STUDENTHOUSING MOHOLT
HAUGENHUSET

MASTER THESIS
SPRING SEMESTER 2021

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MASTER THESIS

MASTER OF SCIENCE IN SUSTAINABLE ARCHITECTURE
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ABSTRACT

DUE TO THE STEADY GROWTH IN STUDENTS IN TRONDHEIM, SIT IS EXPECTED TO FURTHER EXPAND THEIR STUDENT HOUSING STOCK. BY BEEING THE BIGGEST STUDENT HOUSING PROVIDER IN TRONDHEIM, THEY ARE EXPECTED TO FOCUS ON LOWERING THE EMISSIONS OF THEIR EXISTING AND NEW BUILDINGS.

THE NEW STUDENT HOUSING HAUGENHUSET SHOWS A LOW-EMISSION STRATEGIE. FOLLOWED BY PROVIDING A COMFORTABLE CLIMATE AND PROMOTE INTERACTIONS BETWEEN STUDENTS.

THE CONCEPT WAS INSPIRED BY THE CURRENT PANDEMIC SITUATION, IN WHICH THE TOPIC OF LONELINESS PLAYS A MORE IMPORTANT ROLE THAN EVER BEFORE. DUE TO THE GREENHOUSE ABOVE THE STUDENT HOUSING, OUTSIDE SPACES ARE USABLE FOR A LONGER PERIOD OF THE YEAR.

NEW HAUGENHUSET OFFERES SPACE FOR 60 STUDENTS. ONE UNIT IS DESIGNED FOR SIX STUDENTS IN TOTAL.
THIS PROJECT SHOWS THAT NEW LOW ENERGY PROJECTS AND INTEGRATED ENERGY DESIGN CAN BE COMBINED.

APPRECIATION

I WOULD LIKE TO THANK MY MAIN SUPERVISOR TOMMY KLEIVEN FOR HIS USEFUL INPUT AND CONSTANT SUPPORT THROUGHOUT THIS THESIS WORK. EVERY MEETING TOGETHER WITH HIM AND MATTEO TAGNOCCHETTI WAS REALLY HELPFUL AND INSPIRING.

A SPECIAL ACKNOWLEDGMENT GOES TO GAURAV CHAUDHARY FOR HIS CONSTANT SUPPORT WITH ENERGY CALCULATIONS AND HELPING WITH SOFTWARE LIMITATIONS.

I ALSO WANT TO THANK MY STUDENT FRIENDS FOR SHARING THIS JOURNEY AND MAKING THESE PAST TWO YEARS AT NTNU UNFORGETTABLE.

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INTRODUCTION

BACKGROUND

THE CONSTRUCTION INDUSTRY IS GROWING BY 3.6% ANNUALLY, BUT IT IS ALSO RESPONSIBLE FOR 40% OF THE WORLD'S ENERGY CONSUMPTION. IN THIS SENSE, IT IS BECOMING MORE AND MORE IMPORTANT TO BUILD SUSTAINABLY. THE BUILDING SECTOR USES 400 MILLION TONS OF MATERIAL ANNUALLY WORLDWIDE. AROUND THE WORLD, THE CONSTRUCTION INDUSTRY IS RESPONSIBLE FOR AROUND 25% OF GREENHOUSE GAS EMISSIONS, IN EUROPE FOR AS MUCH AS 36%.

FOR THESE REASONS, IT IS INEVITABLE TO BUILD NEW PROJECTS RESOURCES CAREFULLY AND IN THE LOW ENERGY STANDARD.

SIT, THE STUDENT WELFARE ORGANIZATION OF TRONDHEIM IS IN URGENT NEED OF NEW STUDENT HOUSINGS. THE ORGANIZATION IS OPEN-MINDED AND BOUNDED ON BUILDING ENERGY-EFFICIENT AND TRY OUT NEW METHODS. SIT OFFERS AT THE MOMENT HOUSING FOR ABOUT 6400 STUDENTS AND ALMOST 3000 STUDENTS ON THE WAITING LIST EACH YEAR. THE WELFARE ORGANIZATION WILL BUILD FUTURE HOUSES UNDER THE UNs SUSTAINABILITY GOALS AND AIMES TO USE THE NEW HAUGENHUSET AS A LIVING LAB TO TEST OUT NEW VERSIONS OF STUDENT HOUSING.

SCOPE

THE GOAL OF THIS THESIS WORK IS TO CREATE A NEW STUDENT HOUSING ON THE HAUGENHUSET PLOT IN MOHOLT STUDENTBY, TRONDHEIM. KEEPING THE EMISSIONS AND MATERIAL CONSUMPTION, MENTIONED ABOVE , IN MIND. THE MAIN GOAL OF THIS PROJECT, IS TO INCREASE THE SOCIAL INTERACTION OF STUDENTS AND MAXIMIZE THE TIME SPENT IN COMMON AREAS. THE FOCUS OF THIS DESIGN IS TO INTEGRATE THE ENERGY DESIGN AND OPENLY SHOW BUILDING AND CONSTRUCTION MATERIALS.

ENERGY MODEL METHOD

- GREENHOUSE TEMPERATURE AND DRYBULB USED AS NEW WEATHER-FILE
- ENERGY SIMULATION LIMIT WITH HOUSE-IN-HOUSE CONCEPT
- HEATGAINS OF THE GREENHOUSE COMING FROM THE INSIDE BOXES ARE SIMULATED BY HEAT SOURCES

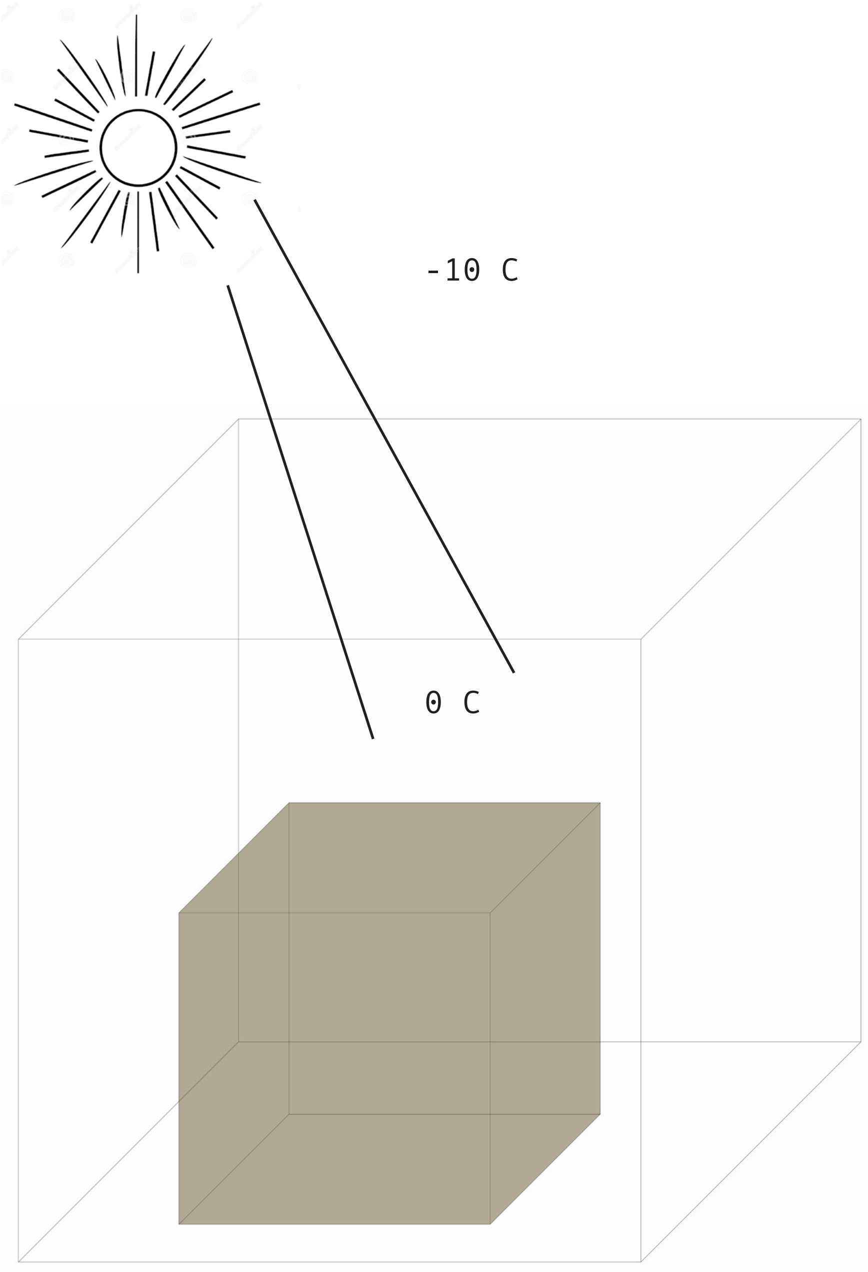


FIG 1. METHODOLOGY

METHODOLOGY

TO FULFILL THIS PROJECT, DIFFERENT STEPS WERE TAKEN. AS THE FIRST STEP, INFORMATION ABOUT THE EXISTING BUILDING, ITS PURPOSE AND MOHOLT STUDENTBY WAS GATHERED.
TO GET AN OVERVIEW OF THE SITE AND AN IDEA OF THE DIMENSIONS, DIFFERENT WELL-KNOWN BUILDINGS OF DIFFERENT SIZES, SUCH AS THE GUGGENHEIM MUSEUM IN NEW YORK AND VILLA TUGENDHAT in BRNO, CZ WERE ADDED TO THE SITE.

THE MAIN GOAL OF THIS STUDENT HOUSING PROJECT WAS TO WORK AGAINST LONELINESS AND TO INCREASE THE USAGE OF THE COMMON AREAS. WITH THAT IN MIND, THE IDEA OF A BOX-IN-BOX CONCEPT WAS SET FROM THE BEGINNING OF THE PROJECT.
- SKETCHING WAS A TOOL FOR CONCEPTS AND IDEA DEVELOPMENT THROUGHOUT THE WHOLE PROJECT.
- FOR CAD DRAWINGS, ARCHICAD WAS THE MAIN PROGRAMM USED.

THE GREENHOUSE SHAPE WAS DEVELOPED AND MODELLED IN SKETCH UP.
- FIRST SOLAR ANALYSIS WAS DONE IN SKETCH UP AS WELL.
- FOR FURTHER ENERGY SIMULATIONS OF THE GREENHOUSE, THE SOFTWARE DESIGN BUILDER WAS USED.

TO SIMULATE THE ENERGY PERFORMANCE OF THE INNER BUILDINGS, DESIGNBUILDER WAS THE MAIN SOFTWARE USED.
PLACEMENT AND SOLAR STUDIES ARE SIMULATED IN SKETCH UP AND GRASSHOPPER.

BY MODELLING A HOUSE-IN-HOUSE CONCEPT, SOFTWARES HAVE CERTAIN LIMITATIONS.
IN THIS PROJECT THE INDOOR AIR TEMPERATURE AND RELATIVE HUMIDITY OF THE GREENHOUSE WERE USED TO CREATE A NEW WEATHER FILE, TO USE FOR THE INNER BUILDINGS. DURING THE PROCESS A SECOND LIMITATION, THE EFFECT OF THE HEAT LOSSES FROM THE INNER BUILDINGS TO THE GREENHOUSE GOT SOLVED BY IMITATING THE INNER BUILDINGS AS A HEAT SOURCE INSIDE THE GREENHOUSE.

