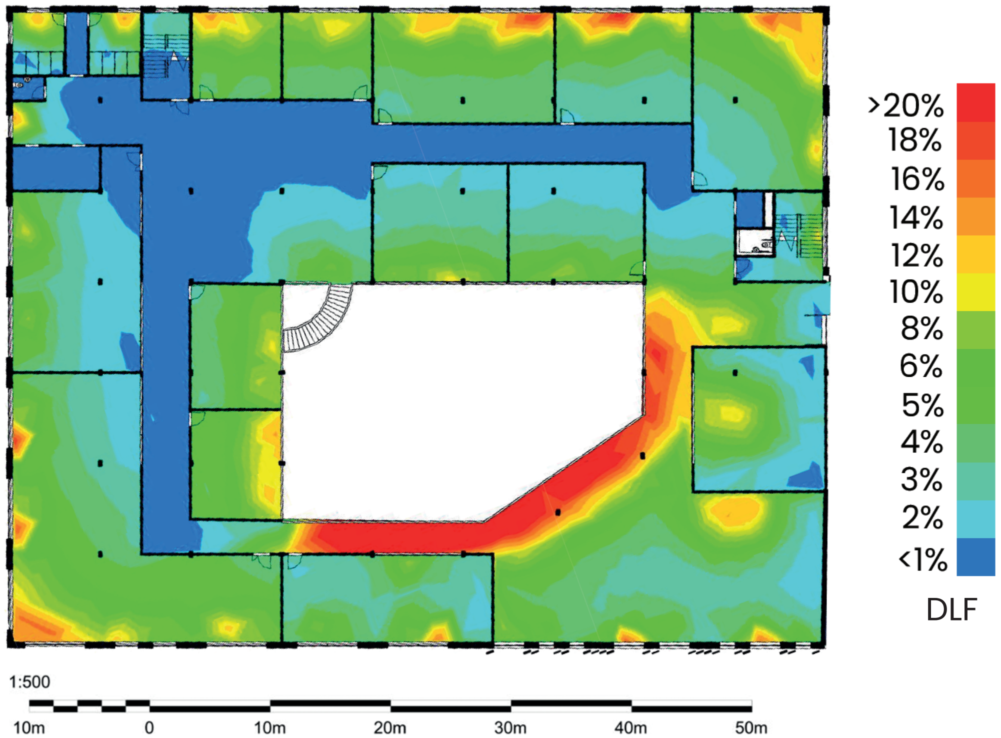


LEVEL 2 & 2.5
1:500

- Central circulation + Cores
- Teaching rooms
- Labs
- NRK
- Library
- Open study space
- Music rehearsal rooms
- Lecture theatre
- Skibolig social event space

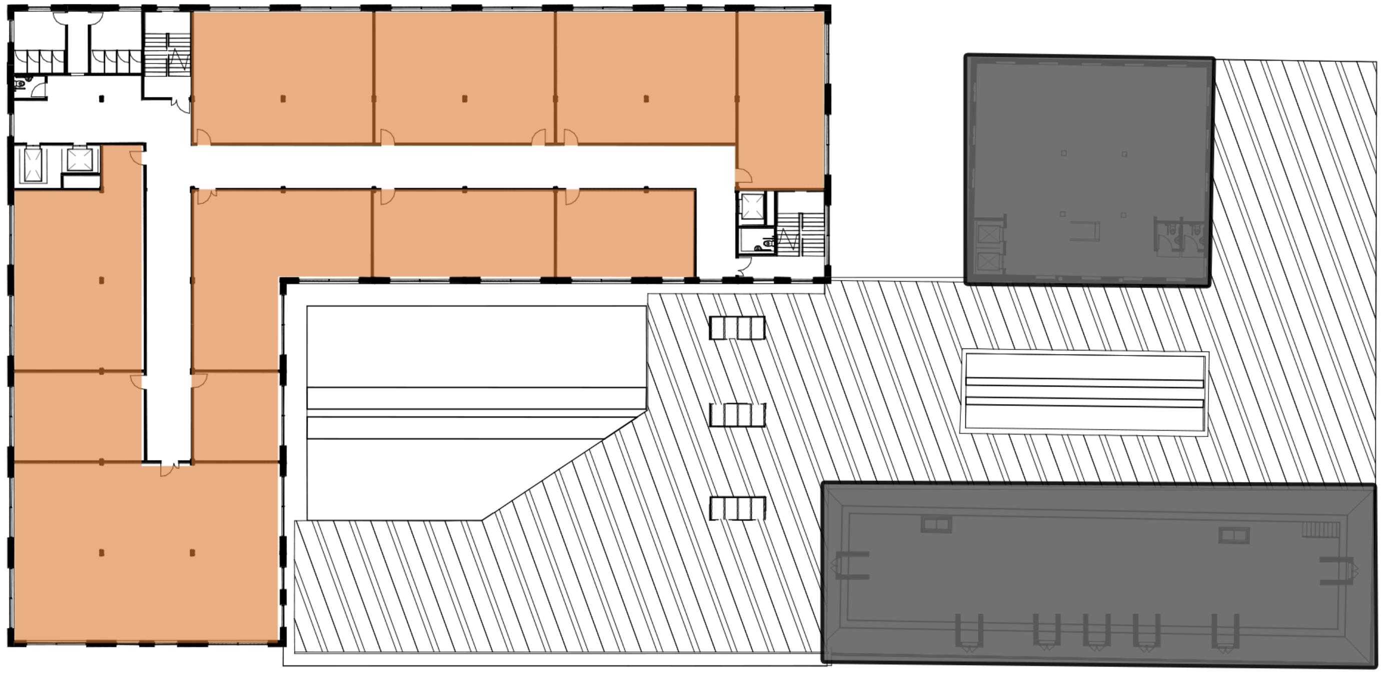


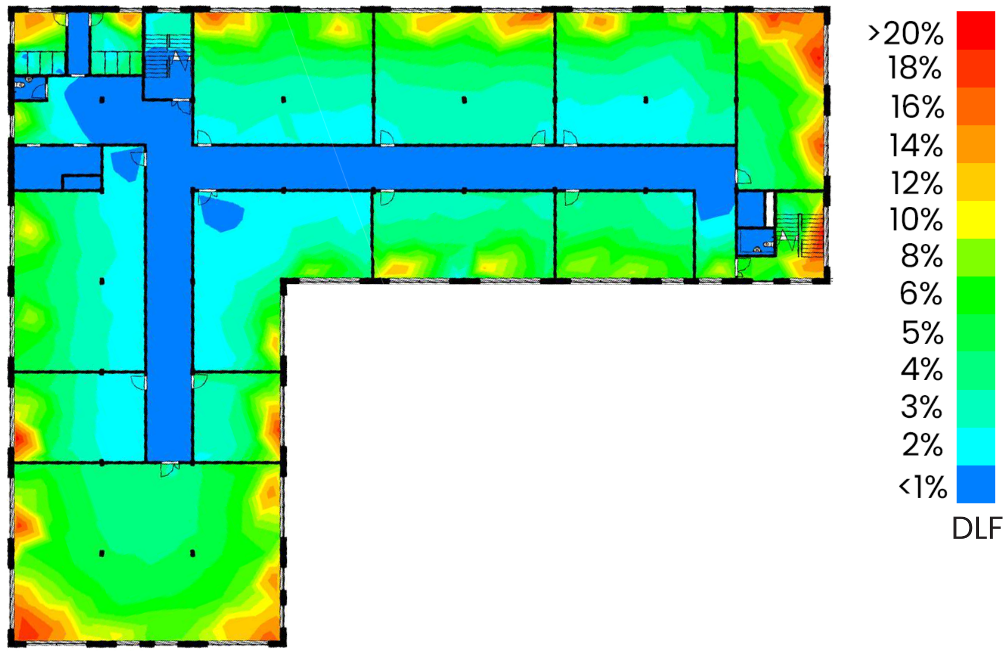




LEVEL 3 & 3.5
1:500

- Central circulation + Cores
- NRK
- Library, printing facilities study space
- Open study space
- Lecture theatre
- Digital design studios
- Canteen
- Kitchen
- Rooftop terrace

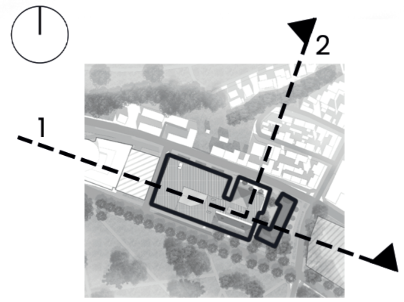




The 4th and 5th floor have been allocated to be optimised around art and design studios as to work with the high day-light factors levels present throughout each room. These will be varied between the faculties of architecture music and design depending on specific requirements for students.

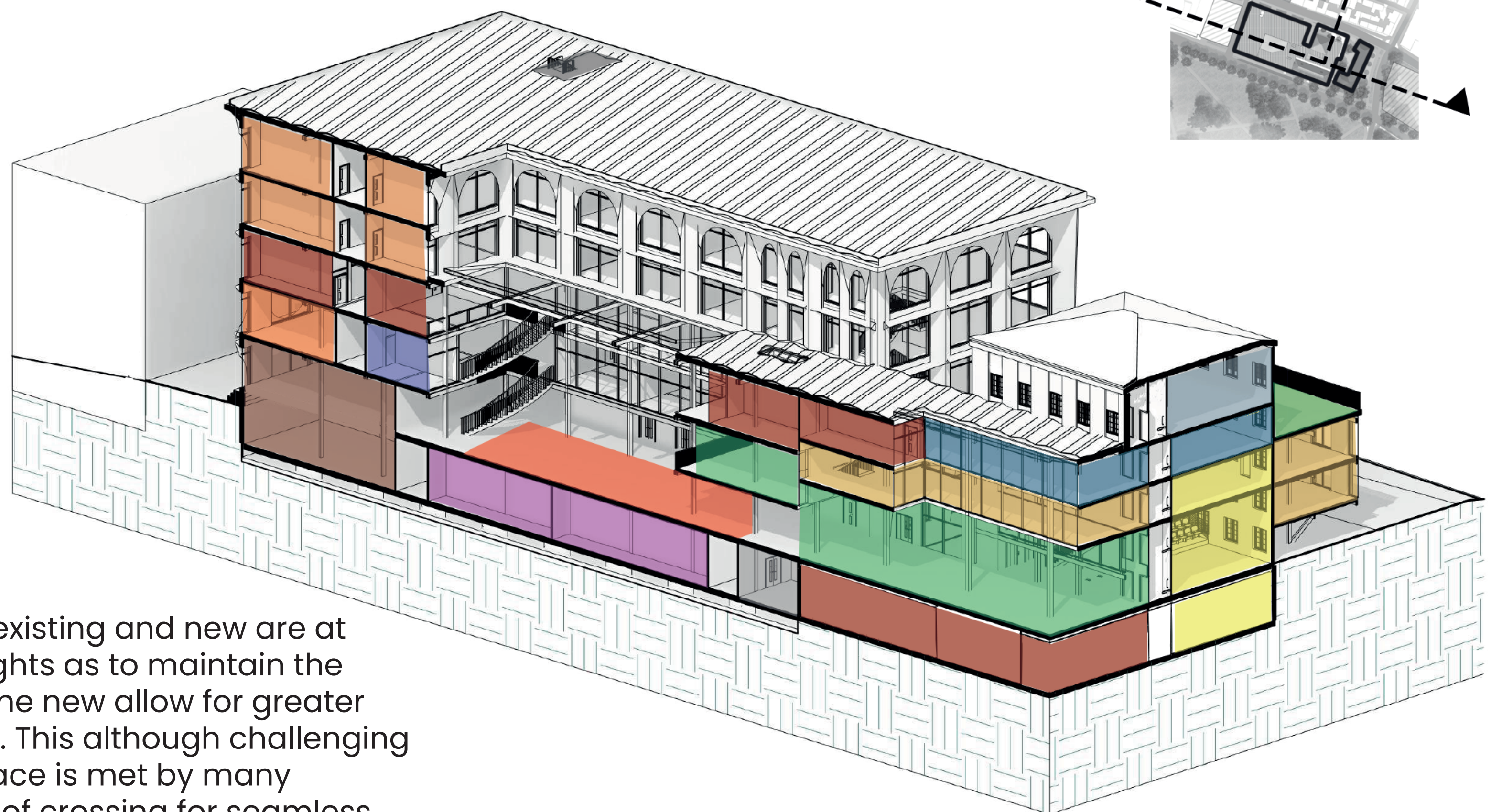
LEVEL 4 & 5
1:500

- Central circulation + Cores
- Art and Design Studios



Sections
1:500

- Central circulation + Cores
- Open multi-use hall
- Workshops
- NRK
- Music & Theatre performance
- hall
- Open study space/Exhibition
- Hall
- Offices
- Display room
- Lecture theatre
- Skibolig social event space
- Cafe
- Labs
- Library
- Teaching rooms
- Digital design studios



The two zones of existing and new are at different floor heights as to maintain the existing but with the new allow for greater flexibility of space. This although challenging in dividing the space is met by many circulation points of crossing for seamless transition.

PROJECT CONTEXT

Initial Programme Requirements	Given Estimate m2
KAMD	
Special Areas (Workshops, Labs, Library)	4200
Teaching space	1100
Open Space	650
Workplace (Study rooms, Offices)	2400
NRK	6000
Existing Not included in total)	2700
TOTAL	14350 (Max +1000)

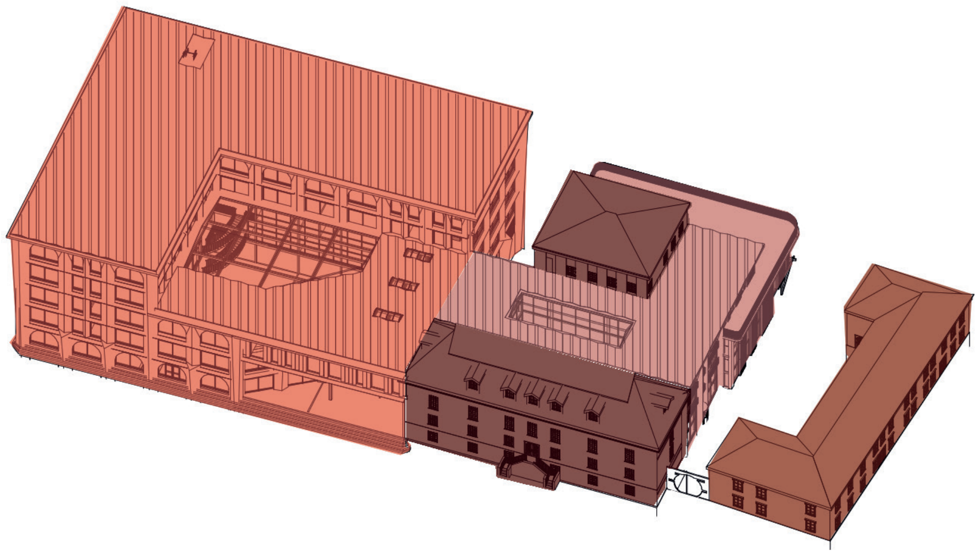
Programme	Level -1 m2	Level 1 & 1.5 m2	Level 2 & 2.5 m2	Level 3 & 3.5 m2	Level 4 & 4.5 m2	Level 5 m2	Total m2
KAMD							
Special Areas	1670	1510	875	1600	900	1050	7605
Teaching space	150	150	515	150	150	-	1115
Open Space	-	435	-	250	-	-	685
Workplace	-	1140	1200	250	150	-	2740
NRK	475	230	330	905	230	-	2400
TOTAL m2	2295	3465	2920	3155	1430	1050	14545

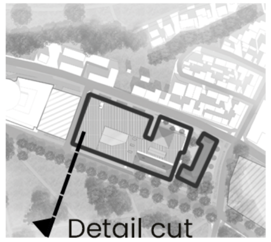
PV Coverage	Given Estimate m2	PV Used
Roof	1500	2900
Facade	1000	300
TOTAL	2500	3200

Displayed are the values to display the given estimate requirements given against a close estimate to the final design such rooms are appropriated under the category's provided yet this does not account for circulation space in which overall footprint is larger than projected.

PV usage as explained in later section varied from the given amount as to accommodate the energy design. One large change is in the facade BIPV reduction to which a large amount of the southern façades are blocked by trees or other context in which it has been used where found appropriate. For the energy calculations and LCA the use of only the New build and existing were taken into account with a total of 12500 as advised by this thesis's supervisor due to implausibility with calculations for the existing buildings. Overall the values correspond with the initial requirements yet the overall choice to reduce NRK's space by over half was to improve the functionality for students foremost and leave possibility for the remaining to be spread between the remaining KAMD sites.