DESIGNBUILDER WAS AS WELL USED FOR DAYLIGHT ANALYSES, PASSIVE STRATEGIES SIMULATIONS, AND CALCULATING THE ELECTRICITY PRODUCTION OF THE PV PANELS.
GETTING INTO DETAIL DRAWINGS, DIMENSIONS OF FOUNDATIONS, BUILDING STRUCTURE, AND MATERIALS ARE BASED ON RECOMMENDATIONS FROM BYGGFORSK.
AFTER THE DESIGN WAS MOSTLY FINISHED, THE EMISSIONS FROM THE CONSTRUCTION AND OPERATION OF THE BUILDING WERE CALCULATED.
-LCA CALCULATIONS ARE DONE BY ONE CLICK LCA.
-EMISSIONS FROM OPERATIONAL ENERGY ARE ALSO CALCULATED IN DESIGNBUILDER.

FOR THE FINAL DELIVERY,
- ADOBE PHOTOSHOP WAS USED TO COLOR AND IMPROVE DRAWINGS
- TO CREATE ILLUSTRATIONS, ADOBE ILLUSTRATOR WAS USED
- THE REPORT AND POSTERS ARE LAYOUTED IN ADOBE INDESIGN.

CONTEXT+SITE

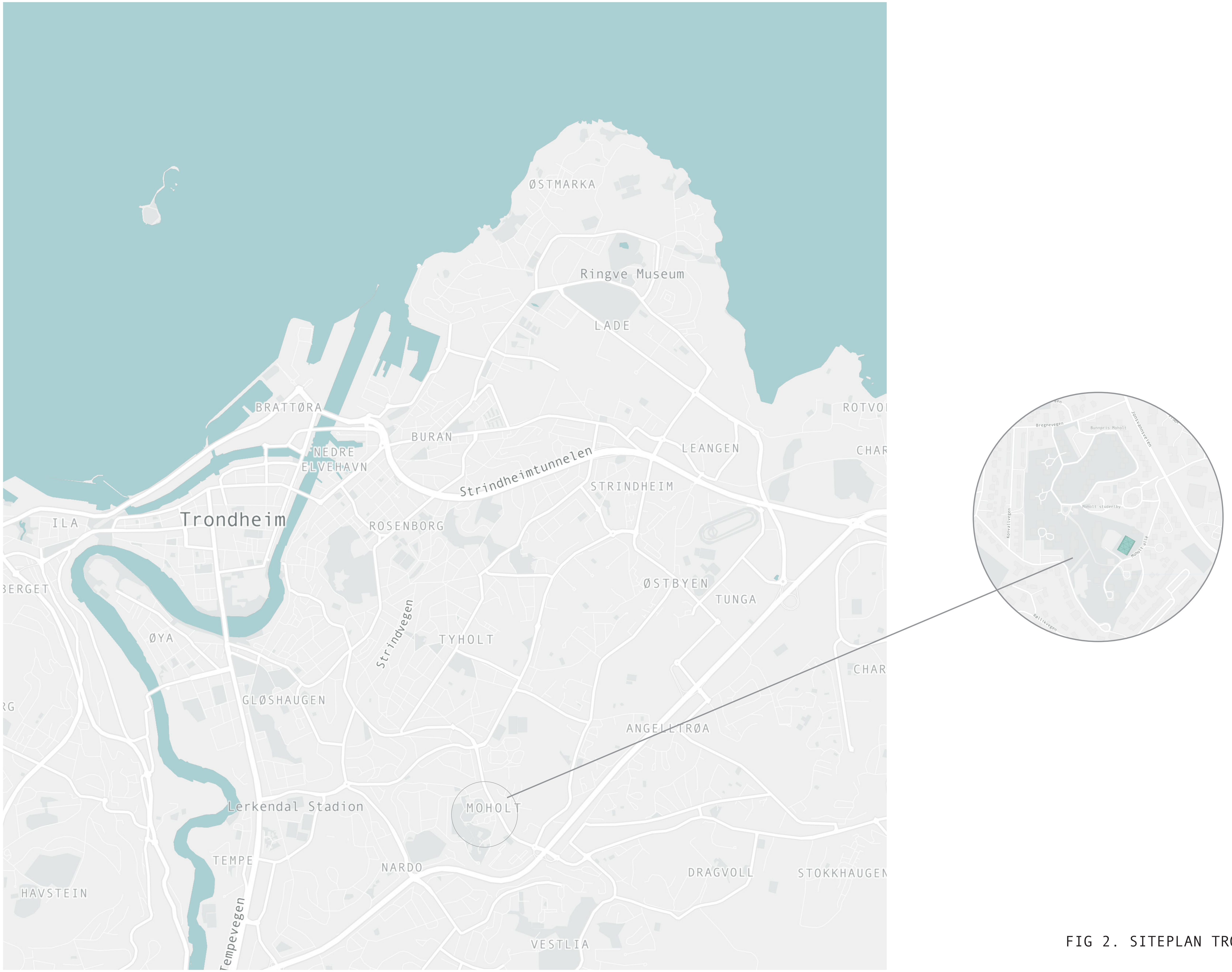


FIG 2. SITEPLAN TRONDHEIM

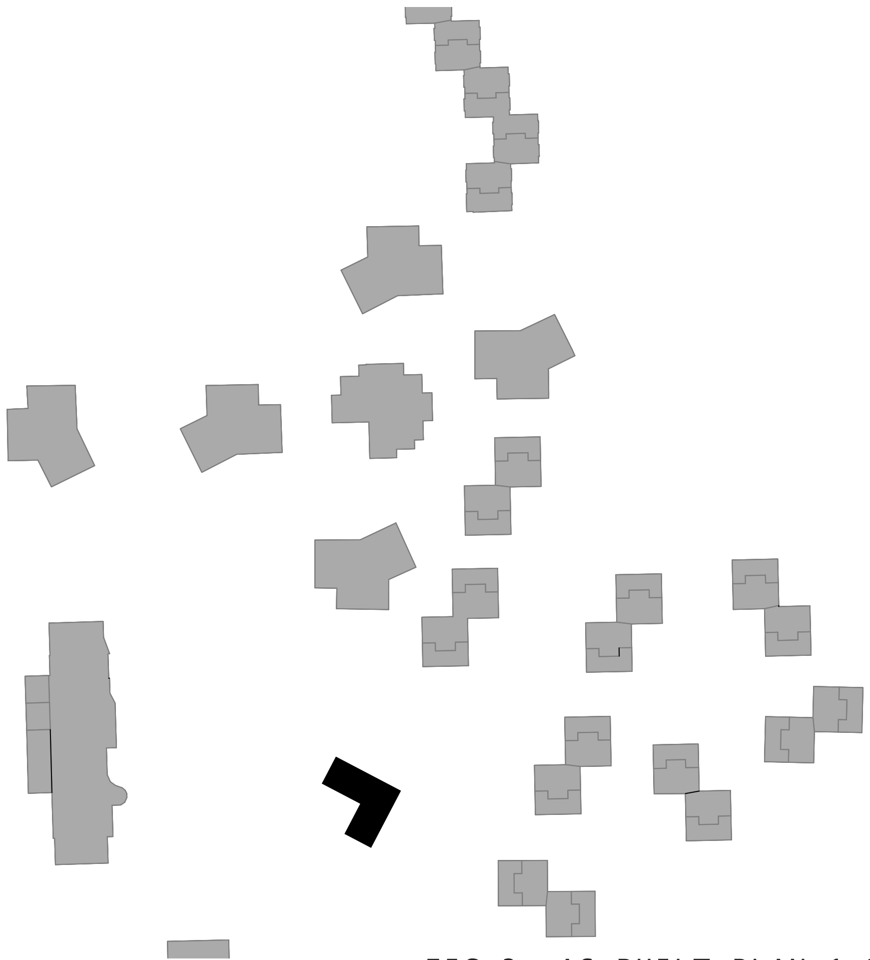


FIG 3. AS-BUILT PLAN 1:2000

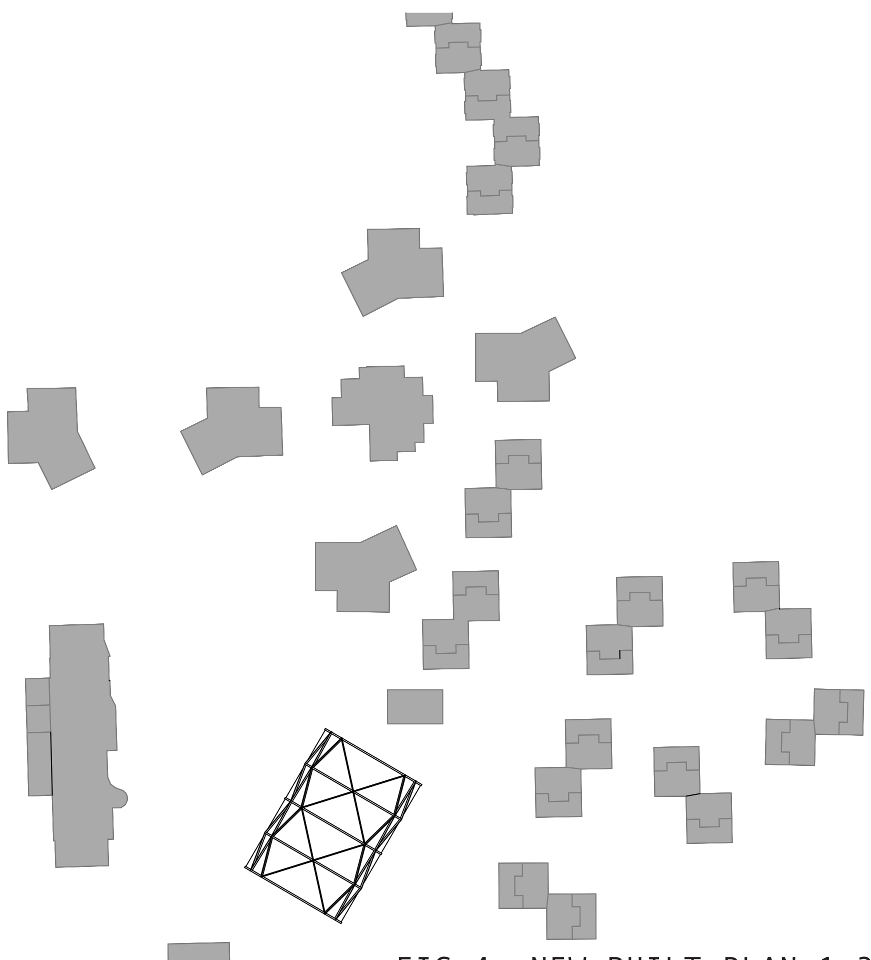


FIG 4. NEW BUILT PLAN 1:2000

SITE ANALYSIS

THE BUILDING PLOT FOR THIS MASTER THESIS PROJECT IS LOCATED IN TRONDHEIM, NORWAY.
TRONDHEIM IS THE THIRD-LARGEST CITY IN NORWAY AND LOCATED AROUND 500 KM NORTH OF OSLO, ON THE WEST COAST.
THE CITY IS IN THE MODERATELY CONTINENTAL CLIMATE ZONE WITH COLD WINTERS AND MILD SUMMERS. THE AVERAGE YEARLY TEMPERATURE IS 4,4°C. THE WARMEST MONTH OF THE YEAR IS JULY WITH AN AVERAGE TEMPERATURE OF 14,6°C. JANUARY IS THE COLDEST MONTH OF THE YEAR WITH AN AVERAGE TEMPERATURE OF -4,5°C.

MOHOLT, THE BIGGEST STUDENTBY IN TRONDHEIM IS LOCATED IN THE SOUTH-EAST OF THE CITY AND HAS A SIZE OF ABOUT 2590 M2.
THE SITE IS ELEVATED ON A SMALL HILL NEXT TO MOHOLT ALLEE. THE MAIN STREET ALONG MOHOLT STUDENTBY IS JONSVANNSVEIEN THAT IS CONNECTED TO THE NEAREST E6 ENTRANCE AND OFFERS PUBLIC TRANSPORTATION TO THE CITY CENTER AND NTNU CAMPUSES.
THE STUDENT HOUSING AREA WAS BUILT IN THE 1960S, THE FIRST STUDENTS MOVED IN IN THE FALL OF 1964.