Zone	Total floor area m2
New Build	10250
Extension	2250
Old state archive	2600
Vollan farm	1550
TOTAL	16650





Construction

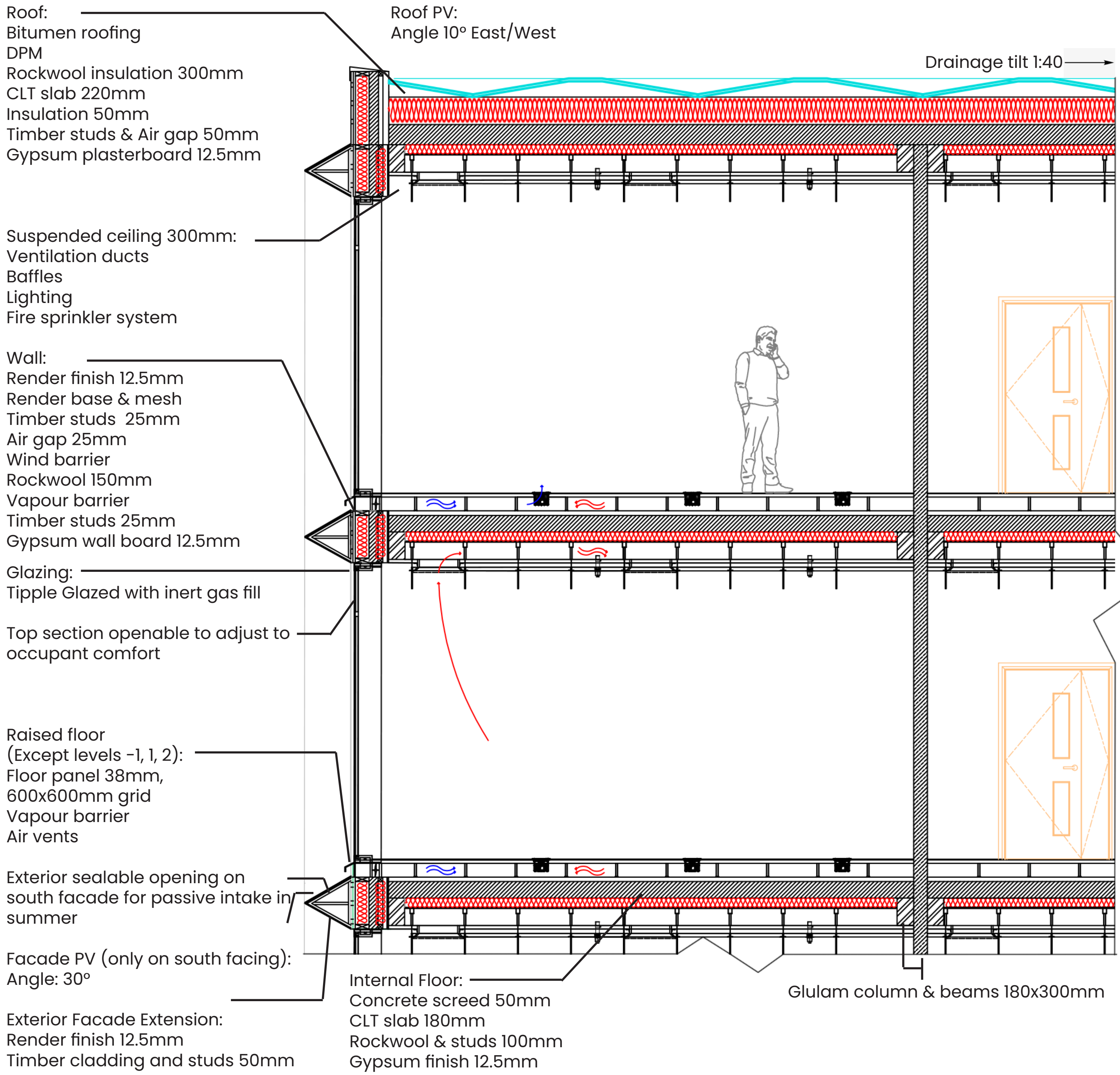
The envelope plays a crucial role on reducing the energy demand of the building. It is important to have sufficient amounts of insulation in the walls, roof and ground. In addition, the air tightness of the building must be as low as possible in order to minimize heating need in winter. The U-values for each element have been designed to fulfill are pass the minimum technical requirements set in TEK17. For the exterior walls and roof, the designed envelope has lower U-value than required by todays standards but are achievable using existing solutions. Where the U-values were calculated between Revit and Simien.

The main construction material chosen, is timber. The columns and beams consist of glue laminated wood. The walls and slabs are constructed from cross-laminated timber (CLT). The main aim was to reduce concrete usage to therefore reduce emissions and promote greater use of such construction strategies and reduce reliance on traditional concrete for projects of this scale in Norway. Additionally, materials will tried to be sourced locally if available to greater reduce emissions from transport and support local industries.

A thin concrete layer on each floor was employed to one add thermal mass and also to reduce sound transfer through floors. This being as according to energy simulations done in SIMIEN, the energy demand of the building can be reduced by having a greater thermal mass in the building.

The structure is also designed for flexibility in following a six by six metre grid system with partition walls that can be reorganised if the future needs of the building change.

ELEMENT	PROJECT U-VALUE	TEK 17
Exterior walls	0.12 W/m²K	0.18 W/m²K
Roof	0.07 W/m²K	0.13 W/m²K
Ground Slab	0.10 W/m²K	0.10 W/m²K
Windows	0.7W/m²K	0.8 W/m²K
Air tightness, N50	0.3 ACH	0.6 ACH



A consideration for acoustics is taken as of the timber construction which could pose a problem yet this has been handled by a few solutions:

- The addition of sound panel baffles in large open spaces absorbs and prevents the echo or sound carrying through these open spaces.
- The use of absorbent materials where necessary.
- Th technical room, performance halls, music recording and practice rooms have all been sufficiently sound insulated
- Further sound insulation between CLT slabs have been added between floors.

An internal view of southern facing design studio of open layout.

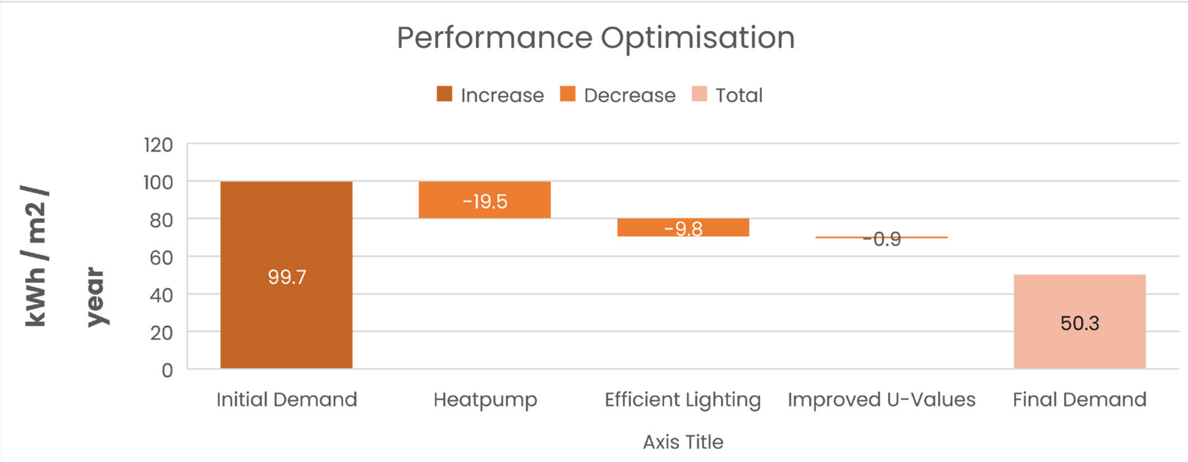
An internal view of the central atrium and open activity space for performance and gallery display. Allowing for a joint space of interaction between all occupants.

An internal view of a concept for the layout of the music and theatre performance hall. Additionally need for similar spaces can be shared with samfundet as of the already existing facilities instead of replicating multiple on this site.

Energy Design

The strategies utilised within the design of the KAMD project have delivered an energy efficient building, that has obtained ZEB O–EQ and positive energy status. The energy budget presented has been calculated according to NS 3031 net energy demand and represents both the demand and generation of energy within the project.

The TEK17 requirement for energy efficiency within office buildings require a maximum of 125 kWh/m² (DIBK, 2017). The KAMD project has a total energy demand of 66.0 kWh/m² and is therefore within the TEK17 requirement. The project building has an energy need of 38.1 kWh/m² when the energy need for technical equipment is subtracted. The total energy balance of the building is -3.4 kWh/m² with the incorporation of PV production (-41.5 kWh/m²), and meets TEK17 ZEB O-EQ positive energy requirements.



Design measures were tested and compared for implementation in aims to reduce operation energy consumption and improve the overall building performance. Some of the strategies utilised include natural ventilation strategies, efficient lighting, thermal mass for heat storage, ground source heat pump, and improved insulation above TEK17 minimum requirements.

ZEB	Value	Data Source
Electricity Demand	476, 040 kWh / year	SIMIEN
On-site PV production	-518, 779 kWh / year	SIMIEN
ZEB BALANCE	-42, 739 kWh / year	SIMIEN

Energy demand

66.0

Energy demand (Minus equipment)

50.3

Energy need (Minus equipment)

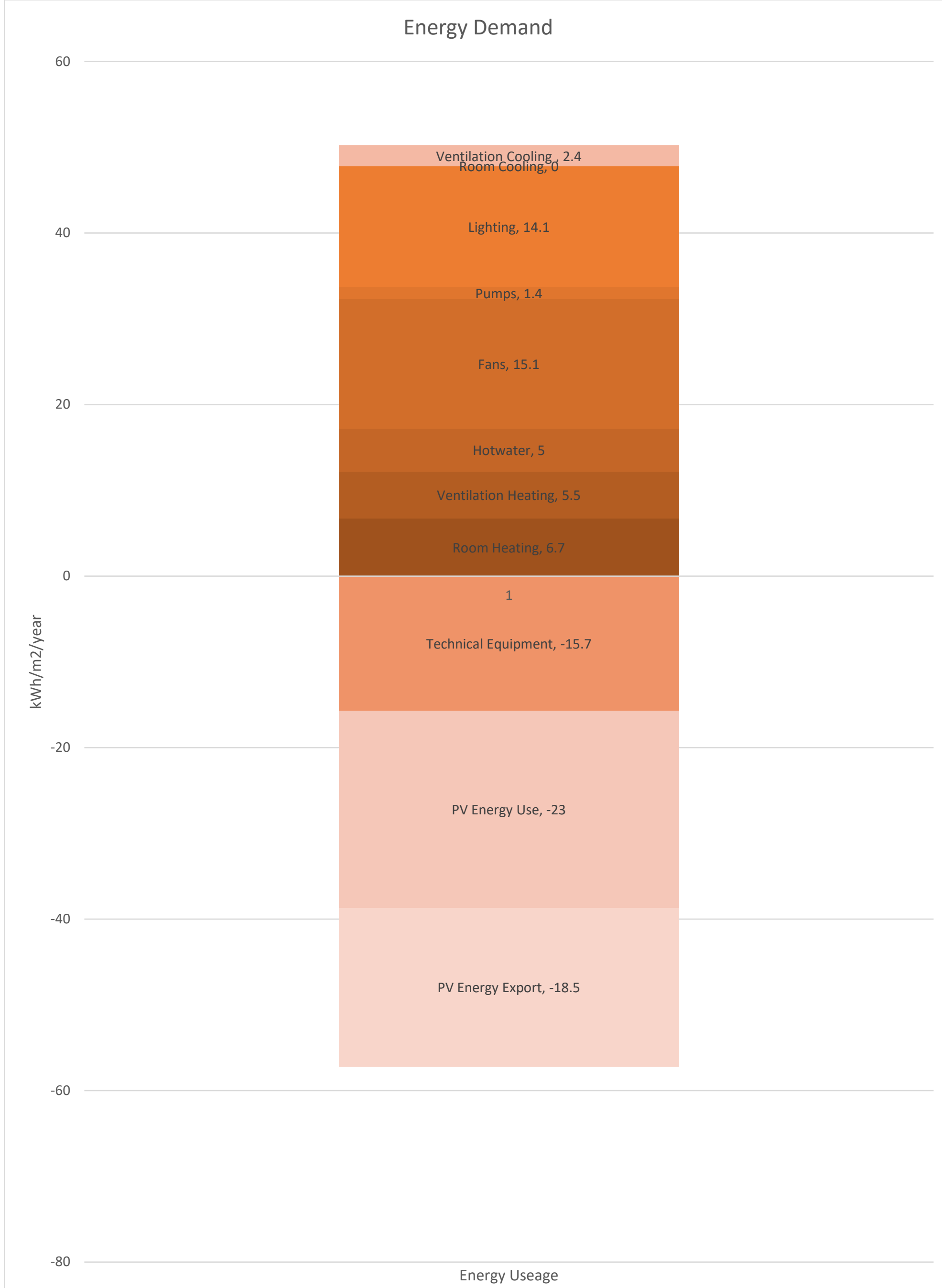
38.1

PV production

-41.5

Zeb 0-eq balance

-3.4



Zeb 0-eq balance

-0.44

kg C0$_2$ eq/year

Energy Design

Strategies

Passive strategies like the envelope and building form have been designed to minimize the need for heating. The active strategy for the heating system is also an important factor for lowering the energy need of the building in order to achieve the overall project energy goals.

Heating

The buildings heating system is centered around a ground source heat pump located in the technical room in the basement that can cover 95% of the buildings heating demand. The remaining 5% can be covered using electricity from an electric boiler in case of heightened demand. A ground source heat pump is chosen due to its high Co-efficient of performance which lowers the energy need for the building and reduce overall energy costs. The heat is designed to be distributed through the supply air of the ventilation system. This minimizes the use of space for the heating system as using heating panels on the walls or by having waterborne floor heating.

The ground source heat pump uses brine to water solution as the medium for transporting heat from the ground to the building. Since the heat distribution is through the ventilation system, there is a need for a water-to-air heat exchanger in the technical room to be in place. In addition, the heating system is designed to have heat recovery from the exhaust air from the atrium. To use this heating energy there is a need for an additional air-to-air heat exchanger.

Ventilation

The building utilizes a CAV ventilation system for mechanical means when the building has a heating demand with displacement ventilation of ground diffusers for air supply and to be extracted from the ceiling extractors. A hybrid system dependent on season is in place where natural ventilation supports summer loads. Openable windows are in place if occupant comfort is effected negatively however simulations suggest the building will have no overheating hours through the year. Additionally, the atriums act as a central space for extraction supported by fans and heat recovery during winter. During the summer this allows for the intake of cool air during periods if support is needed. Ducting between floors will run through the cores placed at each end of the building in the void space to allow for future flexibility.

Additional

Rainwater capture is utilised from the roof to be used for greywater systems in toilets and aid watering green areas such as green facade located on the state archive.

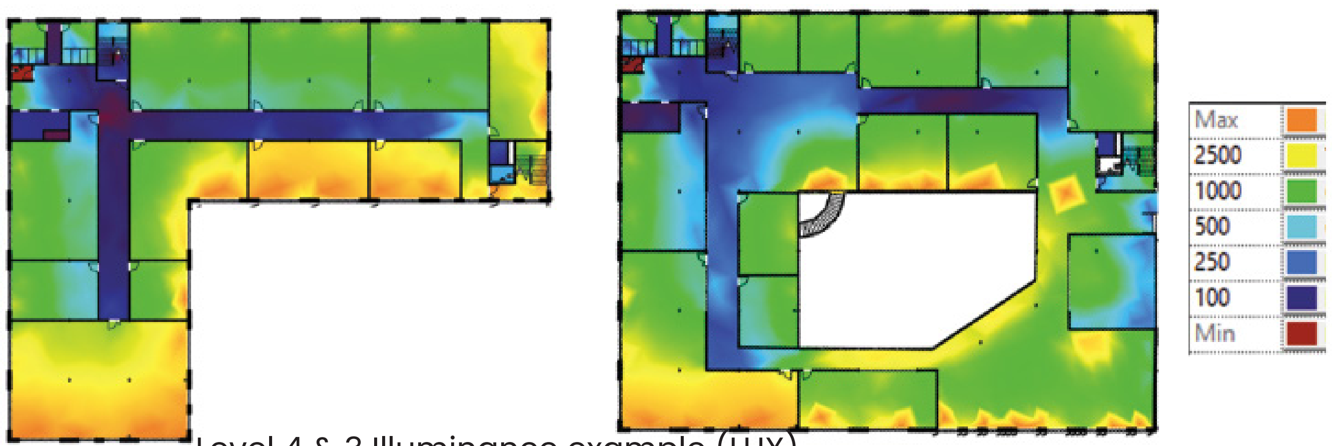
Daylight

The project aims to ensure good daylight qualities are present throughout the newly constructed areas in order to reduce need for artificial lighting support and therefore reduce energy demand and improve visual comfort of the occupants. As the project is mainly comprised of teaching, office and design studios good quality levels of light are necessary. In order to obtain these levels strategies were employed from