MOST OF THE STUDENT HOUSINGS IN TRONDHEIM ARE OPERATED BY SIT A STUDENT WELFARE ORGANIZATION, LOCATED AT THE NTNU CAMPUSES IN GJØVIK, ÅLESUND AND TRONDHEIM.

THE AREA OFFERS STUDENT HOUSING FOR AROUND 1300 STUDENTS. BESIDES THE AROUND 50 PREDOMINANT 4-STORY BRICK HOUSES OF THE ARCHITECT HERMANN KRAGS FROM 1964, 2016 FIVE WOODEN TOWERS, A KINDERGARTEN AND A LIBRARY BUILDING WERE ADDED TO THE SITE. THE LIBRARY INCLUDES A CAFE, RUN BY SIT AND AN EVENT AREA ON THE TOP FLOOR, THAT IS CALLED LOFTET. LOFTET OFFERS CONCERTS, MOVIE NIGHTS AND OTHER COMMUNITY ACTIVITIES.
STUDENTS ALSO HAVE ACCESS TO SUPERMARKETS LIKE BUNNPRIS, REMA 1000 AND KIWI, GYM, KINDERGARTEN AND PUBLIC TRANSPORTATION WITHIN WALKING DISTANCE.

HAUGENHUSET

THE BUILDING HAUGENHUSET WAS BUILD IN 1969 AND SERVED THE PURPOSE OF A RESIDENTIAL BUILDING WITH A TOTAL OF AROUND 250 SQM. THE BUILDING SEEMED TO BE WITHOUT MAJOR RENOVATIONS FOR THE LAST DECADES.

THE L-SHAPED BUNGALOW IS OWNED BY SIT AND GOT DEMOLISHED IN 2020/2021 TO PROVIDE MORE SPACE FOR STUDENT HOUSING ON THE SITE.

THE MAIN BUILDING MATERIALS USED ARE CONCRETE THAT WAS COVERED BY RED BRICKS AND WOODEN CLADDING.
THE BUNGALOWS ROOF WAS A WOODEN STRUCTURE WITH RED ROOF TILES.
THE SHOWN ELEVATION AND FLOORPLANS ARE REDRAWN AFTER THE ORIGINAL PLANS, PROVIDED BY SIT.

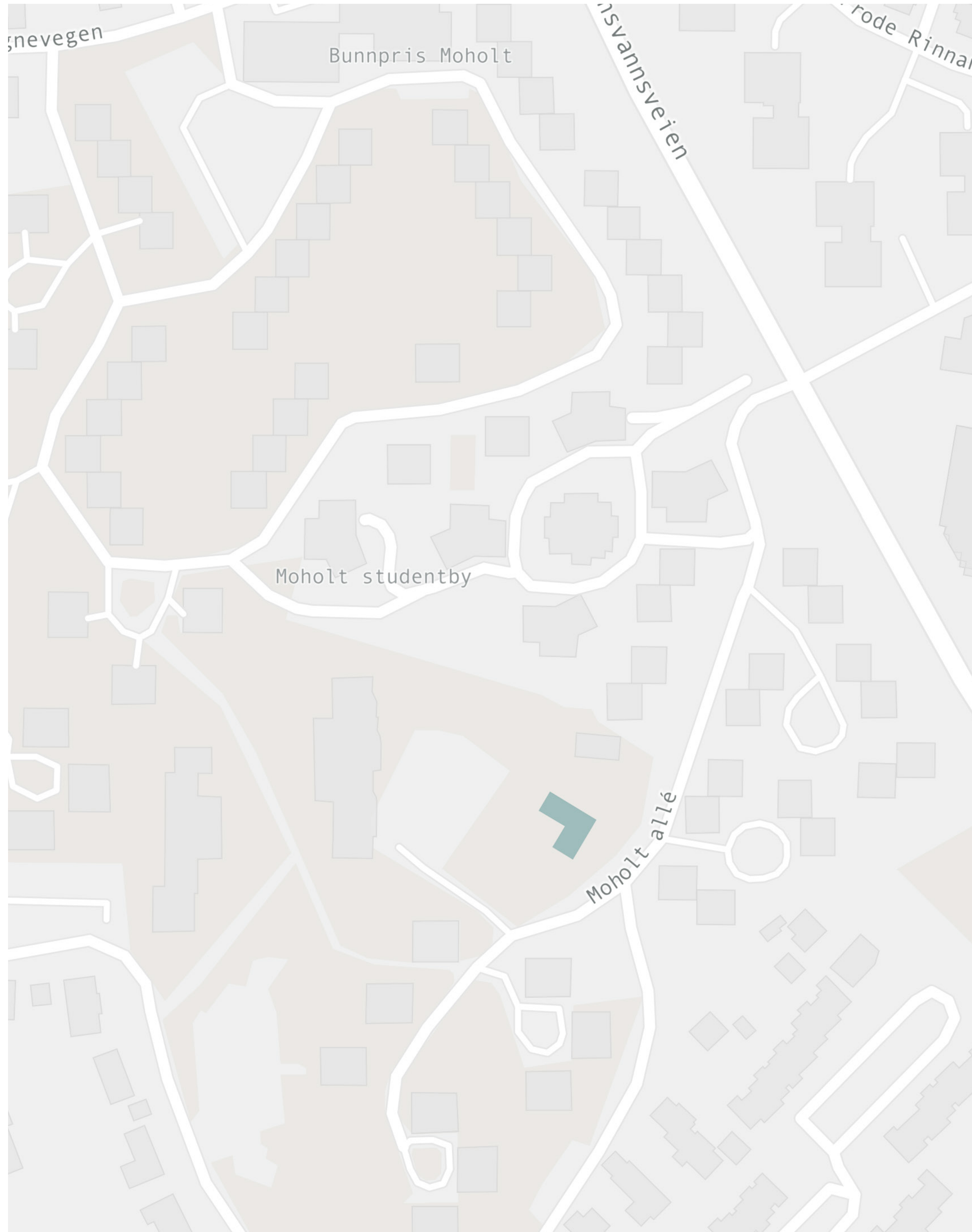


FIG 5. SITE HAUGENHUSET

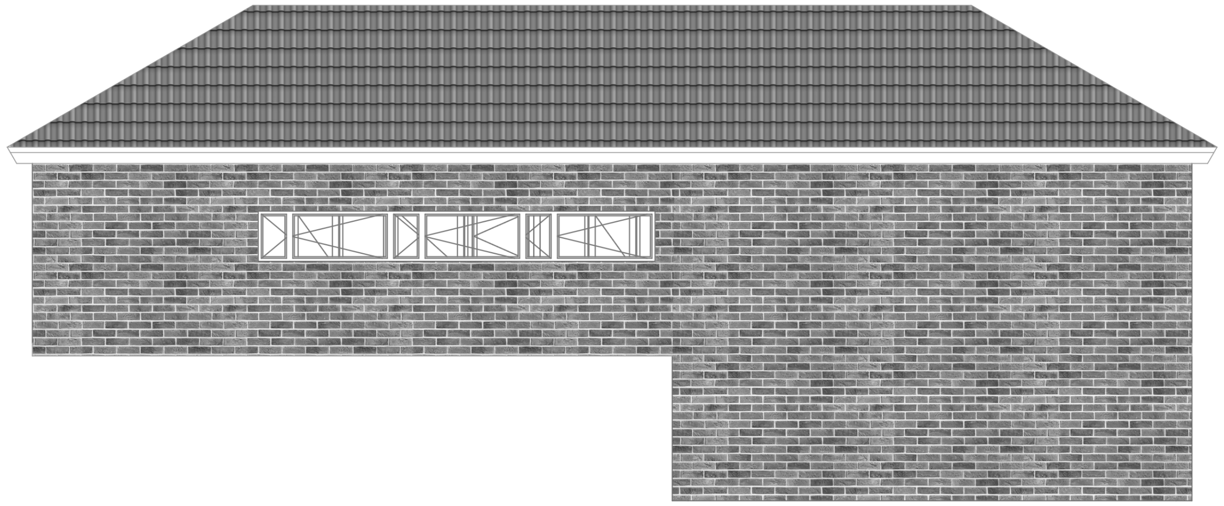


FIG 6. ELEVATION NORTH

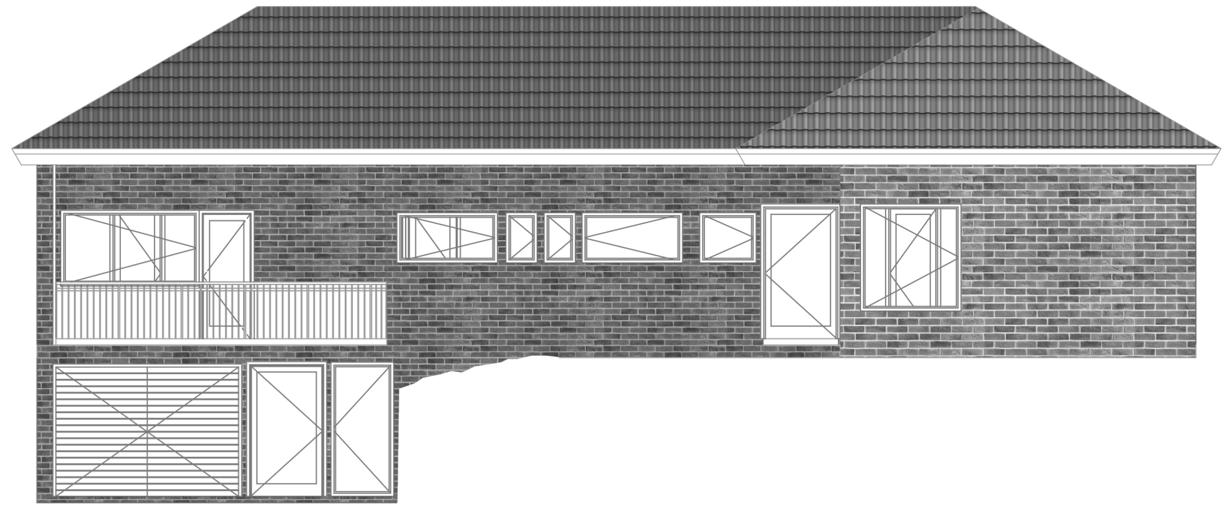


FIG 8. ELEVATION SOUTH

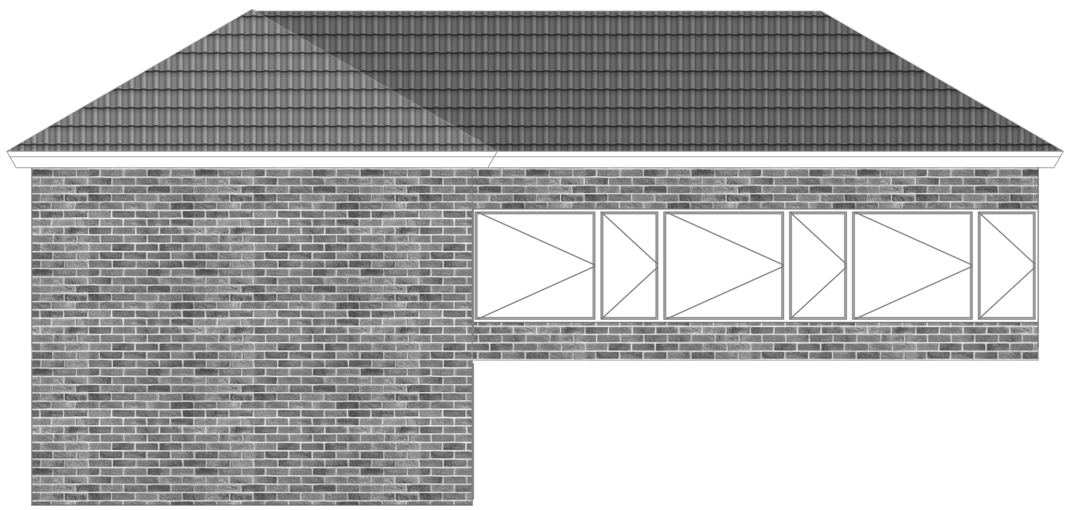


FIG 7. ELEVATION WEST

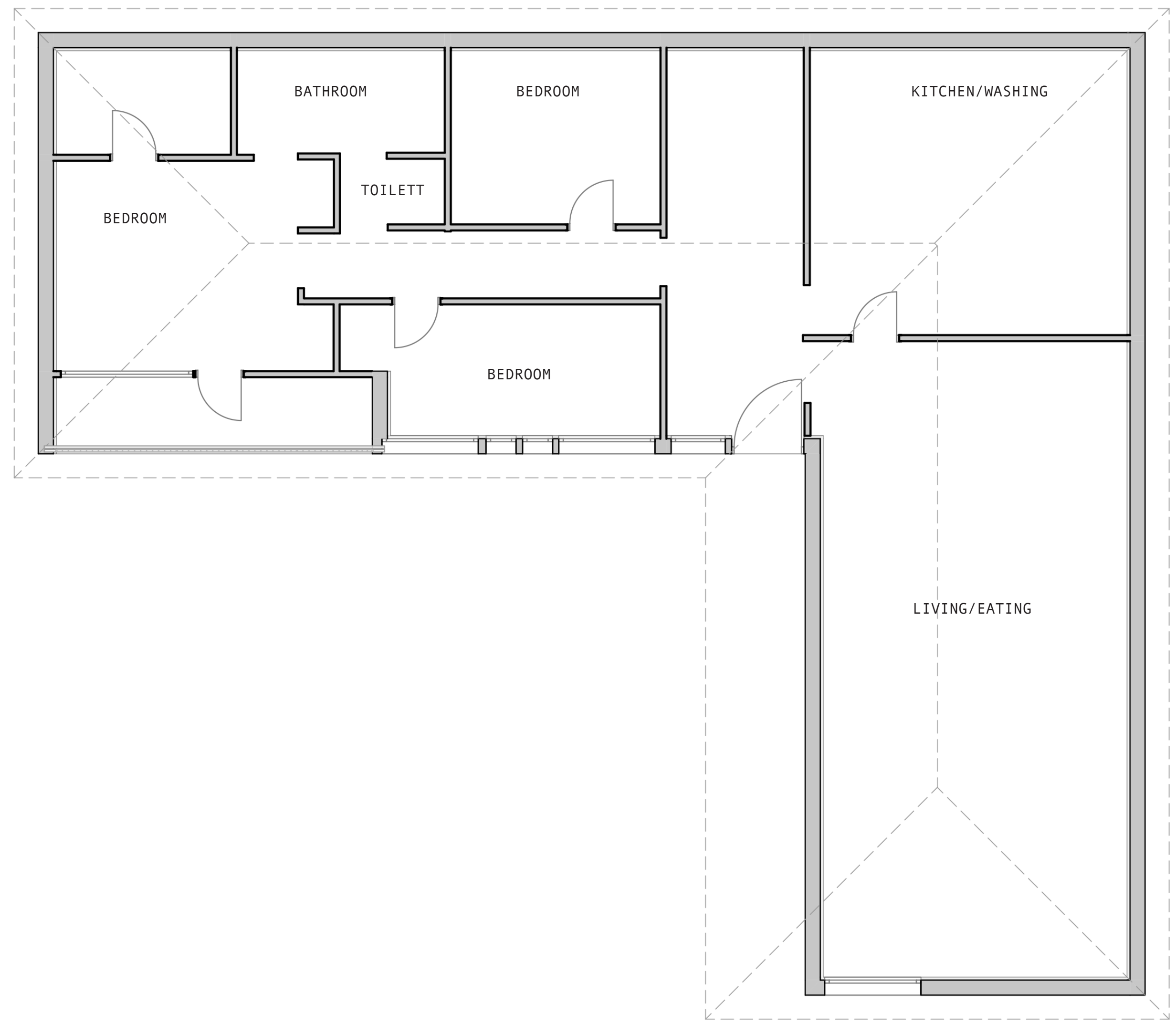


FIG 9. FLOORPLAN GROUNDFLOOR

CONCEPT

CONCEPT

THROUGH OBSERVATIONS WAS ESTABLISHED, THAT THE AREA OF MOHOLT STUDENTBY OFFERS MANY WELL-EQUIPPED PLACES TO STAY OUTSIDE. THERE ARE BARBECUE AREAS, BENCHES, SUNBEDS AND MORE. UNLIKELY, THE MAIN TIME TO USE THESE AREAS IS IN THE SUMMERTIME (MAINLY MAY TO SEPTEMBER).
THESE MONTHS COLLIDE WITH THE STUDENTS SUMMER VACATIONS. THEREFORE THE AREAS ARE NOT AS MUCH USED AS INTENDED.

THE MAIN GOAL OF THIS PROJECT, WAS TO OFFER MORE SOCIAL PLACES FOR STUDENTS, THAT CAN BE USED FOR A LONGER PERIOD DURING THE YEAR. IN THAT CASE, THE IDEA OF A GREENHOUSE OVER THE ACTUAL STUDENT HOUSING WAS BUILT.

ADDITIONALLY, THE CURRENT SITUATION OF COVID-19 SHOWED, THE ISSUE OF LONELINESS, ESPECIALLY FOR STUDENTS THAT MAYBE EVEN COME FROM ABROAD.
TO HAVE AS MUCH SOCIAL INTERACTION IN THE BUILDING AS POSSIBLE, THE STAIRCASES GOT MOVED FROM THE INSIDE OF THE BOXES TO THE CENTER OF THE GREENHOUSE. THE OPEN WALKWAYS ENSURE INTERACTIONS BETWEEN THE PEOPLE LIVING THERE.