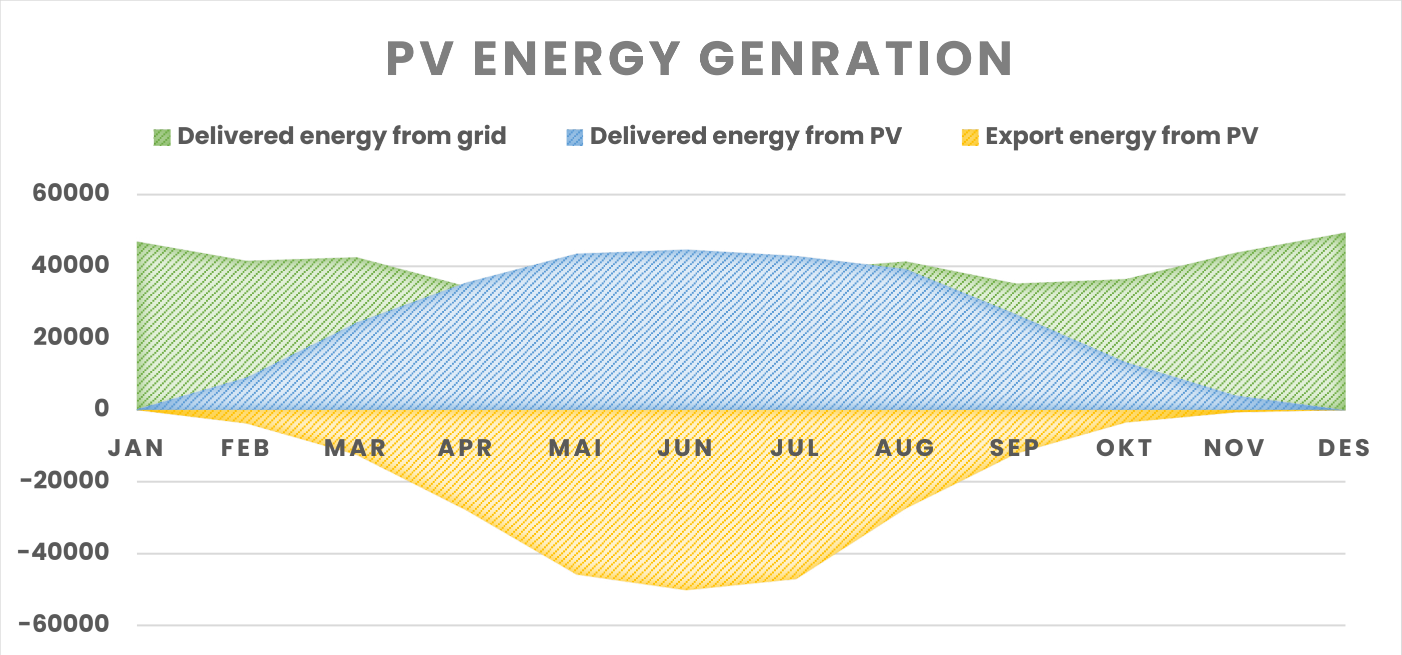
- Daylight simulations were taken at each stage of the design concept which influenced placement of atriums, opening size and glazing percentage. This was done to ensure an average above 2.5% and minimum of 2% though each space is met to ensure it passes TEK17.
- Facade design ensuring glazing rate did not exceed 20% of the total floor area in which is at 17.9% and limited the heat loss of the building. This still however allowed for positive lighting levels through 95% of the usable area for important spaces.
- The atriums contribute to these daylight qualities for deeper penetration whilst also providing benefits to ventilation, heating and open public spaces created.

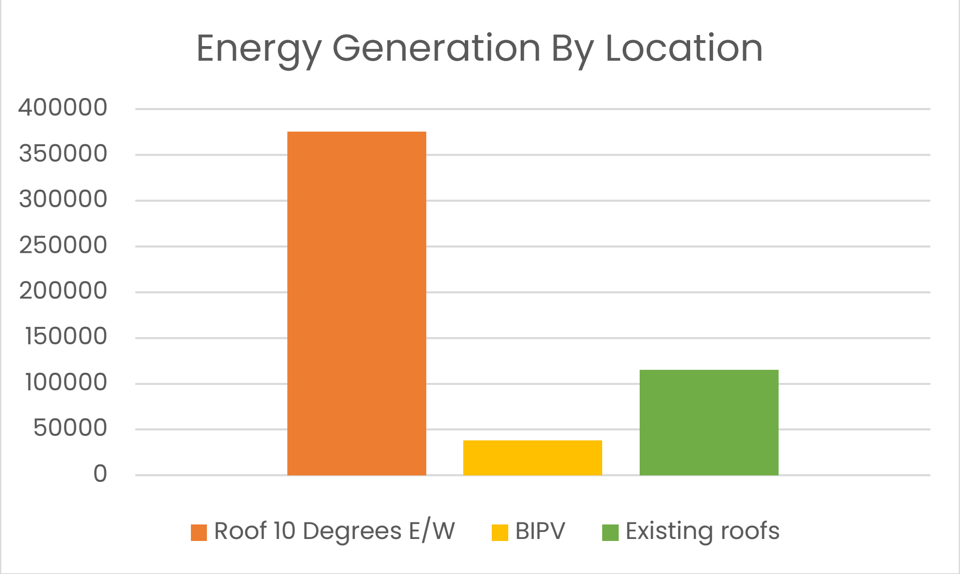
For areas with higher need for artificial support high efficiency LED lighting is in place for zones that do not require daylight conditions such as rehearsal rooms, kitchen, toilets, storage and those zones located within the basement. A smart control system is in place where if no activity is in place automatic detection will turn off said lighting or if daylight levels are high enough sensors will dim artificial to only provide what is necessary. As the glazing area is large per window internal vertical blinds are in place to allow for occupants to control glare and lighting.

The average illuminance in LUX for studios in near to 1000 and where central rooms surrounding the atrium stand at averages of 600 to 700. Zoning is dictated by lighting levels and those on the lower north western facade have lower light demanding zones such as music and theatre performance space which require controlled artificial light.



Level 4 & 3 Illuminance example (LUX)

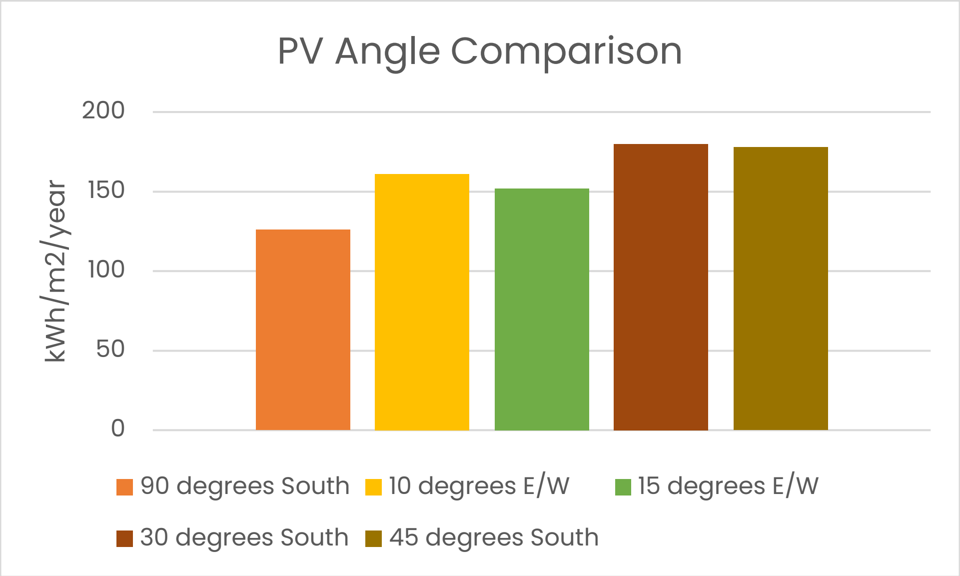




Photovoltaics
The use of Photovoltaics was implemented as they were greatly important in order to reach building performance targets. A combination of rooftop and building integrated PV's have been implemented into the project where various simulations and supporting material were used to assess effectiveness and placement. Where The whole project utilises near to 3220m² of effective area split between 2900m² of roof and 320m2 of facade placement. In total these produce 518152 kWh/year with 287118 kWh/year used by the building and 231034 kWh/year exported covering 109% of the energy demand with the roof producing 90% of the demand.

An assessment was taken to ensure the optimal angle for large scale placement through both Autodesk insight and Simien in comparison to the data given by Multiconsult which found the optimum placement to be East/West facing at 10 degrees for roof placement. Additionally, BIPV provided the highest value per m2 and were placed where appropriate without over encumbering the facade both visually and physically. This benefiting through winter to prevent snow buildup and be more effective against the low lying sun. The placement for these were decided based on a radiation study of the form against its context and found only the southern facade could provided beneficial energy production due to blockages of radiation from the existing buildings and tree coverage surrounding the rest of the site.

Due to the heightened demand for energy during the winter and low output of PV during this time there remains periods where the energy generation cannot cover the demand however due to exports during the rest of the year the overall offset is greater than use. This exported energy will be either exported to the grid or to be distributed throughout the rest of the existing buildings, KAMD and Samfundet.



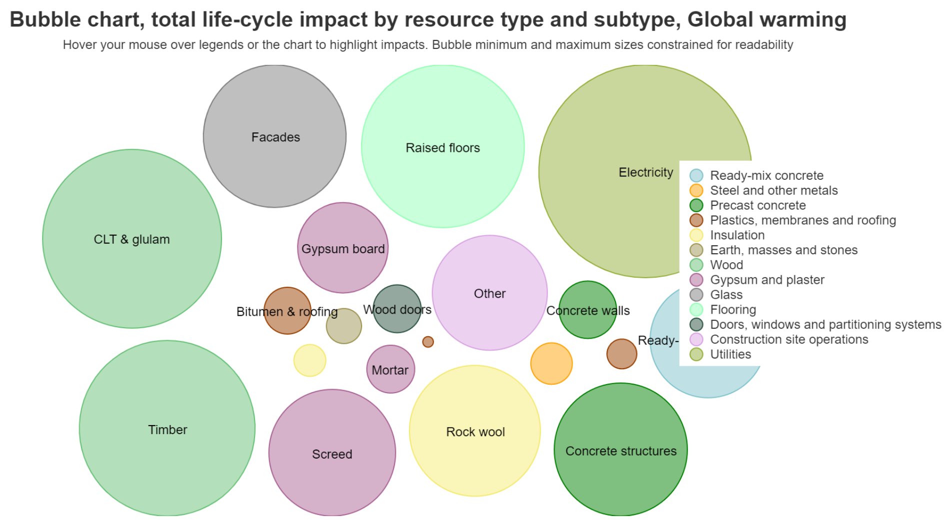
Despite having a lower initial amount 10 degrees E/W allowed for the highest m2 coverage and overall highest output in which dictated choice and correlated with the information provided by multiconsult however the vertical 90 degree simulations placed it the highest which is contradictory to this yet of little concern as of the limited use in the project.

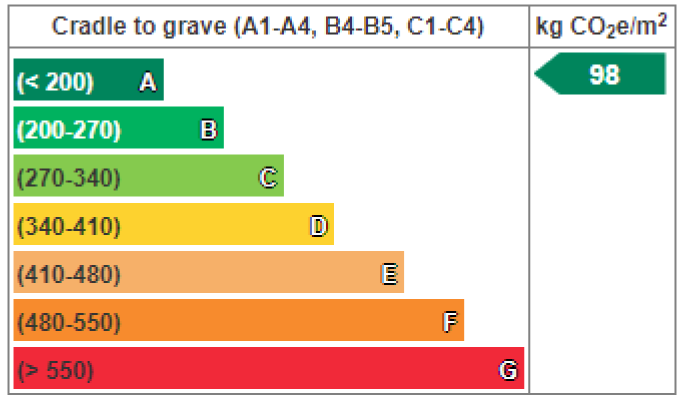
There is one more roof on vollan which is not considered for this project but if half the roof of east facade was used of 250m2 a further 44kwh/yeah could be obtained yet this would not reach the ambition level of ZEB÷OM-EQ still and a further 300m2 totalling an additional 550m2 which seems highly impractical.

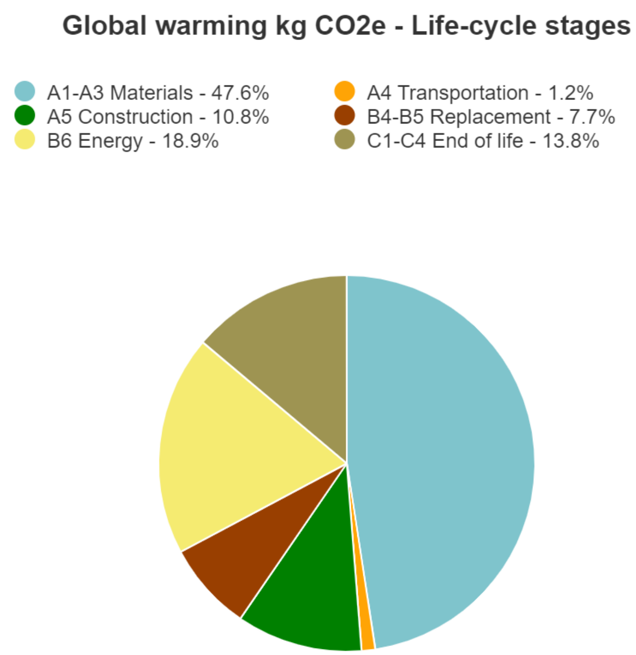
MATERIALS

Result category	Global warming Kg CO2e	Global warming Kg CO2e/m2/year
A1-A3	858 053	1.14
A4	20 941	0.02
A5	194 955	0.26
B1	-886	-0.00
B3	-	-
B4-B5	138 283	0.18
B6 (Not to be included as simien result is already defined)	325311	0.43
C1-C4	249642	0.33
D (Including export)	-2160249	-2.88
Total (A1-A3, B4)	996 336	1.32
Total (A1-A3, B4, B6)	-	0.88
Total	1786299	2.38
Total + D	-373950	-0.50

An Lca study was taken using the material take-off of the materials used under the new construction using OneClick Lca. This allowed for a study to see whether reaching ZEB÷O-EQ is possible in which found that the project did not reach this level at 0.88 kg Co2/m2/year yet if including all and D which is not covered by ambition levels the total would reach -0.50 kg Co2/m2/year. The LCA allowed for examination of materials and their possible alternative along use of EPD's for location and additional impacts. Although a large use of lower emission material alternatives taken were used the large contributing factors which could be minimised to further reduce the balance would be within the concrete from the incorporation of the basement. This would suggest if possible to remove this and expand further into the existing site as increasing the elevation is not advised.







Building LCA Calculations	Value	Data Source
Building Embodied Emission Estimate	98 Kg $C0_2$ eq / m²	OneClick LCA 'A' rating (OneClickLCA, 2021).
Building Embodied Emission Estimate Lifetime	1,225,000 Kg $C0_2$ eq	
Impact of 3220 m² PV system	915,382 $C0_2$ eq / lifetime 142.14 Kg $C0_2$ eq / m²	60 year period with 1x replacement period
Total building Impact	2,140,382 kg $C0_2$ eq / lifetime 171.2 $C0_2$ eq/m²	
Energy usage	671,810 kWh / year	
PV generation	-518,152 kWh / year	
Export PV Only	-231,034 kWh / year	
Demand for equipment	195,770 kWh / year	SIMIEN
Energy Total	-42,112 kWh / year	
Norwegian Grid Energy Intensity	0.130 kg $C0_2$ eq / kWh	NTNU LCA Assumption Guidelines (NTNU, 2021)
Building Lifetime	60 years	NTNU LCA Assumption Guidelines (NTNU, 2021)
Export PV emission reduction	-30,034 kg $C0_2$ eq/ year	kWh / year * Norwegian grid intensity
Carbon sequestration from biogenic carbon storage in materials	- 1,762,986 kg $C0_2$ eq	kWh / year * Norwegian grid intensity
Export PV emission reduction 60 years	- 328,473 kg $C0_2$ eq	
Total Reductions	- 2,091,459 kg $C0_2$ eq	
Embodied Impact (60 years)	48923 kg $C0_2$ eq	Total Building Impact + Equipment Demand and Impact
Embodied total Impact (annual)	815 kg $C0_2$ eq / year	

Conclusion

In summary of this design project although the ambition level of ZEB÷OM-EQ was not reached where the embodied emissions from A1-A3 + B4 are that of 1.32 kgCO2eq/m2/yr and where the operational energy emissions are of 4.96 kgCO2eq/m2/yr. Due to PV optimisation a reduction of 5.40 kgCO2eq/m2/yr totalling a balance of **0.88** kgCO2eq/m2/yr. However, this was still able to reach ZEB÷O-EQ at **-0.44** kgCO2eq/m2/yr. This was not the aimed for outcome and The initial ambition levels were found to be not plausible with the current requirements and context. From this, after different solutions were tested the three main solutions could come from:

1. Increasing PV coverage to existing building roofs further yet this would need an additional 500m2 in order to reach ZEB÷OM-EQ.
2. Increasing BIPV on the southern and Eastern façades by 400m2.
3. Reducing the gross floor areas by 1500m2 would greatly reduce the energy demand and with the same total roof area the PV system could support this and surpass the energy amount to reach ZEB÷OM-EQ. This areas could be done by not expanding on to the existing buildings yet in doing so comes with its own negatives.

Each of these could be applied separately or in combination at lower values to reach this yet as the total PV area is already so vast increasing it only brings further problems in practicality to economic cost and further reducing prevention to ZEB complete as including emission value for PV's are extremely high and would require additional energy generation systems to account for this.

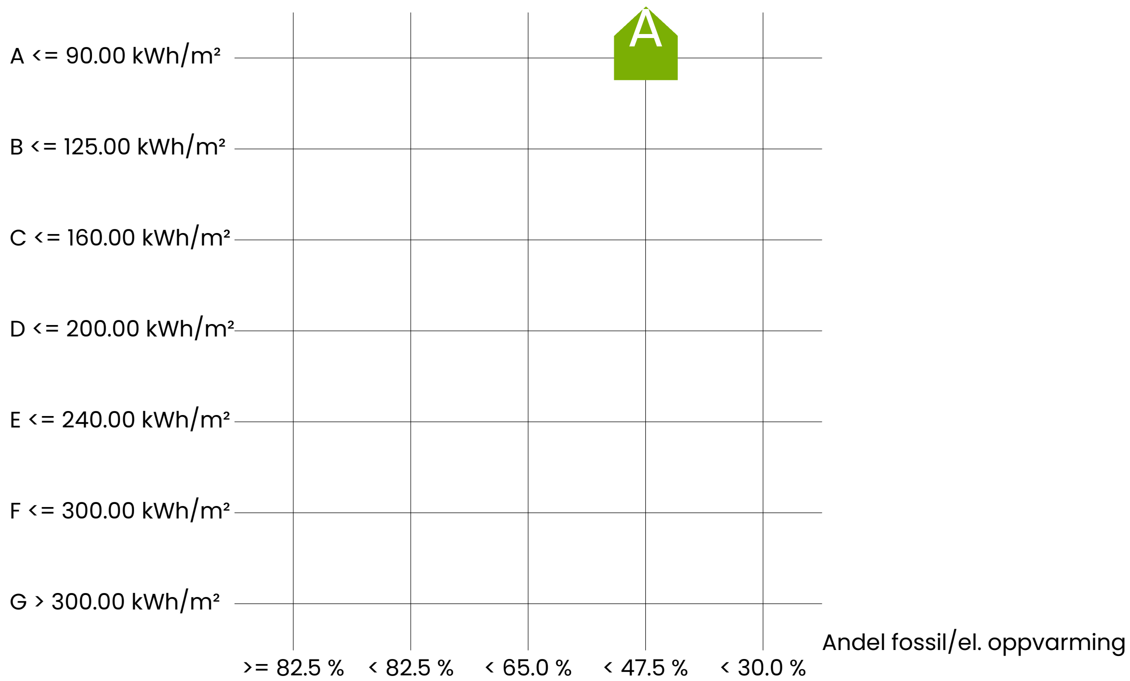
Overall this investigation set out what it aimed to achieve in finding the plausible ZEB ambition level and how to reach it yet further investigation in a larger period of time would produce more in-depth results.

SIMIEN

Energimerke

Simuleringsnavn: Energimerke
Tid/dato simulering: 14:20 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building;

Energikarakter ENERGIMERKE



Beregnet levert energi normalisert klima: 51.79 kWh/m²
Sum andel el/olje/gass av netto oppvarmingsbehov: 36.7 %

SIMIEN; Energimerke Side 1 av 5

References

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Simuleringsnavn: Evaluering
Tid/dato simulering: 14:21 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building;

Resultater av evalueringen	
Evaluering av	Beskrivelse
Energiramme	Bygningen tilfredsstiller energirammen ihht. §14-2 (1)
Minstekrav	Bygningen tilfredsstiller minstekravene i §14-3
Luftmengder ventilasjon	Luftmengdene tilfredsstiller minstekrav gitt i NS3031:2014 (tabell A.6)
Energiforsyning	Fossilt brensel benyttes ikke i oppvarmingsanlegget (§14-4)
Samlet evaluering	Bygningen tilfredsstiller byggeforskriftenes energikrav

Energiramme (§14-2 (1), samlet netto energibehov)	
Beskrivelse	Verdi
1a Beregnet energibehov romoppvarming	2,9 kWh/m²
1b Beregnet energibehov ventilasjonsvarme (varmebatterier)	4,1 kWh/m²
2 Beregnet energibehov varmtvann (tappevann)	5,0 kWh/m²
3a Beregnet energibehov vifter	15,1 kWh/m²
3b Beregnet energibehov pumper	1,4 kWh/m²
4 Beregnet energibehov belysning	14,1 kWh/m²
5 Beregnet energibehov teknisk utstyr	34,4 kWh/m²
6a Beregnet energibehov romkjøling	0,0 kWh/m²
6b Beregnet energibehov ventilasjonskjøling (kjølebatterier)	9,4 kWh/m²
Totalt beregnet energibehov	86,5 kWh/m²
Forskriftskrav netto energibehov	135,0 kWh/m²

Simuleringsnavn: Evaluering
Tid/dato simulering: 14:21 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building;

Minstekrav (§14-3)		
Beskrivelse	Verdi	Krav
U-verdi yttervegger [W/m²K]	0,12	0,22
U-verdi tak [W/m²K]	0,10	0,18
U-verdi gulv mot grunn og mot det fri [W/m²K]	0,07	0,18
U-verdi glass/vinduer/dører [W/m²K]	0,7	1,2
Lekkasjetall (lufttetthet ved 50 Pa trykkforskjell) [luftvekslinger pr time]	0,3	1,5

Energiforsyning (§14-4 (1))	
Beskrivelse	Verdi
Bruker fossilt brensel til oppvarming	Nei

Krav til formålsdelte energimålere (§14-2 (6))
Yrkesbygninger skal ha formålsdelte energimålere for oppvarming og tappevann.
Dette er ikke en del av evaluering i SIMIEN og må derfor dokumenteres på annen måte.

SIMIEN

Evaluering passivhus

Simuleringsnavn: Passivhusevaluering
Tid/dato simulering: 14:20 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building;

Resultater av evalueringen	
Evaluering mot NS 3701	Beskrivelse
Varmetapsramme	Bygningen tilfredsstiller kravet for varmetapstall
Energiytelse	Bygningen tilfredsstiller krav til energiytelse
Minstekrav	Bygningen tilfredsstiller minstekrav til enkeltkomponenter
Luftmengder ventilasjon	Luftmengdene tilfredsstiller minstekrav gitt i NS3701 (tabell A.2)
Samlet evaluering	Bygningen tilfredsstiller alle krav til passivhus

Varmetapsbudsjett	
Beskrivelse	Verdi
Varmetapstall yttervegger	0,03
Varmetapstall tak	0,02
Varmetapstall gulv på grunn/mot det fri	0,02
Varmetapstall glass/vinduer/dører	0,13
Varmetapstall kuldebroer	0,03
Varmetapstall infiltrasjon	0,03
Totalt varmetapstall	0,25
Krav varmetapstall	0,40

SIMIEN

Evaluering passivhus

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Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building;

Energiytelse		
Beskrivelse	Verdi	Krav
Netto oppvarmingsbehov	12,3 kWh/m^2	24,3 kWh/m^2
Netto kjølebehov	2,4 kWh/m^2	6,6 kWh/m^2
Gjennomsnittlig effektbehov belysning	4,5 W/m^2	4,5 W/m^2

Minstekrav enkeltkomponenter		
Beskrivelse	Verdi	Krav
U-verdi glass/vinduer/dører [W/m^2K]	0,72	0,80
Normalisert kuldebroverdi [W/m^2K]	0,03	0,03
Årsmidlere temperaturvirkningsgrad varmegjenvinner ventilasjon [%]	85	80
Spesifikk vifteeffekt (SFP) [kW/m^3/s]:	1,50	1,50
Lekkasjetall (lufttetthet ved 50 Pa trykkforskjell) [luftvekslinger pr time]	0,30	0,60

Passivhusstandarden og byggeforskrifter
Passivstandardene refererer flere steder til at bygningen også må overholde krav i byggeforskriftene (TEK).
Ved evaluering mot byggeforskrifter benyttes det til dels andre normerte data og forutsetnnger.
Krav til byggeforskrifer må derfor dokumenteres ved å kjøre en separat evaluering mot aktuelle byggeforskrifter.

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 14:18 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	83897 kWh	6,7 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	69243 kWh	5,5 kWh/m²
2 Varmtvann (tappevann)	62640 kWh	5,0 kWh/m²
3a Vifter	189172 kWh	15,1 kWh/m²
3b Pumper	18062 kWh	1,4 kWh/m²
4 Belysning	176189 kWh	14,1 kWh/m²
5 Teknisk utstyr	195770 kWh	15,7 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	29577 kWh	2,4 kWh/m²
Totalt netto energibehov, sum 1-6	824550 kWh	66,0 kWh/m²

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Resultater årssimulering

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Prosjekt: KAMD
Sone: New Building

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	603480 kWh	48,3 kWh/m²
1b El. til varmepumpesystem	68330 kWh	5,5 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-287118 kWh	-23,0 kWh/m²
Totalt levert energi, sum 1-7	384692 kWh	30,8 kWh/m²
Solstrøm til eksport	-231034 kWh	-18,5 kWh/m²
Netto levert energi	153659 kWh	12,3 kWh/m²

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Resultater årssimulering

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Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	0,3 kWh/m²	0,3 kWh/m²	0,3 kWh/m²	2,4 kWh/m²	0,0 kWh/m²	46,3 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	6,4 kWh/m²	5,3 kWh/m²	4,8 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	6,7 kWh/m²	5,5 kWh/m²	5,0 kWh/m²	2,4 kWh/m²	0,0 kWh/m²	46,3 kWh/m²

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Resultater årssimulering

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Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Årlige utslipp av CO2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	78452 kg	6,3 kg/m²
1b El. til varmepumpesystem	8883 kg	0,7 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-37325 kg	-3,0 kg/m²
Totalt utslipp, sum 1-7	50010 kg	4,0 kg/m²
Solstrøm til eksport	-30034 kg	-2,4 kg/m²
Netto CO2-utslipp	19976 kg	1,6 kg/m²

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Resultater årssimulering

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Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	603480 kr	48,3 kr/m²
1b El. til varmepumpesystem	68330 kr	5,5 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-287118 kr	-23,0 kr/m²
Årlige energikostnader, sum 1-7	384692 kr	30,8 kr/m²
Solstrøm til eksport	-103965 kr	-8,3 kr/m²
Netto energikostnad	280727 kr	22,5 kr/m²

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Resultater årssimulering

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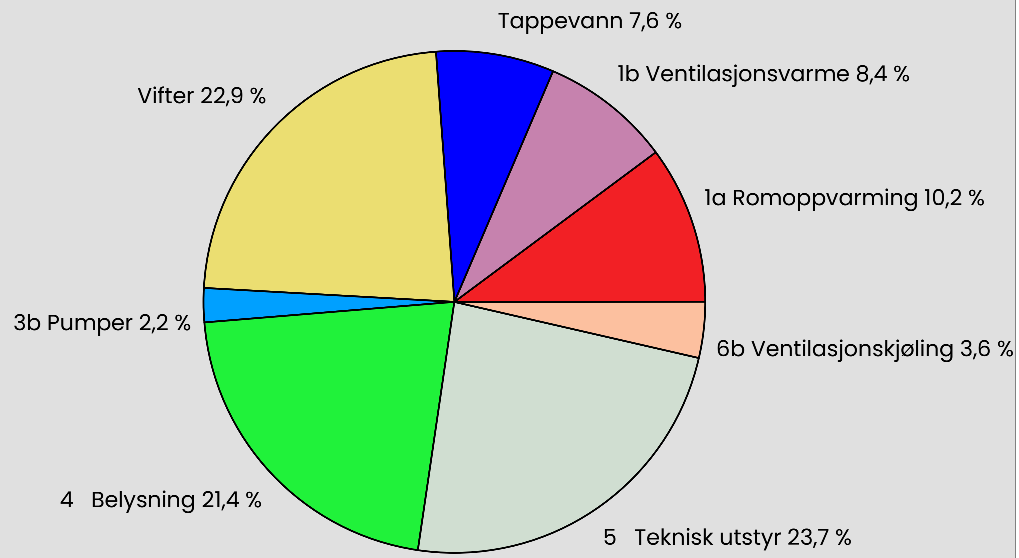
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Årlig energibudsjett



1a Romoppvarming	83897 kWh
1b Ventilasjonsvarme (varmebatterier)	69243 kWh
2 Varmtvann (tappevann)	62640 kWh
3a Vifter	189172 kWh
3b Pumper	18062 kWh
4 Belysning	176189 kWh
5 Teknisk utstyr	195770 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	29577 kWh
Totalt netto energibehov, sum 1-6	824550 kWh

SIMIEN

Resultater årssimulering

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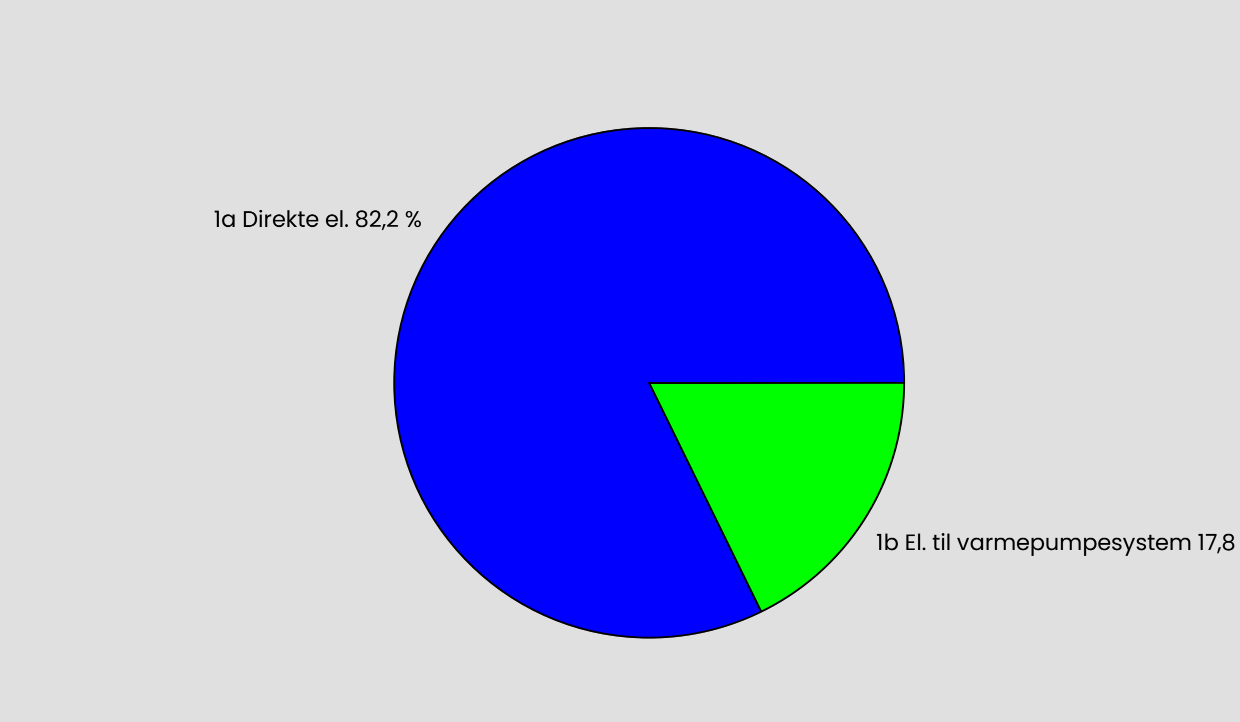
Prosjekt: KAMD
Sone: New Building

Levert energi til bygningen (beregnet)



1a Direkte el.	316362
1b El. til varmepumpesystem	68330
1c El. til solfangersystem	0
2 Olje	0
3 Gass	0
4 Fjernvarme	0
5 Biobrensel	0
6. Annen energikilde	0
Totalt levert energi, sum 1-7	384692