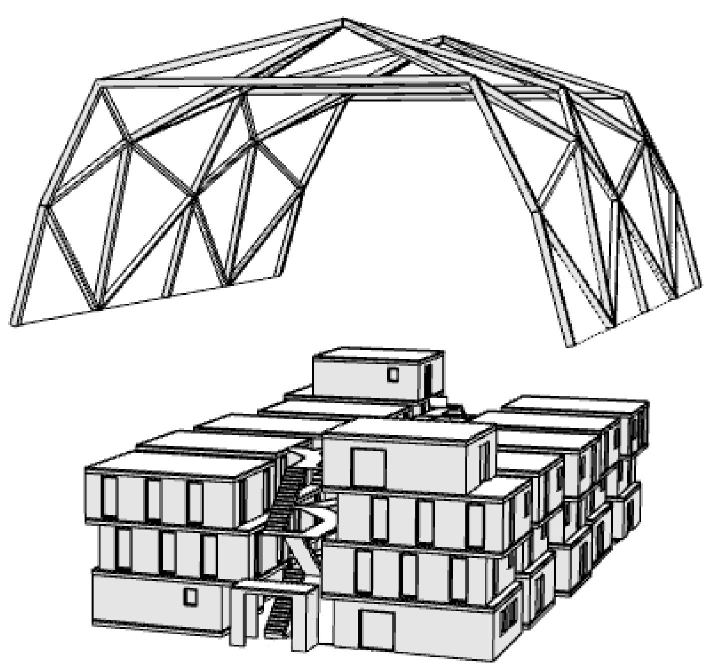


FIG 10. CONCEPT SKETCH

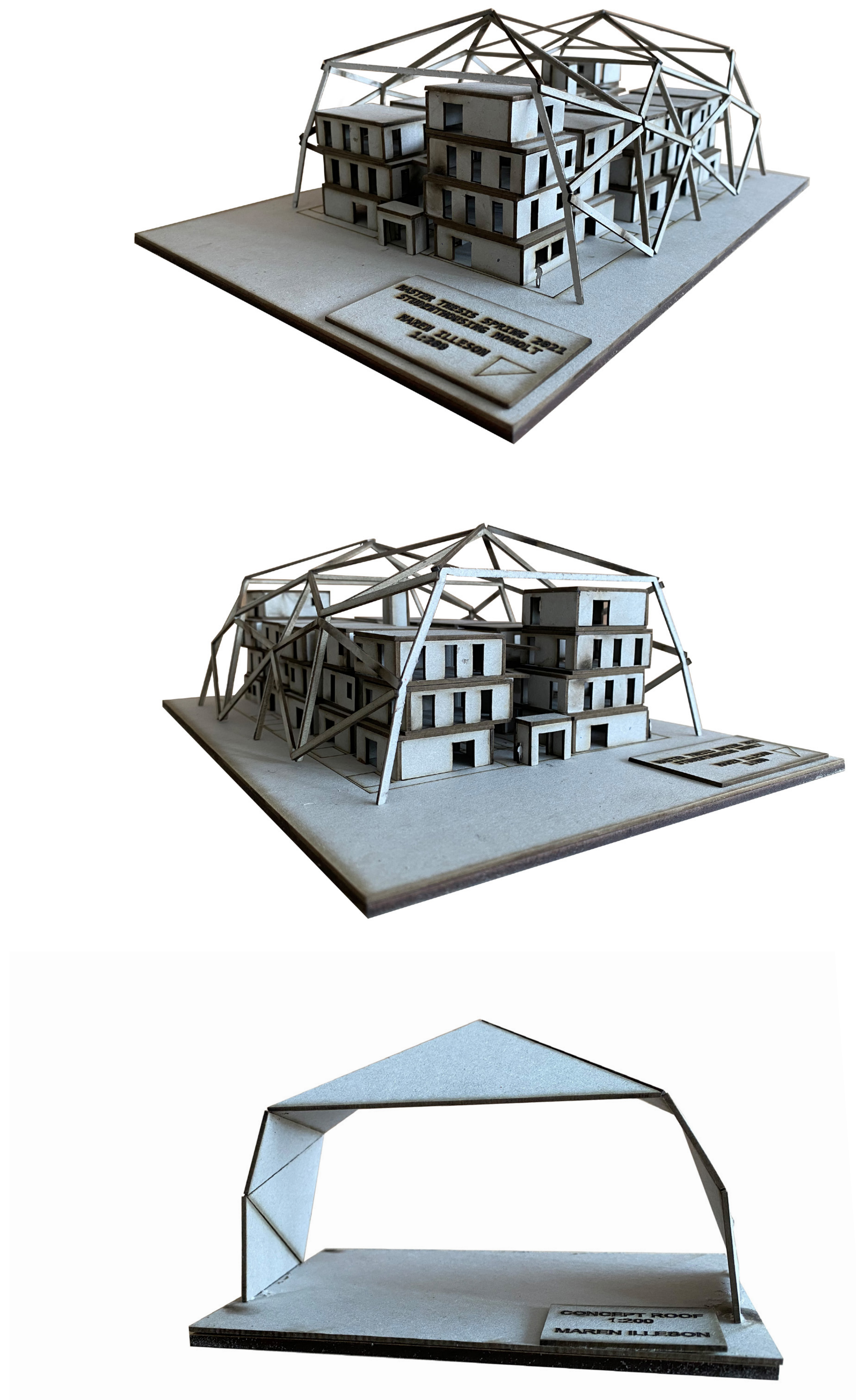


FIG 11. MODEL PICTURES

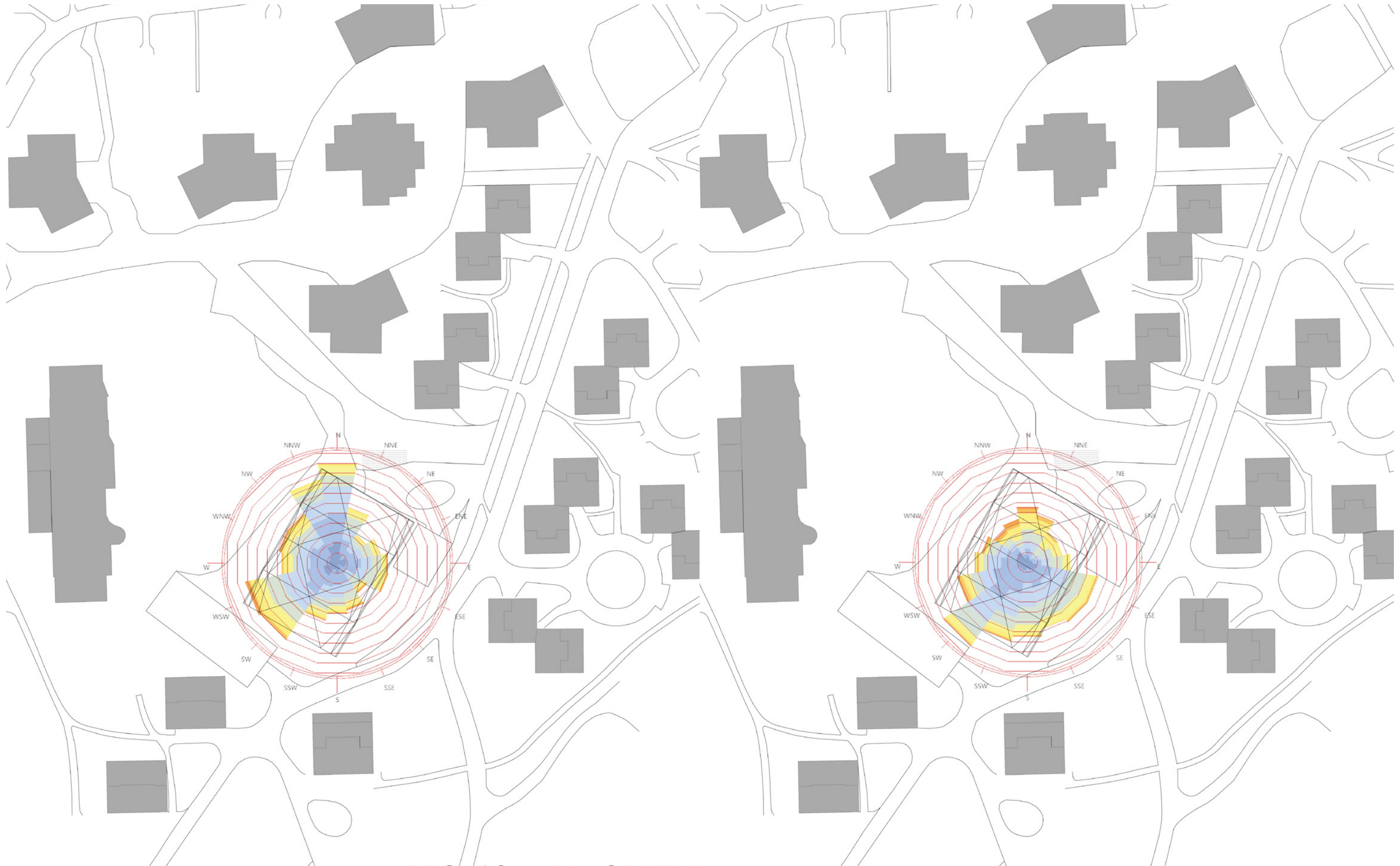


FIG 12. PLACEMENT ACCORDING TO WINDROSE SUMMER / WINTER

WIND STUDIES

AS THE WIND CONDITIONS CHANGE WITH THE SEASONS, THE WIND ROSE IS CONSIDERED SEPARATELY IN SUMMER AND WINTER.
IN SUMMER THE MAJORITY OF THE WIND COMES FROM THE SOUTHWEST AND NORTHWEST. IN WINTER MOST WIND COMES FROM THE SOUTHWEST AND SOUTH.
THE MAIN ENTRANCES OF THE BUILDING THEREFORE GOT PLACED TO THE NORTHEAST. A SECOND ENTRANCE IS ON THE SOUTHEAST FACADE. DUE TO WIND TRAPS, THE ENTRANCES ARE PROTECTED FROM WIND.

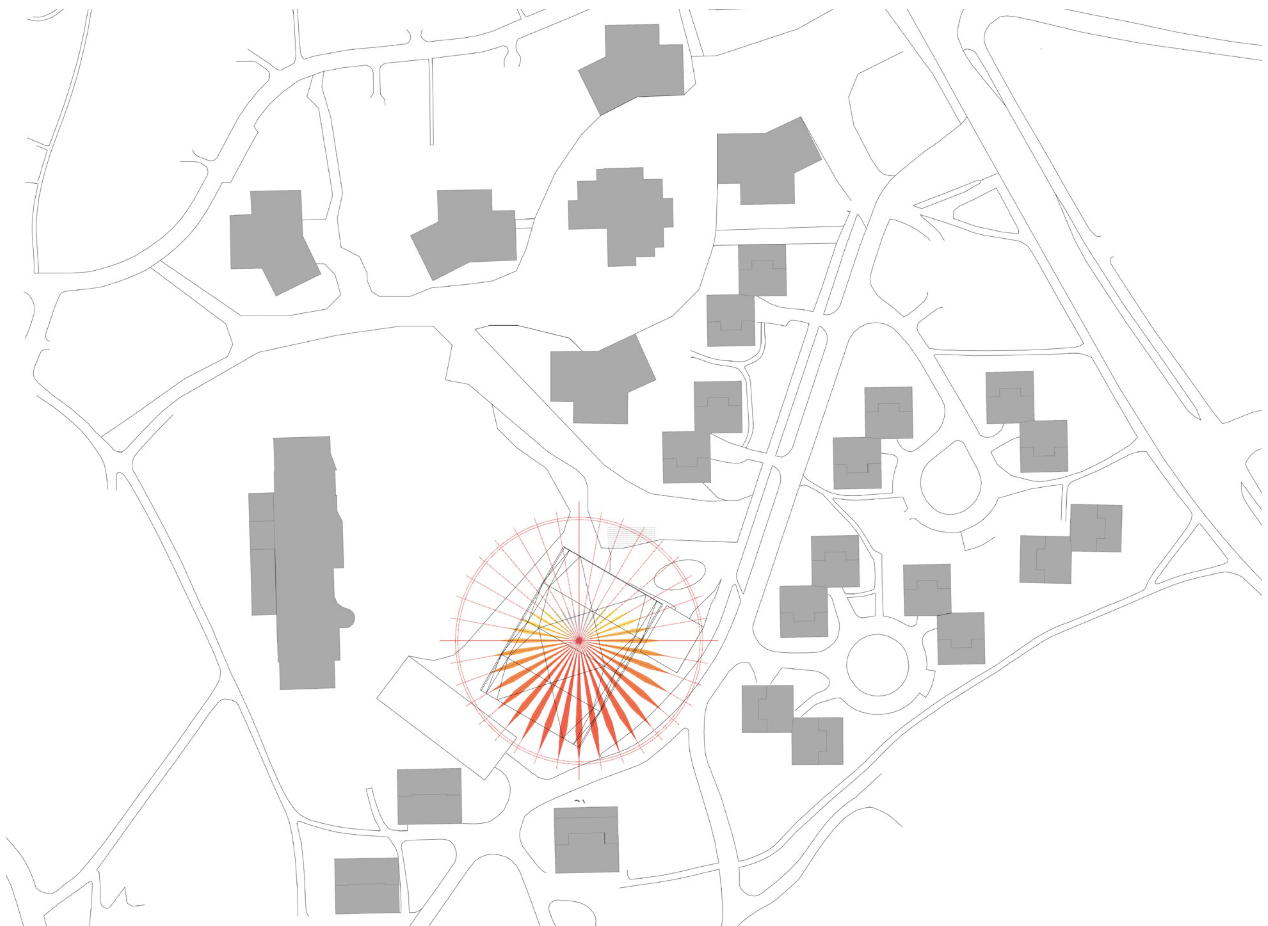


FIG 13. PLACEMENT ACCORDING TO SUNROSE

SUN STUDIES

IN ORDER TO HAVE THE BEST POSSIBLE ALIGNMENT OF THE SOLAR SYSTEM, THE SUN ROSE WAS PLACED ON THE PROPERTY AT THE BEGINNING OF THE DESIGN.
THE YEARLY SUNROSE SHOWS THE MAJORITY OF SOLAR RADIATION COMES FROM THE SOUTH, SOUTH-WEST, AND SOUTH-EAST THROUGHOUT THE YEAR. WITH THAT IN MIND, THE PLACEMENT FOR THE PV PANELS WAS CHOSEN.

FORM AND STRUCTURE

THE DEVELOPMENT OF THE GREENHOUSE CONSTRUCTION IS SHOWN IN FIGURE 15.
THE FORM OF THE GREENHOUSE ROOF WAS INSPIRED BY THE JAPANESE FOLDING TECHNIQUE, CALLED ORIGAMI SHOWN IN FIGURE 14. TO AVOID WATER COLLECTIONS ON THE ROOF AS IN THE FIRST SKETCH, THE FOLDING TECHNIQUE CHANGED. FURTHER THE SHAPE OF THE GREENHOUSE DEVELOPED TO SERVE AN OPTIMAL ANGLE FOR THE PV PANELS ON THE ROOF.

THE GREENHOUSE EXISTS OUT OF 36 MAIN TRIANGLES. THESE ARE EACH DIVIDED INTO SMALLER GLASS ELEMENTS.

THE MAIN STRUCTURE OF THE GREENHOUSE IS CROSS-LAMINATED TIMBER BEAMS THAT ARE JOINT TOGETHER. THE CROSS-SECTION OF THE BEAMS ARE 400X400MM.
TO FIX THE WINDOWS ON TOP OF THE GREENHOUSE, A SUBSTRUCTURE OUT OF 60x100 MM BATTENS WAS DEVELOPED. THE DISTANCE BETWEEN THE SUBSTRUCTURE BEAMS IS 2000 MM.

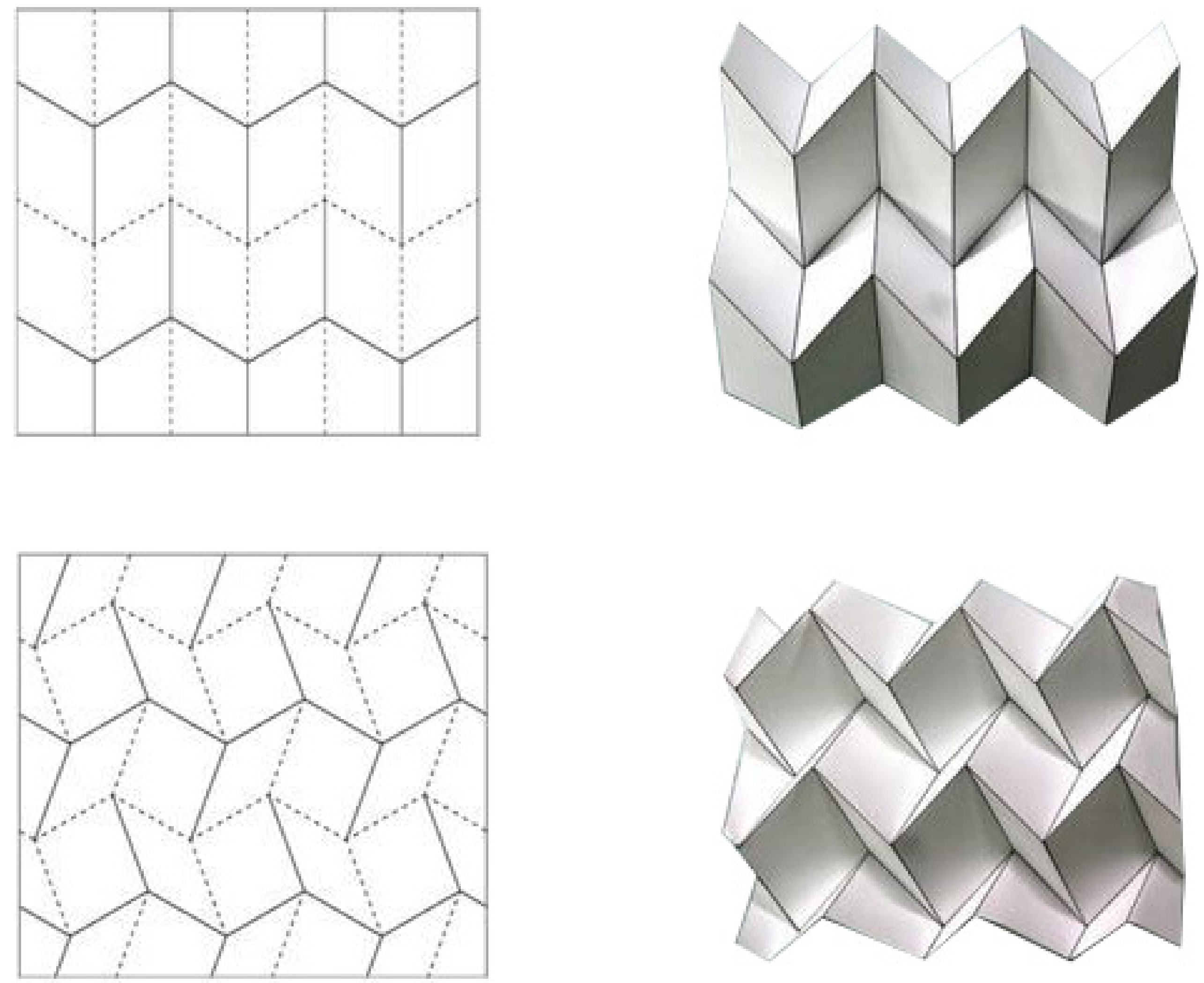


FIG 14. FOLDING TECHNIQUES

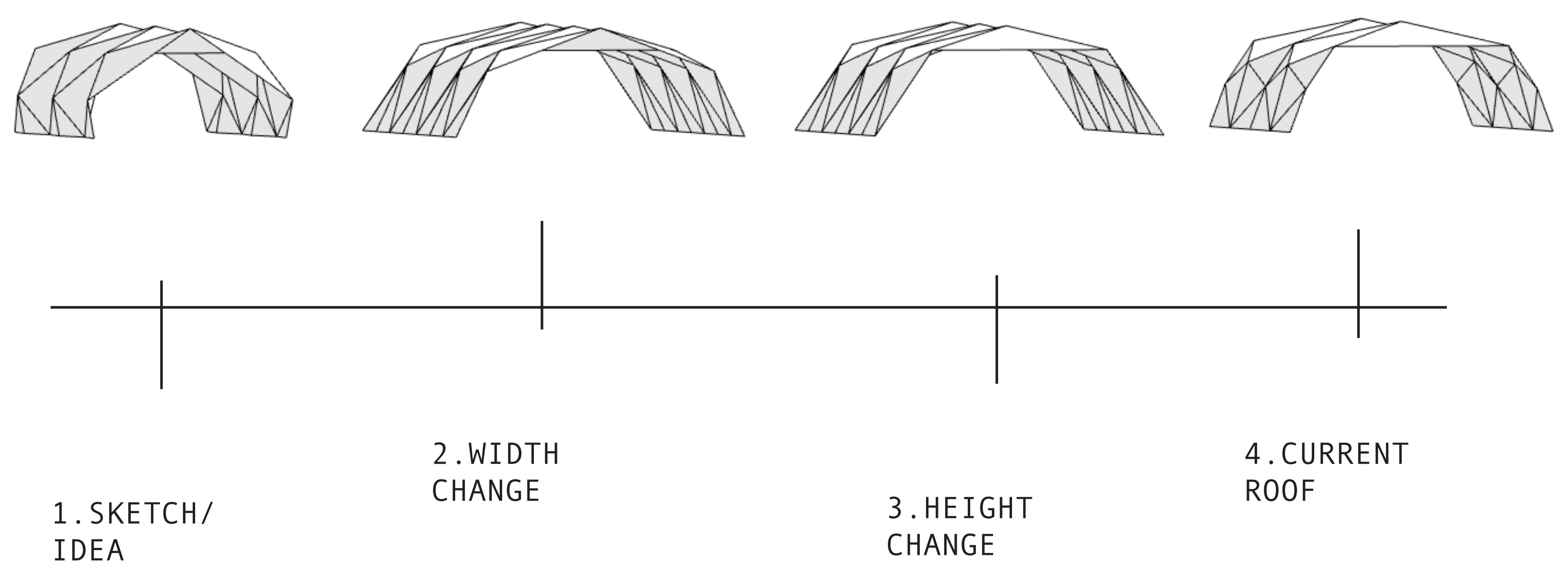


FIG 15. TIMELINE OF ROOF DEVELOPMENT

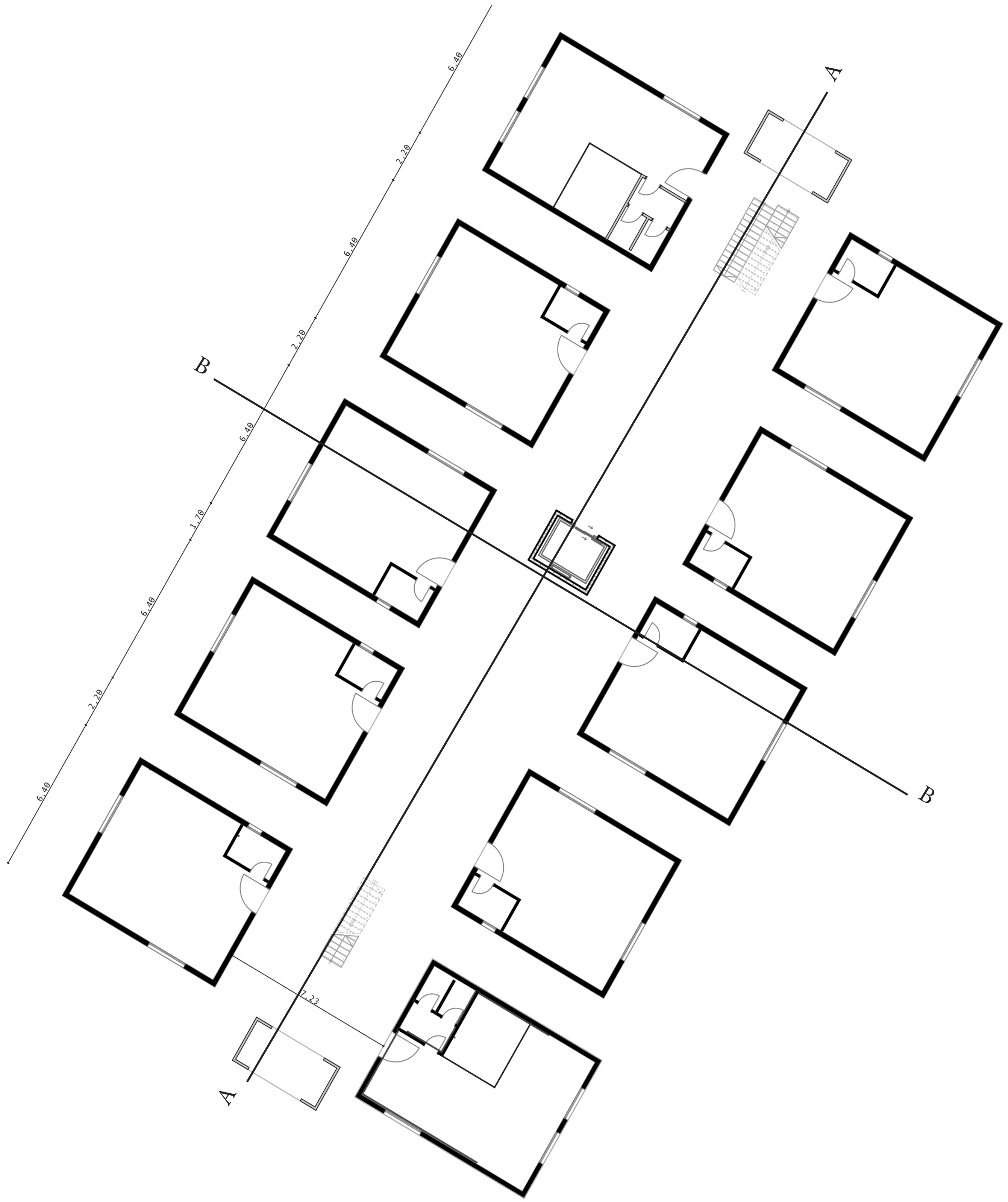


FIG 16. LAYOUT GROUNDFLOOR

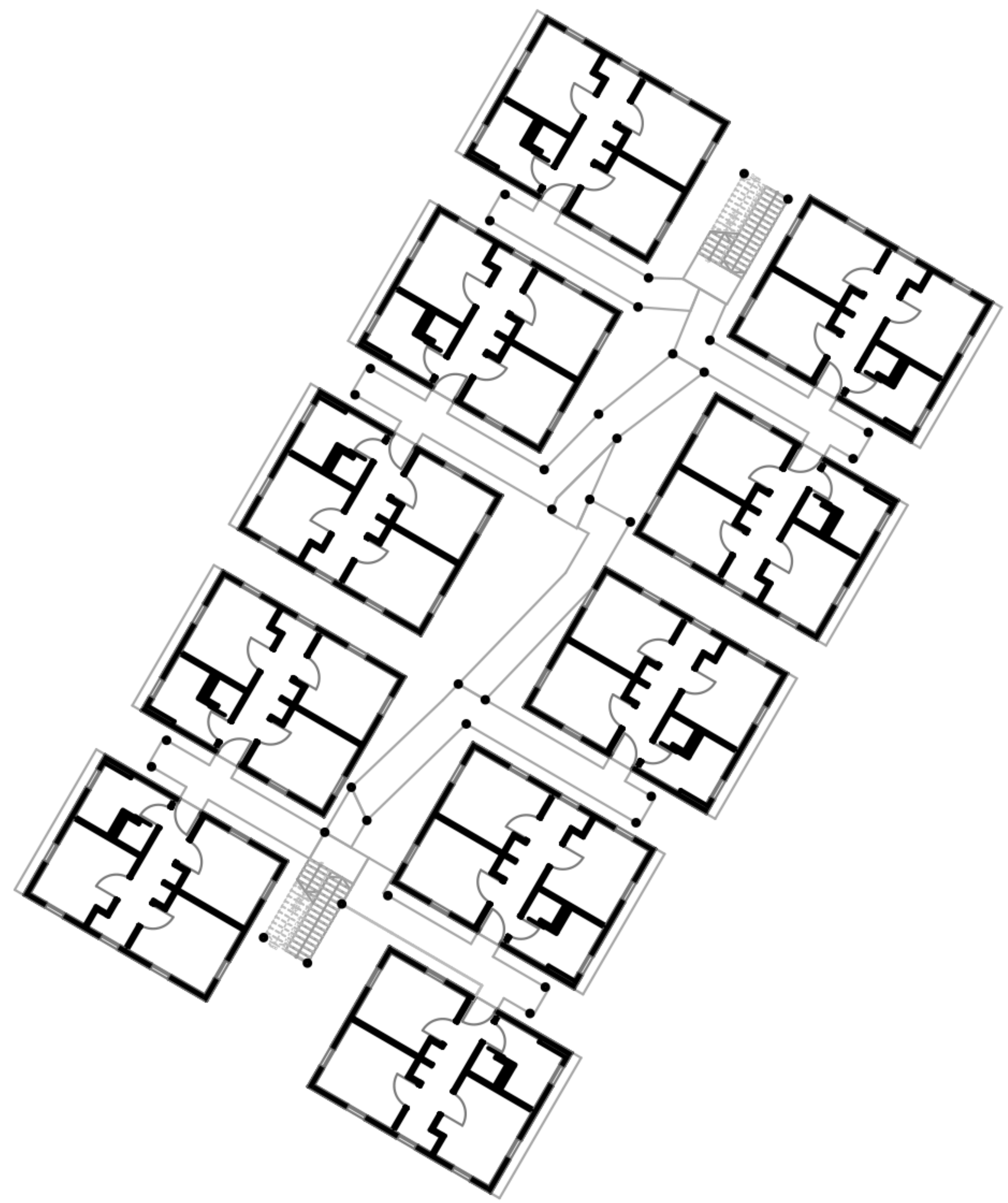


FIG 17. LAYOUT FLOORPLAN 1.FLOOR

THE GROUND FLOOR SERVES TO ACCESS THE BUILDING AND THE OTHER FLOORS. THE CENTRAL ZONE FOLLOWS THE PRINCIPLE OF A STREET WITH SINGLE-FAMILY HOUSES. THE ENTRANCES TO THE RESPECTIVE LIVING ROOMS AND STUDIEROOMS ARE ACCESSIBLE FROM A CENTRAL PATH AND AN ELEVATOR IN THE MIDDLE OF THE BUILDING. THE MIDDLE ZONE CAN BE USED FOR DIFFERENT ACTIVITIES, AS SHOWN IN FIGURE 26.

ON THE FIRST FLOOR, DORM ROOMS AND BATHROOMS ARE PLACED. EACH DORM ROOM BOX HAS THREE STUDENT ROOMS AND ONE BATHROOM. TWO STAIRS, ONE TO THE NORTH AND ONE TO THE SOUTH SERVE THE HANGING BRIDGES THAT LEAD TO EACH BOX.

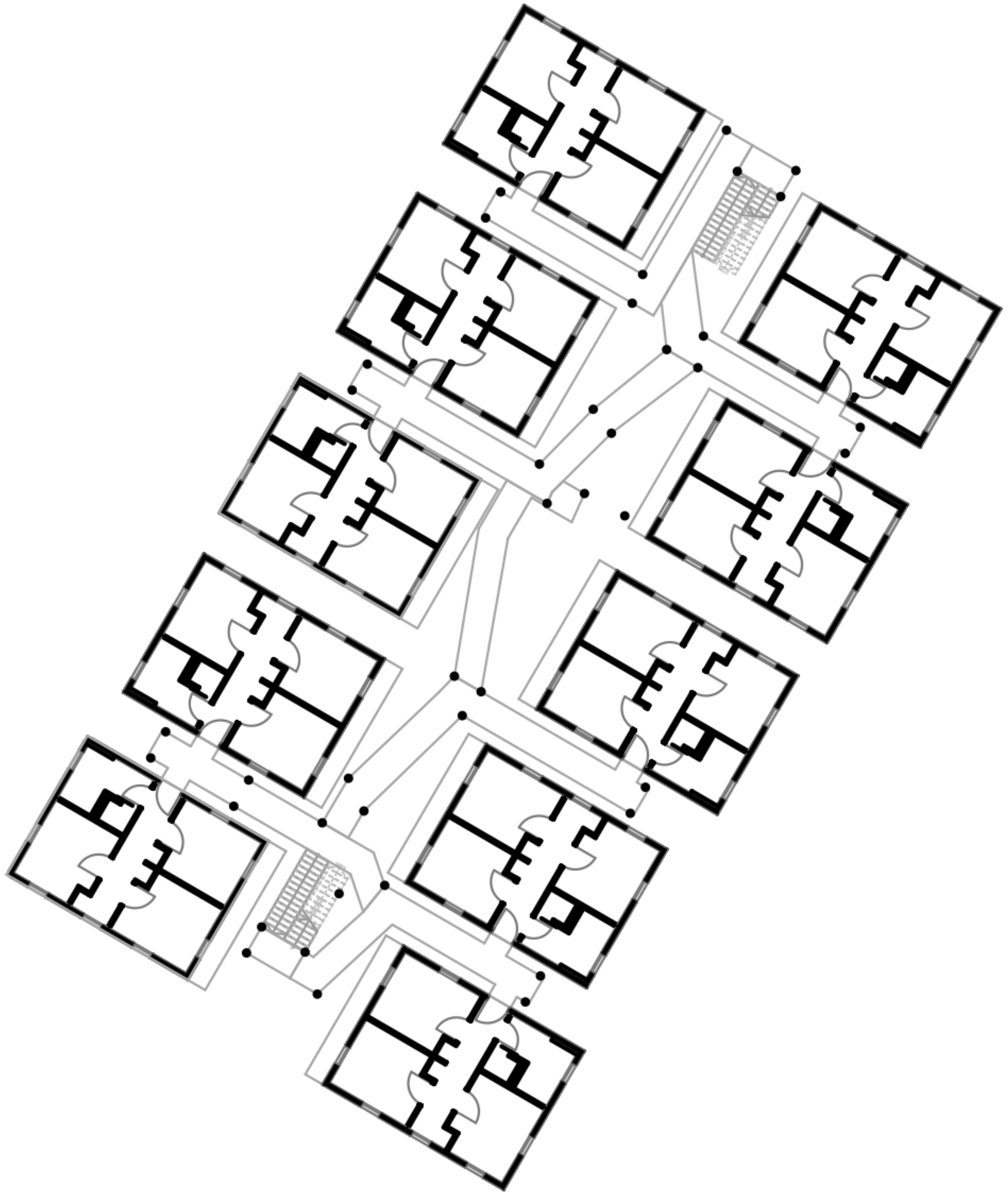