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
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Programversjon: 6.017
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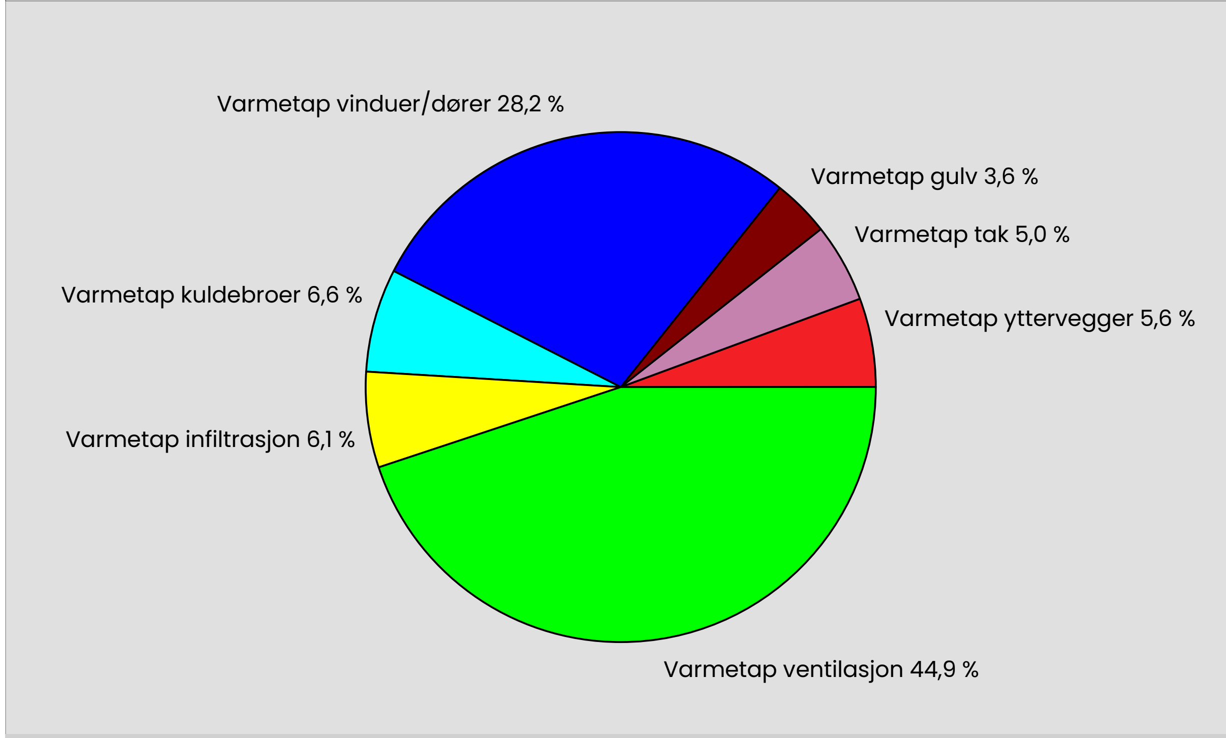
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,03 W/m²K
Varmetapstall tak	0,02 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,02 W/m²K
Varmetapstall glass/vinduer/dører	0,13 W/m²K
Varmetapstall kuldebroer	0,03 W/m²K
Varmetapstall infiltrasjon	0,03 W/m²K
Varmetapstall ventilasjon	0,21 W/m²K
Totalt varmetapstall	0,46 W/m²K

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Resultater årssimulering

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Programversjon: 6.017
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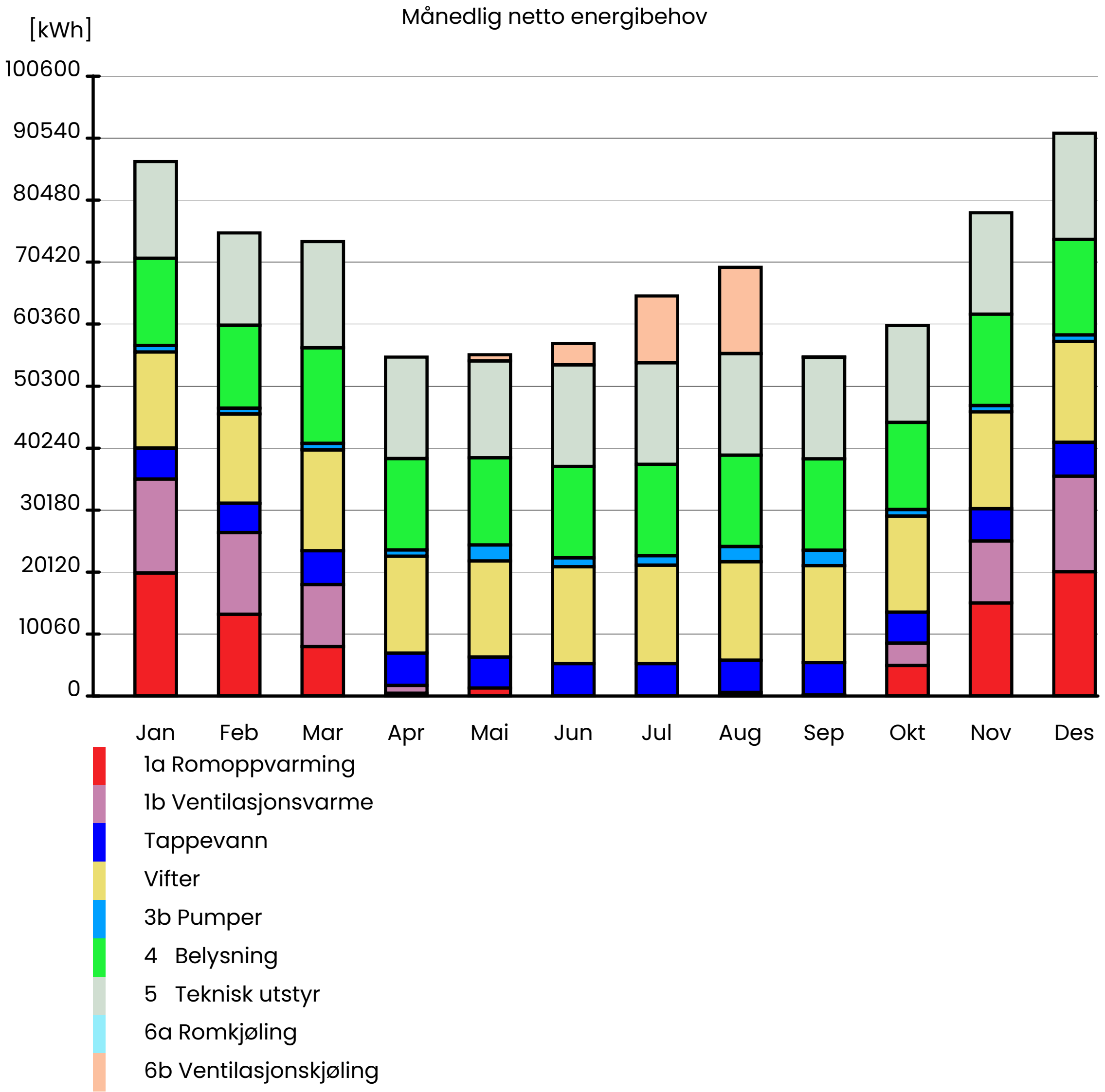
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building



SIMIEN

Resultater årssimulering

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Tid/dato simulering: 14:18 26/5-2022
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Simuleringsansvarlig: Sebastian Ulloa-Thompson
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Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
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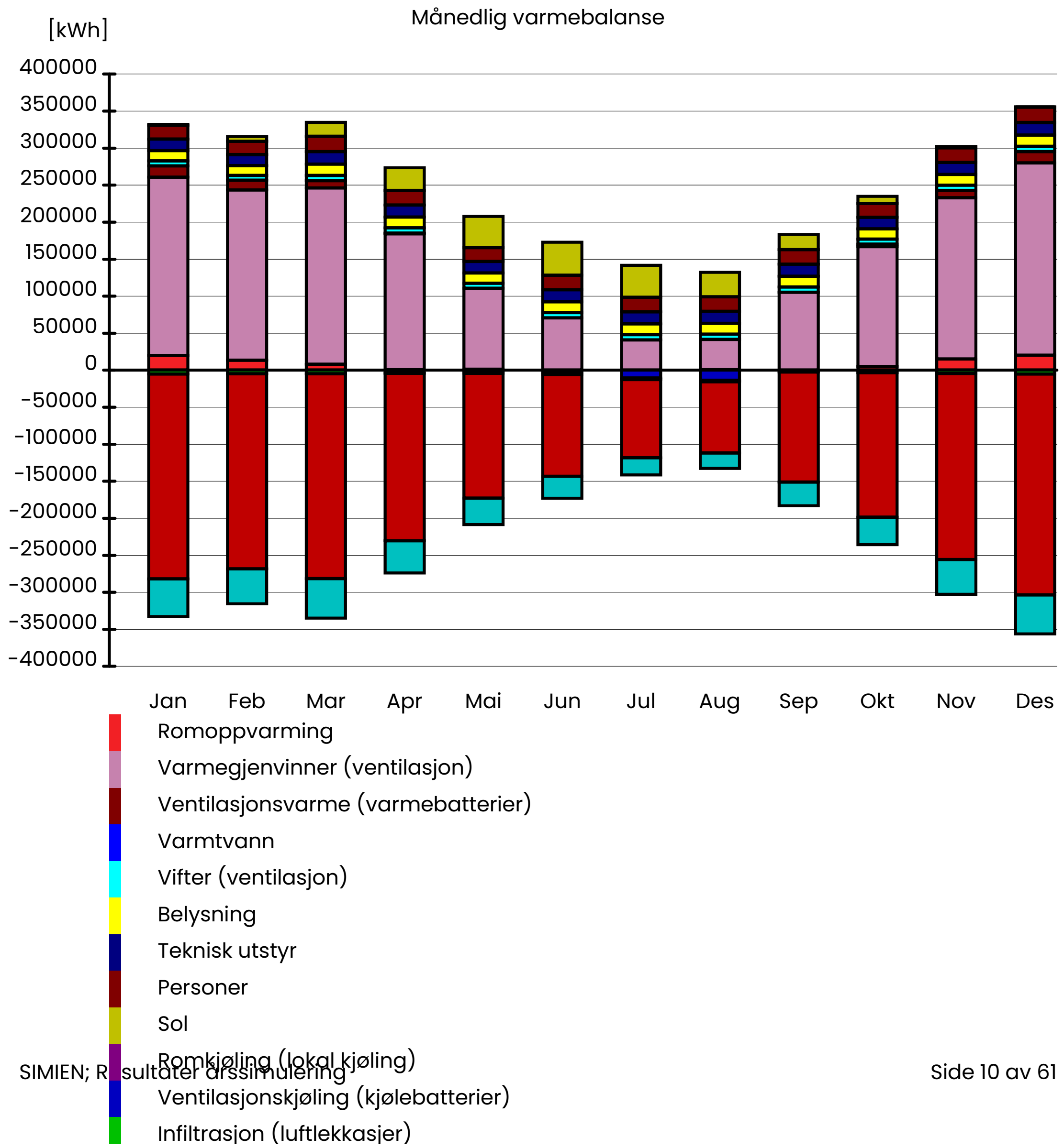

Ventilasjon
Transmisjon (bygningskropp)

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Resultater årssimulering

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Tid/dato simulering: 14:18 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Månedlige temperaturdata (lufttemperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-1,2 °C	8,5 °C	-19,5 °C	20,1 °C	21,6 °C	19,0 °C
Februar	-1,7 °C	9,0 °C	-16,7 °C	20,3 °C	22,0 °C	19,0 °C
Mars	-0,2 °C	10,7 °C	-12,0 °C	20,7 °C	23,2 °C	19,0 °C
April	3,8 °C	14,2 °C	-5,6 °C	21,9 °C	23,8 °C	19,4 °C
Mai	7,4 °C	20,1 °C	-2,4 °C	21,4 °C	23,8 °C	19,2 °C
Juni	11,1 °C	22,7 °C	1,2 °C	22,2 °C	24,7 °C	20,5 °C
Juli	13,8 °C	23,6 °C	4,8 °C	22,5 °C	23,9 °C	21,0 °C
August	13,7 °C	25,0 °C	3,5 °C	21,9 °C	24,0 °C	19,5 °C
September	10,1 °C	20,8 °C	0,6 °C	22,2 °C	23,8 °C	19,9 °C
Oktober	5,2 °C	15,5 °C	-3,3 °C	20,9 °C	23,0 °C	19,0 °C
November	1,0 °C	10,7 °C	-11,1 °C	20,4 °C	22,0 °C	19,0 °C
Desember	-1,9 °C	9,6 °C	-17,6 °C	20,3 °C	21,7 °C	19,0 °C

SIMIEN

Resultater årssimulering

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Prosjekt: KAMD
Sone: New Building

Månedlige temperaturdata (operativ temperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-1,2 °C	8,5 °C	-19,5 °C	20,3 °C	21,8 °C	19,0 °C
Februar	-1,7 °C	9,0 °C	-16,7 °C	20,4 °C	22,0 °C	19,1 °C
Mars	-0,2 °C	10,7 °C	-12,0 °C	20,9 °C	23,3 °C	19,1 °C
April	3,8 °C	14,2 °C	-5,6 °C	22,1 °C	24,0 °C	19,6 °C
Mai	7,4 °C	20,1 °C	-2,4 °C	21,7 °C	23,8 °C	19,5 °C
Juni	11,1 °C	22,7 °C	1,2 °C	22,5 °C	24,7 °C	20,7 °C
Juli	13,8 °C	23,6 °C	4,8 °C	22,7 °C	24,1 °C	21,4 °C
August	13,7 °C	25,0 °C	3,5 °C	22,1 °C	24,3 °C	19,7 °C
September	10,1 °C	20,8 °C	0,6 °C	22,3 °C	24,0 °C	20,1 °C
Oktober	5,2 °C	15,5 °C	-3,3 °C	21,0 °C	23,1 °C	19,0 °C
November	1,0 °C	10,7 °C	-11,1 °C	20,5 °C	22,1 °C	19,0 °C
Desember	-1,9 °C	9,6 °C	-17,6 °C	20,4 °C	21,8 °C	19,0 °C

SIMIEN

Resultater årssimulering

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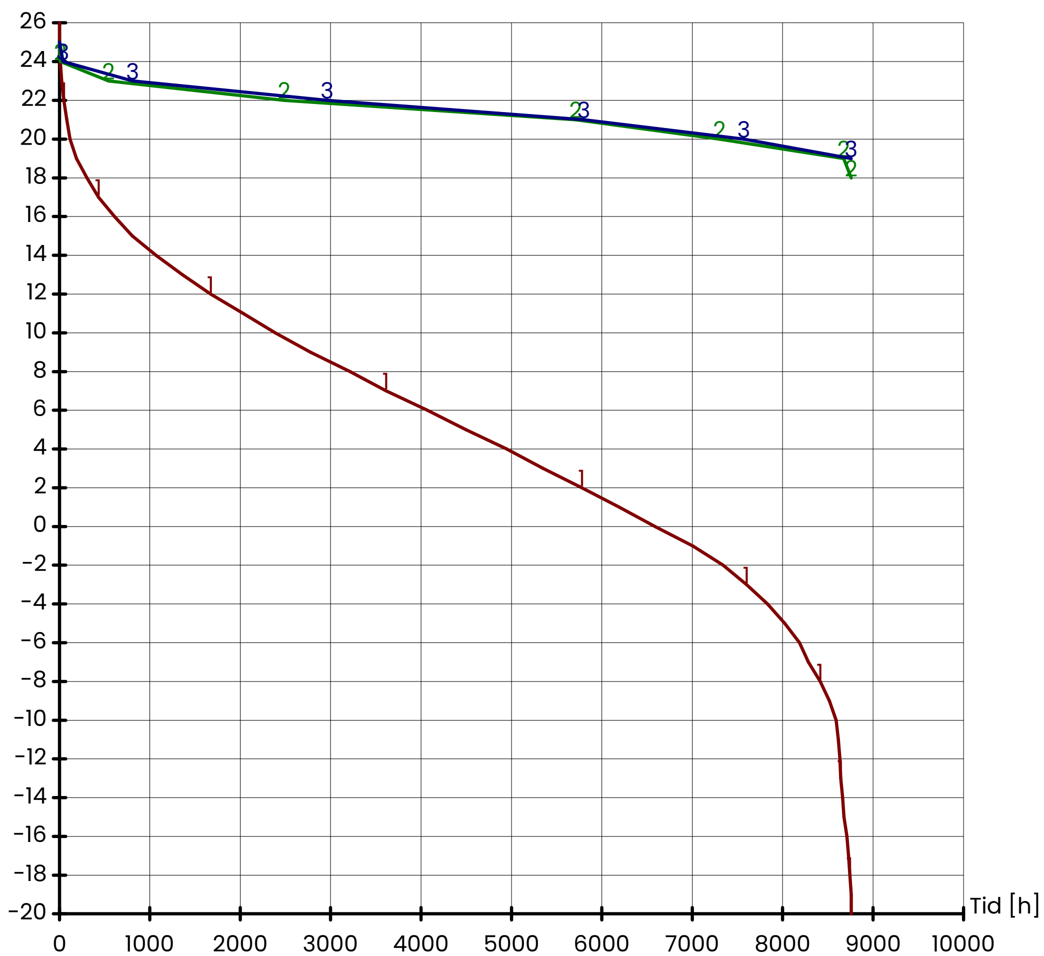

1 Varighet utetemperatur
2 Varighet lufttemperatur
3 Varighet operativ temperatur

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Resultater årssimulering

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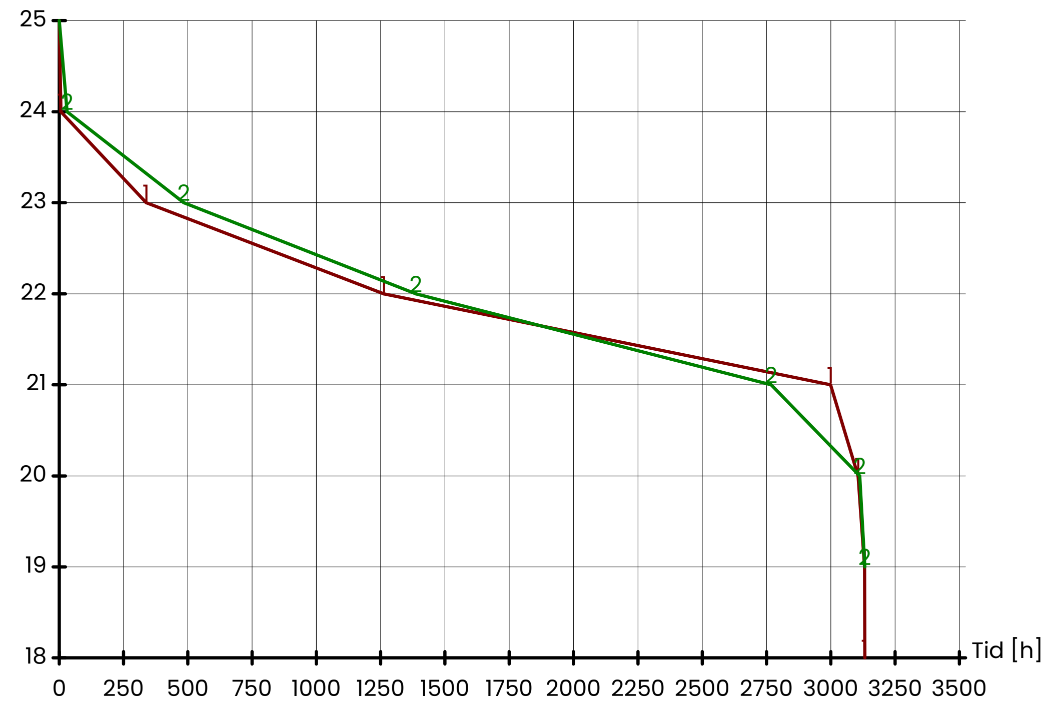

1 Varighet lufttemperatur (i arbeidstiden)
2 Varighet operativ temperatur (i arbeidstiden)

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Resultater årssimulering

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Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	0

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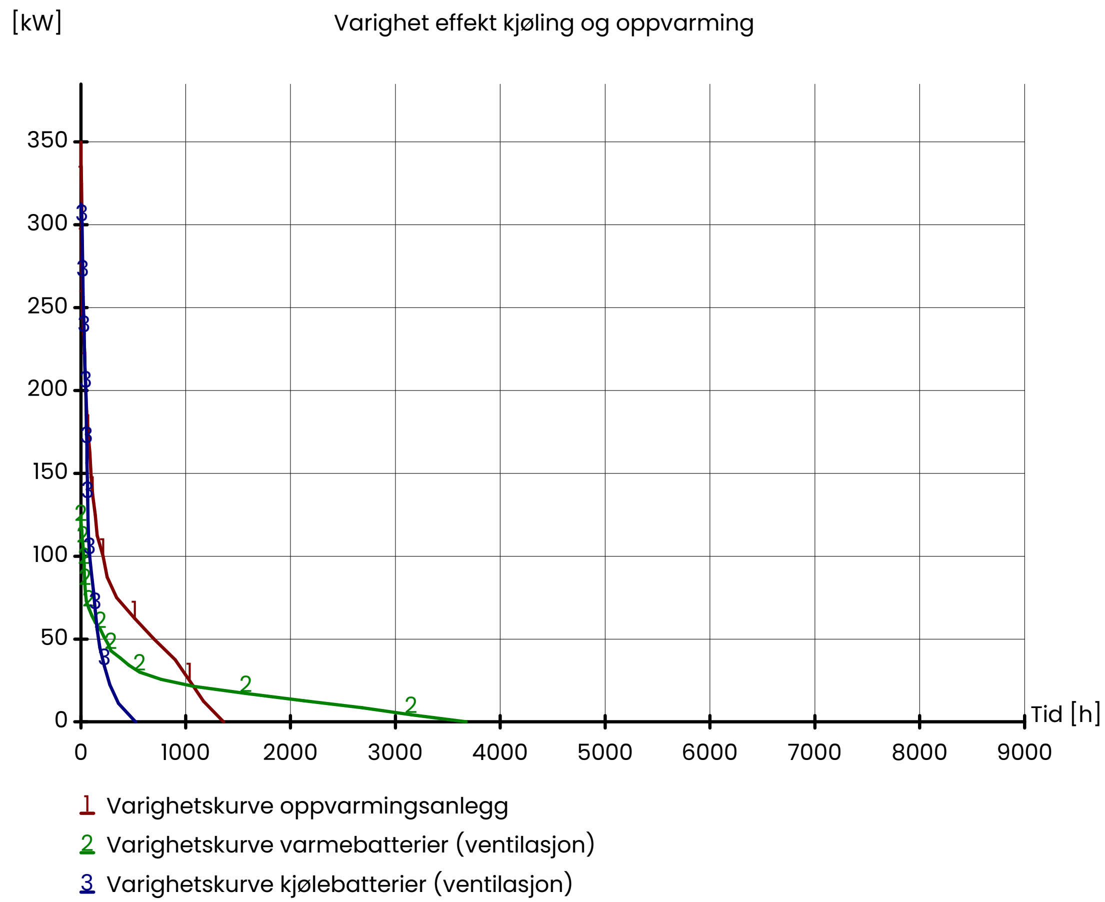

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Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
391 kW (90 %)	100 %
347 kW (80 %)	100 %
304 kW (70 %)	99 %
260 kW (60 %)	98 %
217 kW (50 %)	97 %
174 kW (40 %)	94 %
130 kW (30 %)	89 %
87 kW (20 %)	78 %
43 kW (10 %)	55 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

SIMIEN

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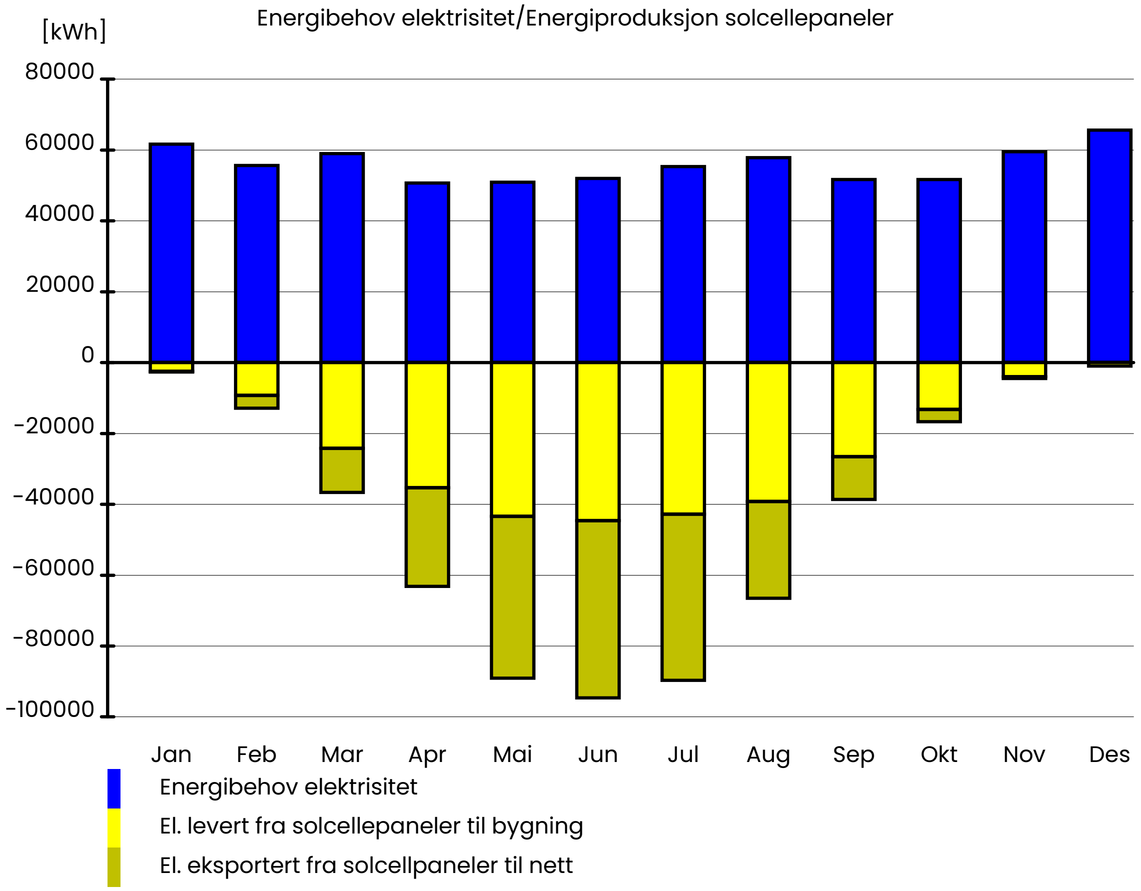

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Sone: New Building

Energiproduksjon solceller [kWh]											
Panel	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov
Produsert PV_Mainroof2	1693	6411	19186	34125	49318	52732	49738	36399	20791	8751	2313
Produsert PV_Mainroof3	581	2198	6578	11700	16909	18079	17053	12480	7128	3000	793
Produsert PV_Facade_overhang	68	299	667	1014	1239	1254	1238	1000	632	310	100
Produsert PV_Facade_vertical 1	171	764	1309	1547	1442	1333	1385	1289	1010	631	257
Produsert PV_Facade_vertical 2	70	313	535	633	590	545	567	527	413	258	105
Produsert PV_Facade_Existing	151	677	1393	2002	2296	2275	2283	1908	1258	654	225
Produsert PV_Facade_Existing 2	109	481	1074	1633	1994	2018	1992	1609	1018	499	160
Produsert PV_Extensionroof2	0	1961	6030	10725	15500	16573	15632	11440	6534	2750	727
Sum produsert	2842	13105	36772	63380	89288	94810	89887	66651	38785	16855	4680
Levert til bygning	2568	9370	24258	35431	43494	44694	42896	39271	26636	13319	4091
Eksportert til nett	275	3734	12514	27948	45793	50116	46991	27379	12150	3536	589

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 14:18 26/5-2022
Programversjon: 6.017
Simuleringsansvarlig: Sebastian Ulloa-Thompson
Firma: Student
Inndatafil: C:\Users\Seb\Documents\NTNU\KAMD\Energy Analysis\kamd new+mg.smi
Prosjekt: KAMD
Sone: New Building

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	2620	
Areal tak [m²]:	2856	
Areal gulv [m²]:	2884	
Areal vinduer og ytterdører [m²]:	2237	
Oppvarmet bruksareal (BRA) [m²]:	12500	
Oppvarmet luftvolum [m³]:	50000	
U-verdi yttervegger [W/m²K]	0,12	
U-verdi tak [W/m²K]	0,10	
U-verdi gulv [W/m²K]	0,07	
U-verdi vinduer og ytterdører [W/m²K]	0,72	
Areal vinduer og dører delt på bruksareal [%]	17,9	
Normalisert kuldebroverdi [W/m²K]:	0,03	
Normalisert varmekapasitet [Wh/m²K]	63	
Lekkasjetall (n50) [1/h]:	0,30	
Temperaturvirkningsgr. varmegjenvinner [%]:	85	

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Dokumentasjon av sentrale inndata (2)		
Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	85,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	8,00	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,69	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,40	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	25	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

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Dokumentasjon av sentrale inndata (3)		
Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	4,50	
Varmetilskudd belysning i driftstiden [W/m²]	4,50	
Effektbehov utstyr i driftstiden [W/m²]	5,00	
Varmetilskudd utstyr i driftstiden [W/m²]	5,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,80	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	6,00	
Total solfaktor for vindu og solskjerming:	0,27	
Gjennomsnittlig karmfaktor vinduer:	0,20	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	0,83/0,88/0,95/0,89	

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Universitets- og høgskolebygg
Simuleringsansvarlig	Sebastian Ulloa-Thompson
Kommentar	

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Inndata klima	
Beskrivelse	Verdi
Klimasted	Trondheim
Breddegrad	63° 30'
Lengdegrad	10° 22'
Tidssone	GMT + 1
Årsmiddeltemperatur	5,1 °C
Midlere solstråling horisontal flate	102 W/m²
Midlere vindhastighet	4,6 m/s

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Inndata energiforsyning	
Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,86 Systemvirkningsgrad varmtvann: 0,98 Systemvirkningsgrad varmebatterier: 0,89 Kjølefaktor romkjøling: 2,40 Kjølefaktor kjølebatterier: 2,40 Energipris: 1,00 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 5,0% Andel oppv, tappevann: 5,0% Andel varmebatteri: 5,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 3,00 Systemvirkningsgrad varmtvann: 3,00 Systemvirkningsgrad varmebatterier: 3,00 Kjølefaktor romkjøling: 2,40 Kjølefaktor kjølebatterier: 2,40 Energipris: 1,00 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 95,0% Andel oppv, tappevann: 95,0% Andel varmebatteri: 95,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier	
Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

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Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	12500,0 m²
Oppvarmet luftvolum	50000,0 m³
Normalisert kuldebroverdi	0,03 W/(m²K)
Varmekapasitet møbler/interiør	4,0 Wh/m² (Middels møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,30 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	22
Driftsdager i Juli	22
Driftsdager i August	22
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	23

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Inndata belysning	
Beskrivelse	Verdi
Navn:	Internal_Gains (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 4,5 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)	
Beskrivelse	Verdi
Navn:	Internal_Gains (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 5,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata oppvarming av tappevann	
Beskrivelse	Verdi
Navn:	Internal_Gains (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 0,8 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 0,0 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

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Inndata varmetilskudd personer (internlast)	
Beskrivelse	Verdi
Navn:	Internal_Gains (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 6,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 12:00

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Inndata CAV	
Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 8.0 m³/hm², avtrekk = 8.0 m³/hm² Utenfor driftstiden: tilluft = 2.0 m³/hm², avtrekk = 2.0 m³/hm² Helg/feridag: tilluft = 2.0 m³/hm², avtrekk = 2.0 m³/hm²
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 17.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	 Maks. kapasitet: 25 W/m²
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.85
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 kW/m³/s

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SIMIEN

Resultater årssimulering

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Inndata oppvarming	
Beskrivelse	Verdi
Navn:	Heating_Groundsource_HP (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	45,0 °C
Returtemperatur	35,0 °C
Spesifikk pumpeeffekt	0,50 kW/(l/s)

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Main > NS3720 Project KAMD > KAMD > Carbon footprint, NS 3720

KAMD - Carbon footprint, NS 3720

Project basic information

Result report: KAMD

Project	NS3720 Project KAMD - KAMD
User	Sebastian Ulloa-Thompson - 22.05.2022
Tool	Carbon footprint, NS 3720
Details	Building life-cycle assessment according to the Norwegian standard NS 3720 Metode for klimagassberegninger for bygninger. This LCA software covers life cycle stages from cradle to grave with separate reporting to product stage, construction process, use stage, operational energy, and end of life.
General information	
Type	Educational buildings
Country	Norway
Address	Klostergata 9, 7030 Trondheim
Gross Floor Area (m²)	12500
Number of above ground floors	5
Frame type	timber
Certifications pursued	BREEAM NOR 2016

Commercial usage is forbidden. For Norway: Trial for NS3720 (14 days), TRIAL, Sebastian Ulloa-Thompson 22.05.2022 01:13

1 786 Tons CO_2e **89 315 € Social cost of carbon**

Carbon Heroes Benchmark

Results

Greenhouse gas emissions according to NS 3720:2018 - main scenario

Download Results Summary

Main scenario always uses Norwegian 60 year degressive energy and transport mixes. Alternative scenarios are shown separately below

	Result category	Global warming kg CO_2e	Biogenic carbon storage kg CO_2e bio	Global Warming Potential, LULUC kg CO_2e	
A1-A3	Construction Materials	858 053	2 613 924	156	Details
A4	Transportation to site	20 941		0	Details
A5	Construction/installation process	194 955		19	Details
B1	Use Phase	−886		0	Details
B3	Repair	0		0	Details
B4-B5	Material replacement and refurbishment	138 283		0	Help

	Result category	Global warming kg CO_2e	Biogenic carbon storage kg CO_2e bio	Global Warming Potential, LULUC kg CO_2e	
B6	Energy use	325 311		63	Details
B8	Operational transport	TRIAL	TRIAL	TRIAL	Hide empty
C1-C4	End of life	249 642		0	Details
D	External impacts (not included in totals)	−2 161 950		−77	Details
	Total	**1 786 299**	**2 613 924**	**238**	
	Results per denominator				
	Per year	29 772	43 565	4	
	Per m2 BTA	143	209	0	
	Per m2 BTA per year	2	3	0	
	Per user per year				

Biogenic carbon storage is only shown as separate information. Please note that all manufacturers do not yet supply this information, so comparisons based on this data may be misleading. Climate impacts from land use and land use changes (LULUC) are shown separately.

Alternative energy and transport scenarios (optional)

Use EU28+NO degressive energy mix and alternative transport scenarios, if relevant.