FIG 18. LAYOUT FLOORPLAN 2.FLOOR

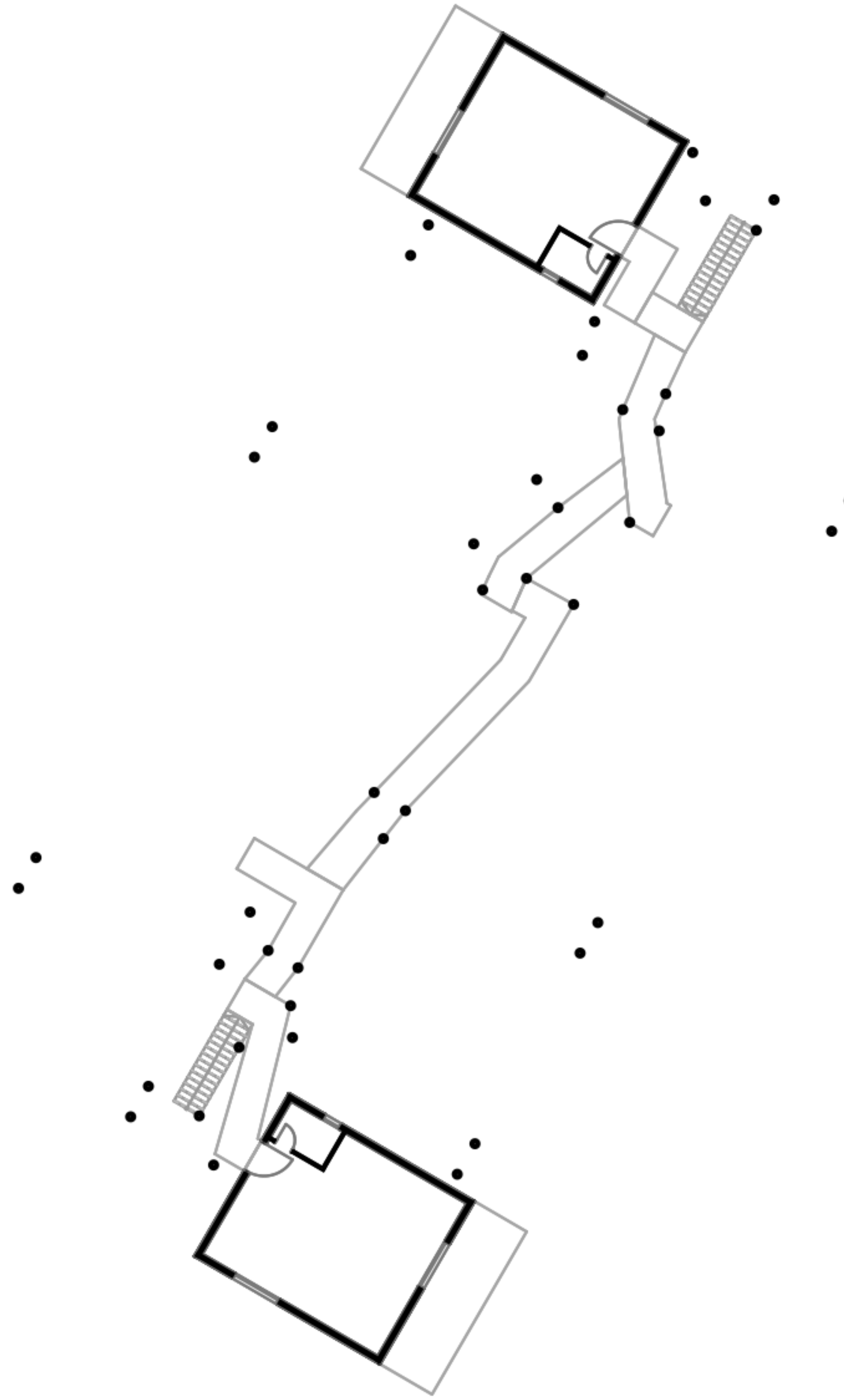


FIG 19. LAYOUT FLOORPLAN 3.FLOOR

THE SECOND FLOOR SERVES THE SAME PURPOSE AS THE FIRST FLOOR. TEN DORM ROOM BOXES ARE PLACED PER STOREY AND THEREFORE HOST 30 STUDENTS. A CENTRALY PLACED ELEVATOR ENSURES AN ACCESSIBLE DEVELOPEMENT.

TO HAVE THE TWO STUDIEROOMS ON THE GROUND FLOOR, THE LIVING ROOMS OF THESE UNITS ARE ELEVATED TO THE TOP FLOOR. INSTEAD OF HAVING A PRIVATE GARDENING AREA BEHIND THE LIVING ROOM, THESE TWO LIVING ROOMS ARE HAVING A ROOF TERRACE.

FLOORPLAN STUDIEROOM

THE STUDY AREAS ARE PLACED TO THE NORTH AND SOUTH OF THE BUILDING. THIS ENSURES A HIGHER DAYLIGHT FACTOR, IN ADDITION TO THE FLOOR-TO-CEILING WINDOW FACING NORTH / SOUTH. EACH STUDIEROOM HAS WORKPLACES FOR EIGHT STUDENTS AND AN ADDITIONAL MEETING ROOM FOR FOUR PEOPLE. TO HAVE A HIGHER COMFORT, A BATHROOM FOR TWO IS PLACED INSIDE AS WELL.