	Result category	Global warming kg CO_2e	
B6-scenario	Energy use - scenario		Hide empty
B8-scenario	Operational transport - scenario	0	Details

Project description

Building area

	Answer	Quantity	Comment
Building area	Bruttoareal (BTA), Norway	12500	

− Bill of materials

Answer	Quantity	Unit	Comment	Bygningsdel	Wastage	EPD
Glued laminated timber (Glulam)	65	m3		22	16.7 %	No
Dry mortar, for facade render	3200	m2		29	13 %	No
Cross-laminated timber (CLT)	250	m3		23	16.7 %	No
Rock wool insulation	652	m3		23	8 %	No
Gypsum plaster board, regular, generic	2500	m2		23	12.5 %	No
Sawn/dried construction wood, from pine and spruce	2000	m3		23	17.9 %	No
Glued laminated timber (Glulam) studs and columns	20	m3		23	16.7 %	No
Spruce construction timber	21	m3		23	17.9 %	No
Insulated glazing, triple pane	2270	m2		233	0.0 %	No
Footing foundations for hard soils (sand, gravel, silt or clay) per GFA	460	m2		216		No
Ready-mix concrete, normal-strength, generic	22265	kg		23	4 %	No
Reinforcement steel (rebar), generic	1449	kg		216	4.85 %	No
Reinforcement steel (rebar), generic	7920	kg	30 kg/m3	21	4.85 %	No
Prefabricated foundation piling	270	m3		222	0.0 %	No
Concrete ground floor slab, for apartment building, EPS	2200	m2		21		No
Ready-mix concrete, normal-strength, generic	2200	m2		23	Help	

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Filter fabric N2	2200	m2		21	10 %	No
Insulation, EPS 100	2200	m2		21	4 %	No
Macadam (8…16 mm), wet bulk density	2200	m2		21	0.0 %	No
Precast concrete wall elements (solid, uninsulated), generic	750	m2		21	0.0 %	No
Waterproofing roof membrane	760	m2		21	10 %	No
Rock wool insulation	1500	m2		21	8 %	No
Cross-laminated timber (CLT)	564	m3		25	16.7 %	No
Multi layer waterproofing system with flexible sheets for roofing, fully torched, European average	3200	m2		26	10 %	No
Glued laminated timber (Glulam)	160	m3		25	16.7 %	No
Aluminium frame glass façade system, enamelled double glazing	378	m2		233	0.0 %	No
Lightweight bituminous underlays for roof waterproofing, category B	3200	m2		25	10 %	No
Rock wool insulation	483	m3		25	8 %	No
Rock wool insulation	7500	m2		25	8 %	No
Gypsum plasterboard	3200	m2		25	12.5 %	No
Raised access flooring system, linoleum	5000	m2		253	5 %	No
Self-leveling screed, fiber-reinforced	543569	kg		25	13 %	No
Gypsum plaster board, regular, generic	158	m3		24	12.5 %	No
Cross-laminated timber (CLT)	350	m3		24	16.7 %	No
Rock wool insulation	6000	m2		24	8 %	No
Concrete assembly for stairs per one metre height	40	m		28		No
Ready-mix concrete, normal-strength, generic	24	m3	Flights of stairs 1200 mm wide, with rise of 200 mm and going of 300 mm. Supporting structure (assumed share 25 %) and turning landing (assumed share 33 %) included.	28	4 %	No
Reinforcement steel (rebar), generic	2394	kg	Reinforcement for staircase 100 kg/m3	28	4.85 %	No
Wooden interior door, per unit	89	unit		234	0.0 %	No

Completeness (100%) and plausibility checker (grade: A)

All required and recommended elements are present in the design for scope: Greenhouse gas inventory, basis - NS 3720 (FutureBuilt) ×

LCA Checker overall grade: A. Grade is based on data you have provided. ×

LCA Checker overall grade: A

LCA Checker checks the embodied impacts plausibility. These results reflect plausibility for 12500.0 m^2 project of type new construction, whole building with frame type timber frame with scope consisting of foundations and substructure, structure and enclosure, finishings and other materials, services. To edit these parameters open LCA Parameters query. The result is intended as indicative of the plausibility; and exceptions may occur.

No.	Check description	Project value	Threshold value	Typical value	Unit	Type	Validated ?
1	**Services mass credible:** Has no materials	0.0	greater than 2		kg/m^2	×	
2	**Embodied carbon credible:** Value seems unusual but is within allowable deviation range	98.285	150 - 1000		kg CO_2e/m^2	⚠	
3	**Horizontal materials mass:** Value seems unusual but is within allowable deviation range	90.672	100 - 1300		kg/m^2	⚠	
4	**Embodied carbon credible (timber frame):** Value seems unusual but is within allowable deviation range	68.644	80 - 350		kg CO_2e/m^2	⚠	
Validated checks							
5	**Foundation mass credible**	190.978	greater than 100		kg/m^2	✔	

Help

https://oneclicklcaapp.com/app/sec/design/results?childEntityId=627cf49037b1b6663df2191d&indicatorId=BuildingLifecycleAssessmentNS3720… 3/14

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No.	Check description	Project value	Threshold value	Typical value	Unit	Type	Validated ?
6	**Structure mass credible**	208.063	greater than 150		kg/m^2	✔	
7	**Finishes mass credible**	10.349	greater than 10		kg/m^2	✔	
8	**Project mass credible**	438.162	300 - 3500		kg/m^2	✔	
9	**Ready mix and reinforcement ratio**	1.649	1 - 7		%	✔	
10	**Replacements share credible**	11.645	10 - 100		%	✔	
11	**Too few materials to be credible**	29	greater than 20		nr.	✔	
12	**Too dominant single material**	13.973	less than 50		%	✔	
13	**Project mass credible (timber frame)**	218.413	200 - 1000		kg/m^2	✔	
14	**Insulation mass credible**	8.349	1 - 21		kg/m^2	✔	
15	**Gypsum board and plaster mass credible (no cement)**	63.9	0.0 - 80		kg/m^2	✔	
16	**Glass and openings mass credible**	7.304	2 - 25		kg/m^2	✔	
17	**Vertical materials mass**	117.392	50 - 700		kg/m^2	✔	
18	**Wood mass credible (wood frame)**	121.186	35 - 220		kg/m^2	✔	
19	**Gypsum board mass credible**	15.295	3 - 40		kg/m^2	✔	
20	**Mortar mass credible**	5.12	0.4 - 50		kg/m^2	✔	
21	**Glass mass credible**	6.875	1 - 13		kg/m^2	✔	
22	**Brick mass credible**	0.0	0.0 - 100		kg/m^2	✔	
23	**Roofing bitumen mass credible**	2.662	0.5 - 4		kg/m^2	✔	

Most contributing materials (Global warming)

Compare data

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives	
1.	Prefabricated foundation piling ?	120 tons CO_2e	14.0 %	Show sustainable alternatives	Add to compare
2.	Rock wool insulation ?	110 tons CO_2e	12.8 %	Show sustainable alternatives	Add to compare
3.	Insulated glazing, triple pane ?	108 tons CO_2e	12.5 %	Show sustainable alternatives	Add to compare
4.	Cross-laminated timber (CLT) ?	105 tons CO_2e	12.2 %	Show sustainable alternatives	Add to compare
5.	Self-leveling screed, fiber-reinforced ?	74 tons CO_2e	8.7 %	Show sustainable alternatives	Add to compare
6.	Sawn/dried construction wood, from pine and spruce ?	71 tons CO_2e	8.3 %	Show sustainable alternatives	Add to compare
7.	Ready-mix concrete, normal-strength, generic ?	67 tons CO_2e	7.8 %	Show sustainable alternatives	Add to compare
8.	Raised access flooring system, linoleum ?	44 tons CO_2e	5.1 %	Show sustainable alternatives	Add to compare
9.	Aluminium frame glass façade system, enamelled double glazing ?	37 tons CO_2e	4.3 %	Show sustainable alternatives	Add to compare
10.	Gypsum plaster board, regular, generic ?	31 tons CO_2e	3.6 %	Show sustainable alternatives	Add to compare
11.	Precast concrete wall elements (solid, uninsulated), generic ?	16 tons CO_2e	1.9 %	Show sustainable alternatives	Add to compare
12.	Glued laminated timber (Glulam) ?	16 tons CO_2e	1.9 %	Show sustainable alternatives	Add to

Help

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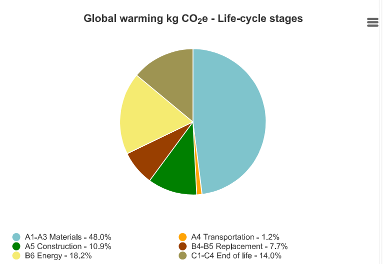
No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives	
13.	Dry mortar, for facade render ?	9,9 tons CO_2e	1.2 %	Show sustainable alternatives	Add to compare
14.	Ready-mix concrete, normal-strength, generic ?	7,7 tons CO_2e	0.9 %	Show sustainable alternatives	Add to compare
15.	Reinforcement steel (rebar), generic ?	7,3 tons CO_2e	0.9 %	Show sustainable alternatives	Add to compare
16.	Gypsum plaster board, regular, generic ?	6,9 tons CO_2e	0.8 %	Show sustainable alternatives	Add to compare
17.	Gypsum plasterboard ?	5,4 tons CO_2e	0.6 %	Show sustainable alternatives	Add to compare
18.	Wooden interior door, per unit ?	5 tons CO_2e	0.6 %	Show sustainable alternatives	Add to compare
19.	Insulation, EPS 100 ?	3,4 tons CO_2e	0.4 %	Show sustainable alternatives	Add to compare
20.	Macadam (8…16 mm), wet bulk density ?	3,9 tons CO_2e	0.4 %	Show sustainable alternatives	Add to compare
21.	Lightweight bituminous underlays for roof waterproofing, category B ?	3,2 tons CO_2e	0.4 %	Show sustainable alternatives	Add to compare
22.	Waterproofing roof membrane ?	2,9 tons CO_2e	0.3 %	Show sustainable alternatives	Add to compare
23.	Glued laminated timber (Glulam) studs and columns ?	2,2 tons CO_2e	0.3 %	Show sustainable alternatives	Add to compare
24.	Spruce construction timber ?	1,2 tons CO_2e	0.1 %	Show sustainable alternatives	Add to compare
25.	Footing foundations for hard soils (sand, gravel, silt or clay) per GFA ?	kg CO_2e	0.0 %	Show sustainable alternatives ⚠	

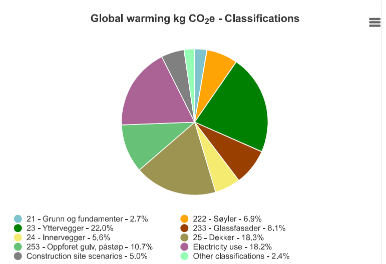
Graphs

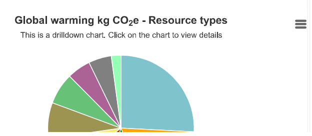
Overview Bubble Sankey Treemap Life-cycle stages Annual Stages - stacked Materials - stacked Classifications **All graphs**

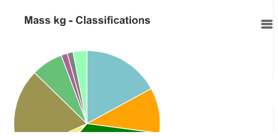
Life-cycle overview of Global warming

Pie Bar Column Treemap









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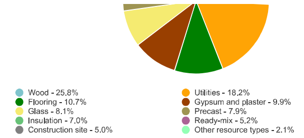
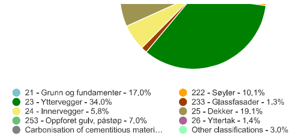




Show data table: ☐Global warming kg CO_2e - Life-cycle stages ☐Global warming kg CO_2e - Classifications ☐Global warming kg CO_2e - Resource types ☐Mass kg - Classifications

Global warming kg CO_2e - Life-cycle stages

Item	Value	Unit	Percentage %
A1-A3 Materials	860 000	kg CO_2e	48.04 %
A4 Transportation	21 000	kg CO_2e	1.17 %
A5 Construction	190 000	kg CO_2e	10.91 %
B1 Use Phase	-890	kg CO_2e	-0.05 %
B4-B5 Replacement	140 000	kg CO_2e	7.74 %
B6 Energy	330 000	kg CO_2e	18.21 %
C1-C4 End of life	250 000	kg CO_2e	13.98 %

Global warming kg CO_2e - Classifications

Item	Value	Unit	Percentage %
21 - Grunn og fundamenter	48 000	kg CO_2e	2.69 %
222 - Søyler	120 000	kg CO_2e	6.91 %
23 - Yttervegger	390 000	kg CO_2e	22.04 %
233 - Glassfasader	140 000	kg CO_2e	8.11 %
24 - Innervegger	100 000	kg CO_2e	5.65 %
25 - Dekker	330 000	kg CO_2e	18.27 %
253 - Oppforet gulv, påstøp	190 000	kg CO_2e	10.73 %
Electricity use	330 000	kg CO_2e	18.21 %
Construction site scenarios	90 000	kg CO_2e	5.04 %
Other classifications	42 000	kg CO_2e	2.36 %

Global warming kg CO_2e - Resource types

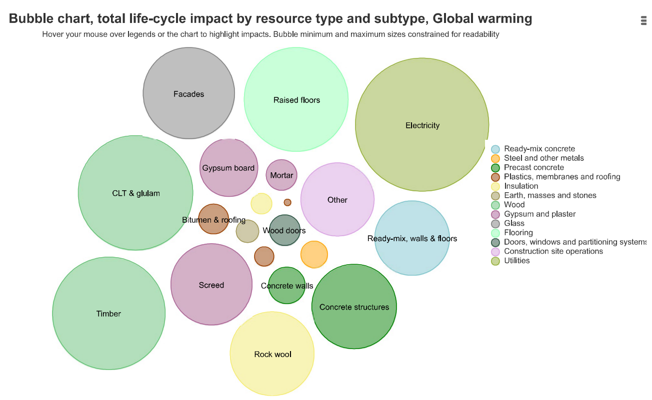
Item	Value	Unit	Percentage %
Wood	460 000	kg CO_2e	25.82 %
Utilities	330 000	kg CO_2e	18.21 %
Flooring	190 000	kg CO_2e	10.73 %
Gypsum and plaster	180 000	kg CO_2e	9.89 %
Glass	140 000	kg CO_2e	8.11 %
Precast	140 000	kg CO_2e	7.94 %
Insulation	120 000	kg CO_2e	6.96 %
Ready-mix	93 000	kg CO_2e	5.19 %
Construction site	90 000	kg CO_2e	5.04 %
Other resource types	38 000	kg CO_2e	

Help

APPENDIX

Mass kg - Classifications

Item	Value	Unit	Percentage %
21 - Grunn og fundamenter	1 100 000	kg	17.04 %
222 - Søyler	640 000	kg	10.09 %
23 - Yttervegger	2 200 000	kg	33.96 %
233 - Glassfasader	86 000	kg	1.35 %
24 - Innervegger	370 000	kg	5.79 %
25 - Dekker	1 200 000	kg	19.07 %
253 - Oppforet gulv, påstøp	450 000	kg	6.98 %
26 - Yttertak	89 000	kg	1.39 %
Carbonisation of cementitious materials	82 000	kg	1.28 %
Other classifications	190 000	kg	3.05 %



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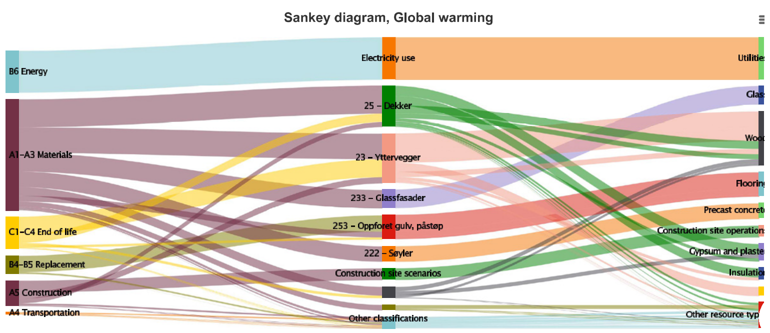

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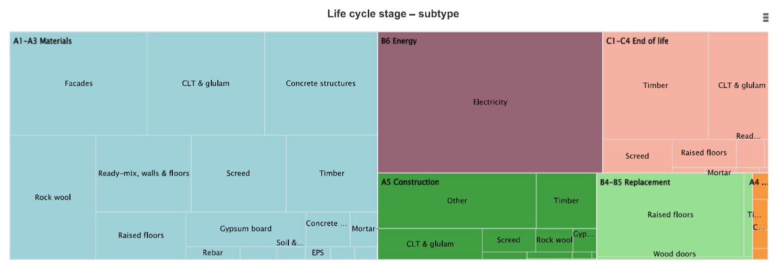
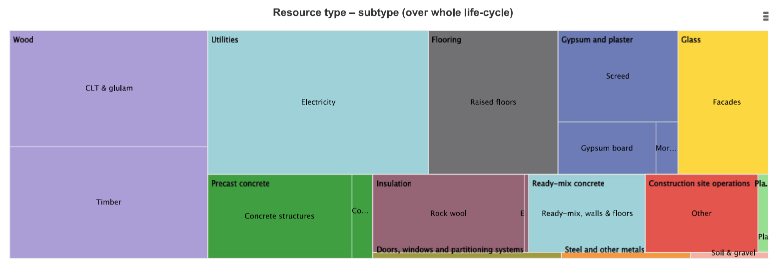
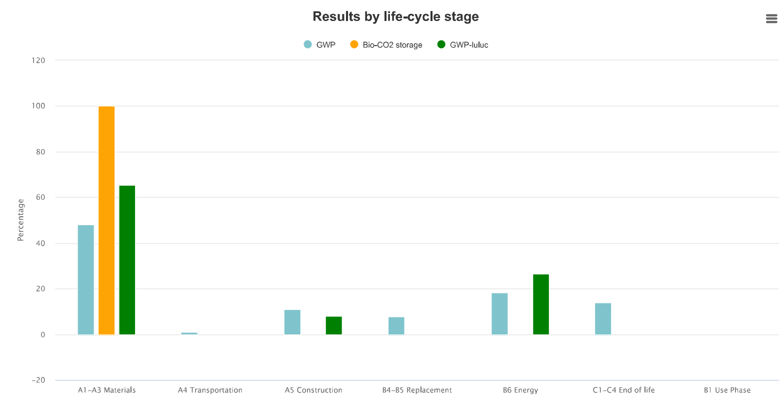
Treemap , Global warming







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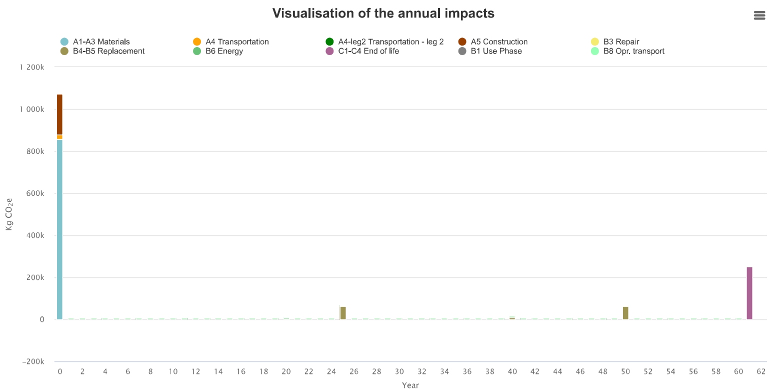
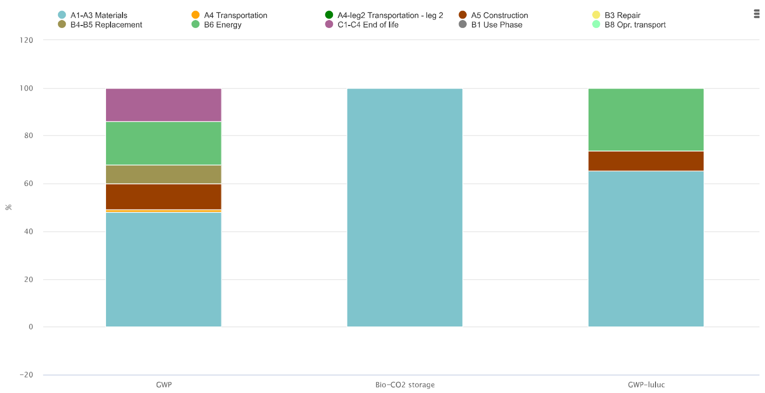
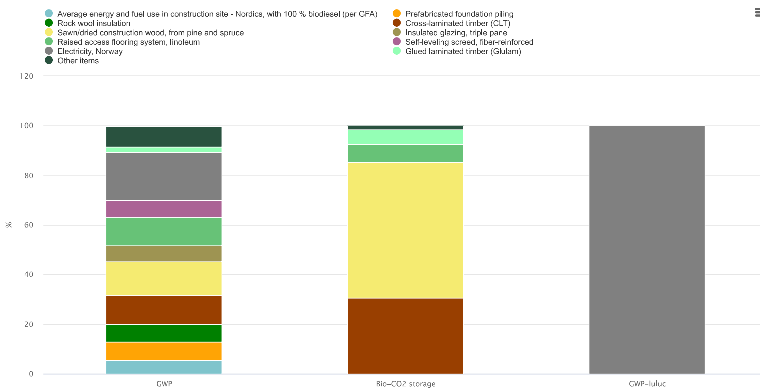


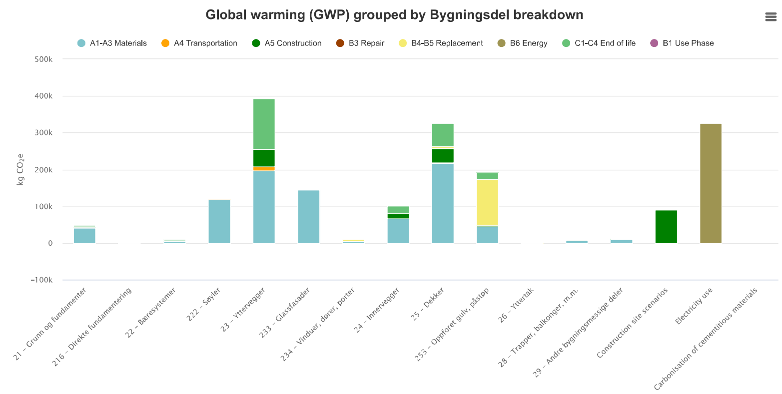
Life-cycle impacts by stage as stacked columns ❓



Life-cycle impacts by material as stacked columns ❓

Help





+ Show breakdowns for all categories

Data sources

Sources

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Der

Help

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Der
Aluminium frame glass façade system, enamelled double glazing	41,17 kg/m2		Eiler Thomsen Alufacader	EPD Danmark	MD-20036-EN	EPD Aluminium façades, within the ETA50 system	EN15804+A1	Third-party verified (as per ISO 14025)	2020	denmark	GaBi	
Concrete assembly for stairs per one metre height				One Click LCA		One Click LCA generic construction definitions				LOCAL	Other	
Concrete ground floor slab, for apartment building, EPS	U = 0,16 W/m2K (Määräystaso)			One Click LCA		One Click LCA generic construction definitions				finland	Other	
Cross-laminated timber (CLT)	420 kg/m3		Splitkon	EPD Norge	-	EPD Krysslimt tre Splitkon AS	EN15804+A1	Self declared	2020	norway	ecoinvent	420
Dry mortar, for facade render	20 kg / 1 m2 per 10 mm	webertherm 342 fasadbruk	Saint-Gobain	EPD Norge	NEPD-1834-786-EN	EPD webertherm 342 fasadbruk Saint-Gobain Sweden AB	EN15804+A1	Internally verified	2019	sweden	ecoinvent	200
Electricity, Norway				One Click LCA		LCA study for country specific electricity mixes based on IEA, OneClickLCA 2022		Internally verified	2019	norway	ecoinvent	
Filter fabric N2				One Click LCA	-	Polypropylene (PP), Environmental Product Declarations of the European Plastic Manufacturers	ISO14040	Internally verified	2008	LOCAL	ecoinvent	330
Footing foundations for hard soils (sand, gravel, silt or clay) per GFA	Includes: point and strip footings			One Click LCA		One Click LCA generic construction definitions				LOCAL	Ecoinvent	
Glued laminated timber (Glulam)	425 kg/m3, GL30c stength class		Moelven Limtre	EPD Norge	NEPD-1577-605-NO	EPD Prosjektlimtre	EN15804+A1	Third-party verified (as per ISO 14025)	2018	norway	ecoinvent	425
Glued laminated timber (Glulam) studs and columns			Kjeldstad	EPD Norge	NEPD-1385-455-NO	EPD K-stender Kjeldstad Trelast AS	EN15804+A1	Third-party verified (as per ISO 14025)	2017	norway	ecoinvent	425
Gypsum plaster board, regular, generic	6,5-25 mm (0.25-0.98 in), 10,725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3)			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	858

Help

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Der
Gypsum plaster board, regular, generic	6,5-25 mm (0.25-0.98 in), 10,725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3), 90% recycled gypsum			One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2022	LOCAL	ecoinvent	858
Gypsum plasterboard	12.5 mm, 9 kg/m2	Normal – Standard	Gyproc	EPD Norge	NEPD-1260-406-EN	EPD Gyproc® Normal – Standard Plasterboard Saint-Gobain Gyproc AS	EN15804+A1	Third-party verified (as per ISO 14025)	2017	norway	ecoinvent	720
Insulated glazing, triple pane	31,3 kg/m2			OKOBAUDAT	-	Oekobau.dat 2020-II	EN15804+A1	Third-party verified (as per ISO 14025)	2020	germany	GaBi	
Insulation, EPS 100	0.035 W/mK, 18-22 kg/m3 (100 kPa), without flame retardant		EUMEPS	IBU	EPD-EPS-20130077-CBG1-EN	Expanded Polystyrene (EPS) Foam Insulation (without flame retardant, density 20 kg/m³), EPS 100, EUMEPS (region Scandinavia)	EN15804+A1	Third-party verified (as per ISO 14025)	2013	finland, sweden, denmark	-	20.(
Lightweight bituminous underlays for roof waterproofing, category B	1.3-1.8 mm, 1.5-1.9 kg/m2		European Waterproofing Association	International EPD System	S-P-01329	EPD Lightweight underlays For Roof Waterproofing – sector EPD	EN15804+A1	Third-party verified (as per ISO 14025)	2018	denmark, norway, sweden, finland, italy, russia	ecoinvent	
Macadam (8… 16 mm), wet bulk density	2000 kg/m3			One Click LCA	-	LCA inventory for gravel production, Ecoinvent 2014	ISO14040	Internally verified	2014	LOCAL	ecoinvent	200
Multi layer waterproofing system with flexible sheets for roofing, fully torched, European average	3.8 (top) + 3.1 (bottom) mm, 4.8 (top) + 3.9 (bottom) kg/m2		EWA	International EPD System	S-P-00414, ver. 2019	EPD Flexible Bitumen Sheets For Roof Waterproofing – sector EPD, ver. 2019	EN15804+A1	Third-party verified (as per ISO 14025)	2019	belgium, netherlands, portugal, austria, spain, france, germany, italy, sweden, denmark, finland, norway	ecoinvent	
Precast concrete wall elements (solid, uninsulated), generic	C30/37 (4400/5400 PSI), 40% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3), incl. reinforcement			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	240
Prefabricated foundation piling	d 555 mm	Mofix	Spennconn Rail	EPD Norge	NEPD-1259-405-NO	EPD Mofix fundament ø355 og ø555 Produkt Spenncon Rail AS Eier av deklarasjonen	EN15804+A1	Third-party verified (as per ISO 14025)	2017	norway	ecoinvent	238

Help

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Der
Raised access flooring system, linoleum	600 x 6000 x 30 mm, 28.77 kg/m2	SD 30R linoleum	Dipso Pavimentos	International EPD System	S-P-01725	EPD OF TECHNICAL FLOOR – MEDIUM RANGE (SD) FROM DIPSO PAVIMENTOS, S.A.	EN15804+A1	Third-party verified (as per ISO 14025)	2019	spain	ecoinvent	
Ready-mix concrete, normal-strength, generic	C30/37 (4400/5400 PSI), 10% (typical) recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3)			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	240
Ready-mix concrete, normal-strength, generic	C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3)			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	240
Reinforcement steel (rebar), generic	90% recycled content, A615			One Click LCA	-	One Click LCA	EN15804+A1	Internally verified	2018	LOCAL	ecoinvent	785
Rock wool insulation	L = 0.037 W/mK, 32 kg/m3, 37 mm for R=1, 45-245 mm, Lambda=0.037 W/(m.K)	Flexibatts 37	Rockwool	EPD Norge	NEPD-1762-735-EN	EPD ROCKWOOL stone wool thermal insulation ROCKWOOL International A/S (ROCKWOOL Nordics)	EN15804+A1	Third-party verified (as per ISO 14025)	2019	denmark, norway	GaBi	32.(
Sawn/dried construction wood, from pine and spruce	456 kg/m3, moisture content 16 %		Træ- og Møbelindustrien	EPD Danmark	MD-20002-EN	EPD Træ.dk c/o Træ og Møbelindustrien	EN15804+A1	Third-party verified (as per ISO 14025)	2020	norway, sweden, finland	ecoinvent, GaBi	456
Self-leveling screed, fiber-reinforced	8-60 mm, 1.7 kg/l, 25 Mpa	Proplan multi NT	Heydi AS	EPD Norge	NEPD-3391-2011-NO	EPD Heydi Proplan Multi NT Heydi AS	EN15804+A1	Internally verified	2022	norway	ecoinvent	
Spruce construction timber	38mm x 48mm-98mm x 223mm, 467.36 kg/m3		InnTre Kjeldstad AS	EPD Norge	NEPD-3282-1918-NO	EPD Konstruksjonsvirke av gran InnTre Kjeldstad AS	EN15804+A1	Third-party verified (as per ISO 14025)	2021	norway	ecoinvent	467
Waterproofing roof membrane	1.2 mm, 1420 g/m2	SE 1.2	Protan	EPD Norge	NEPD-32-219-EN	NEPD-32-219-EN SE 1.2 Roof Membrane	EN15804+A1	Third-party verified (as per ISO 14025)	2015	norway	ecoinvent	118
Wooden interior door, per unit	809x2053 mm, 42x92 mm frame, 52 mm door leaf		Nordic Dørfabrikk	EPD Norge	NEPD-1535-525-EN	EPD Climate door / interior door Nordic Dørfabrikk AS	EN15804+A1	Third-party verified (as per ISO 14025)	2018	norway	ecoinvent	

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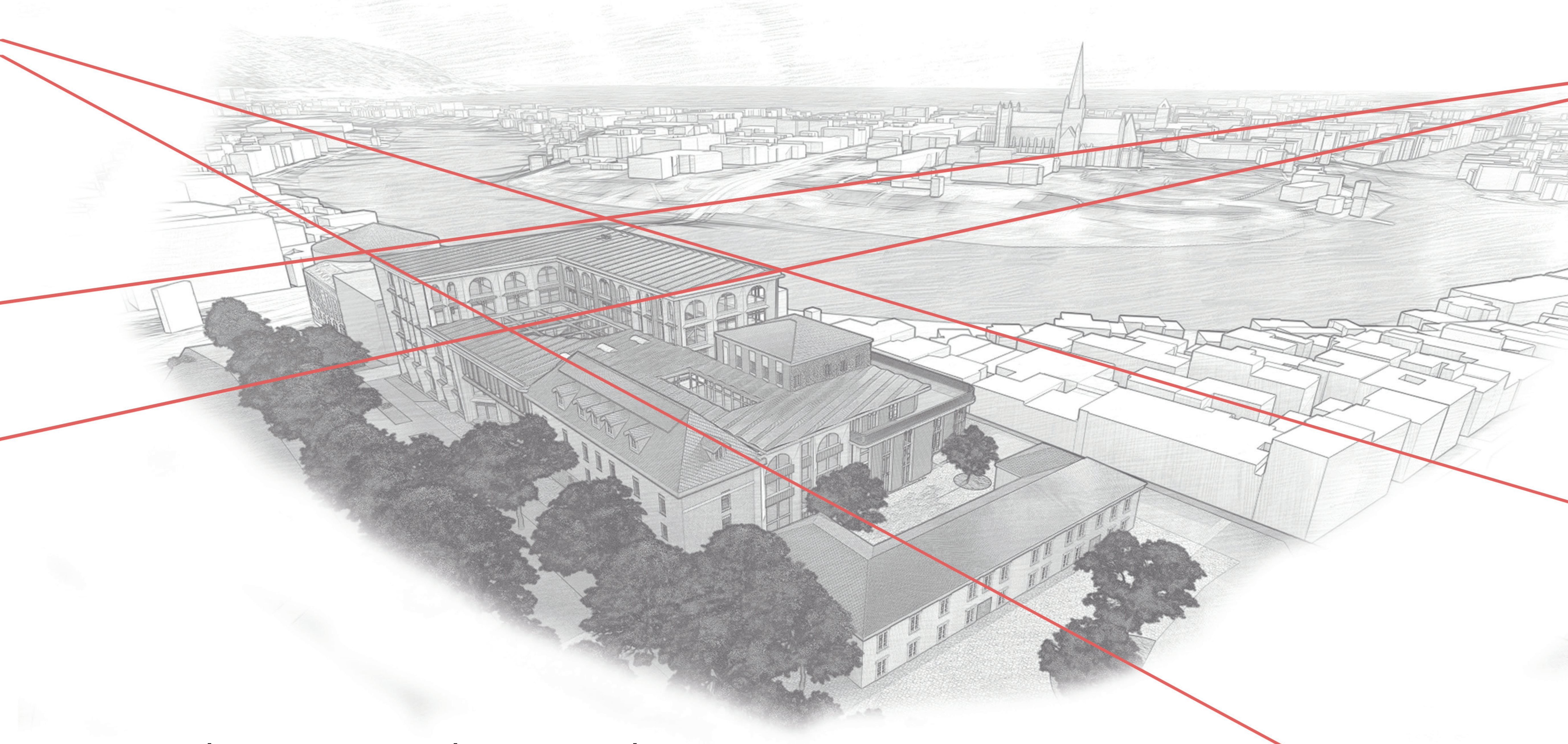

Kunst/Arkitektur/Musikk/Design

Master's Thesis In Sustainable Architecture Design Project

May 2022

Supervisor / Michael Gruner

Sebastian Ulloa-Thompson / 546953

NTNU Department of Architecture and Technology

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