THE STUDIEROOM CAN BE USED BY ALL STUDENTS LIVING INSIDE THE BUILDING. BY HAVING COMMON WORK AREAS, GROUP WORK AND ALSO SOCIAL INTERACTIONS ARE EASIER.

FIG 20. FLOORPLAN STUDIEROOM 1:50

FLOORPLAN LIVINGROOM

EIGHT OUT OF TEN LIVING ROOMS ARE PLACED ON THE GROUND FLOOR. THE TWO OTHER ONES ARE IN THE 3. FLOOR AND SWITCHED POSITION WITH THE STUDIEROOMS.
A LIVING ROOM AND KITCHEN ARE USED BY SIX STUDENTS, THAT LIVE ABOVE OR BELOW THE LIVING ROOM AND SERVES AS THE COMMON AREA OF ONE COLLECTIVE. THE LAYOUT OF THE LIVING ROOM IS FLEXIBLE AND CAN BE USED DIFFERENTLY ACCORDING TO THE NEEDS OF THE STUDENTS. A GUEST TOILET IS ADDED, TO DECREASE WALKING DISTANCES TO THE ROOMS UPSTAIRS / DOWNSTAIRS.

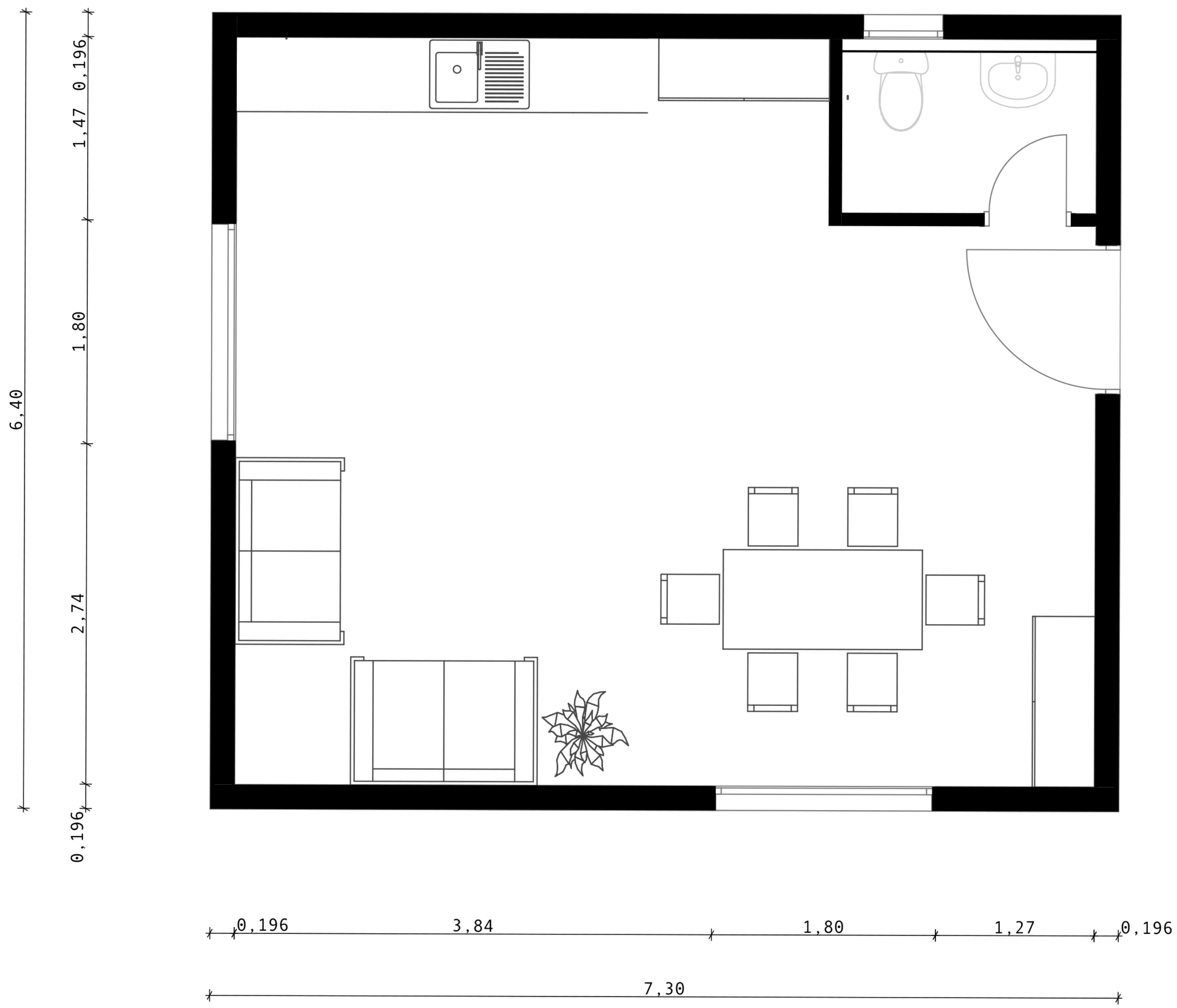


FIG 21. FLOORPLAN LIVINGROOM 1:50

FLOORPLAN DORM ROOM

EACH DORM ROOM BOX HAS SPACE FOR THREE STUDENTS. THE ROOMS ARE SIMILAR IN SIZE AND LAYOUT. A BATHROOM WITH A SEPARATE TOILET AREA IS LOCATED TO THE WEST / EAST. EACH ROOM HAS SPACE FOR A BED, WORK DESK, CLOSET, AND A SMALL SOFA. THE FLOOR-TO-CEILING HIGH WINDOWS ENSURE SUFFICIENT DAYLIGHT. A GLAZED ENTRANCE DOOR AND A LARGE WINDOW ON THE OPPOSITE SIDE OF THE HALLWAY ARE GIVING DAYLIGHT TO THAT AREA. EACH ROOM HAS A STORAGE AND WARDROBE AREA NEXT TO THEIR ENTRANCE DOOR FOR ADDITIONAL STORAGE.

FIG 22. FLOORPLAN DORMROOM 1:50

ROOM	AREA	
STUDIEROOM	TOTAL	46,46
STUDIE AREA		32,51
TOILETS		5,66
MEETINGROOM		7,31
LIVING ROOM / KITCHEN	TOTAL	41,81
KITCHEN		38,30
TOILET		2,66
DORMROOM	TOTAL	47,84
ROOM 1		9,98
ROOM 2		9,98
ROOM 3		9,87
BATHROOM		7,47

TAB 1. AREAS IN M2

FIG 23. ELEVATION / SECTION A-A 1:250

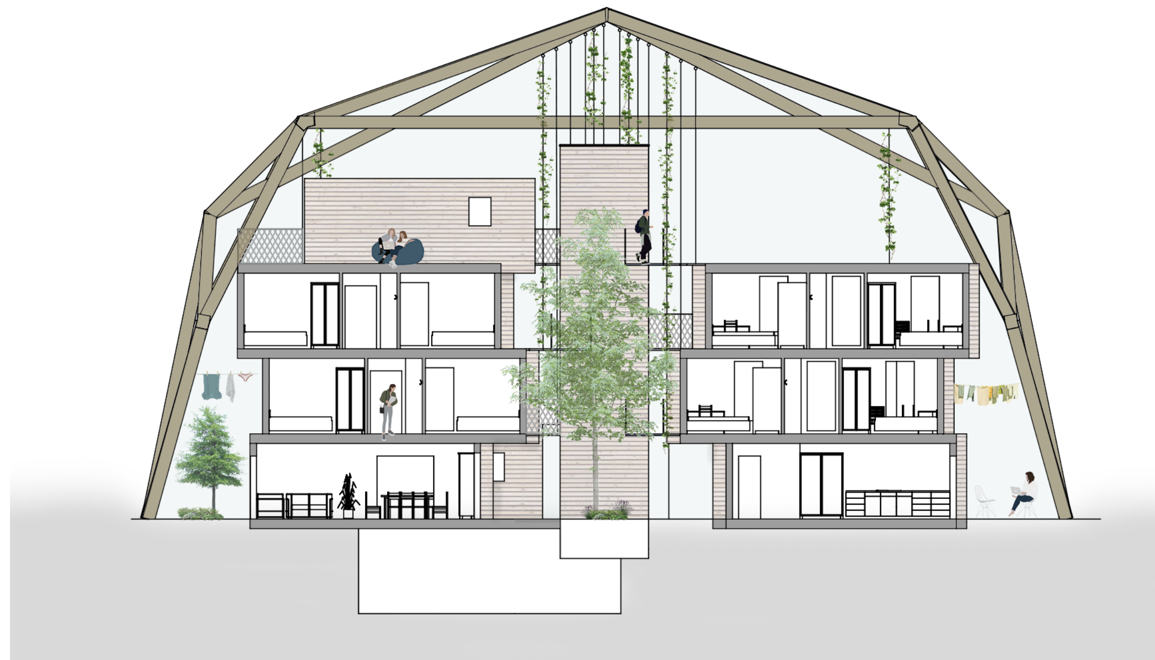


FIG 24. SECTION B-B 1:250

SECTION A-A

FIGURE 23 SHOWS A NORTH-SOUTH SECTION / ELEVATION THROUGH THE WHOLE BUILDING. THE ELEVATOR AND PARTS OF THE STAIRS ARE CUT, AS WELL AS THE TECHNICAL ROOM IN THE BASEMENT. THE FIGURE SHOWS THE BUILDING AND FACADE MATERIALS AND CONSTRUCTION. THE METAL CABLES THAT ARE HOLDING THE STAIRS AND WALKWAY BRIDGES ARE PLANTED WITH HANGING PLANTS. MORE PRIVATE GARDENING AREAS ON THE BACK OF THE BOXES AND GREENERY IN THE MIDDLE OF THE BUILDING ARE SHOWN.

SECTION B-B

FIGURE 24 SHOWS A SECTION FROM WEST TO EAST. IN ADDITION TO MORE PRIVATE GARDENING AREAS, THE BACK OF THE BOXES CAN BE USED FOR ADDITIONAL SEATING AND CLOTH DRYING. THE SECTION SHOWS THE LIVING ROOM AND DORM ROOMS CUT, AS WELL AS THE FACA-DE MATERIALS. TWO OF THE TOP ROOF CAN ALSO BE USED AS COMMON AREAS WITH LOUNGE FURNITURE.

PLACEMENT + LANDSCAPING

FIG 25. SITE PLAN 1:1000

FIG 26. ACTIVITY PLAN 1:200

ACTIVITY PLAN

AS EXPLAINED ABOVE, THE CONCEPT OF THIS THESIS PROJECT, IS TO ENCOURAGE STUDENTS TO SOCIALIZE MORE AND INCREASE THE INTERACTION BETWEEN THE PEOPLE LIVING IN THE STUDENT HOUSING.

THE GREENHOUSE AS THE STUDENT HOUSE SURROUNDING LEADS TO A COMFORTABLE CLIMATE AND CAN THEREFORE BE USED MORE OFTEN THAN THE OUTSIDE AREAS IN TRONDHEIM.
DIFFERENT GREEN AREAS IN THE GREENHOUSE CAN BE USED FOR MORE PRIVATE GARDENING IN THE BACK OF THE HOUSES AND MORE SILENT READING AREAS.
THE ROOM BETWEEN THE HOUSES AND THE GREENHOUSE CAN ALSO BE USED FOR DRYING CLOTHES. THIS ASIDE FROM THE PRACTICAL SIDE, LEADS TO A COMFORTABLE CLIMATE INSIDE THE GREENHOUSE.
THE MIDDLE PART OF THE BUILDING IS DESIGNED BY THE EXAMPLE OF A VILLAGE AND THE MAIN STREET WITH THE ENTRANCES TO THE LIVING ROOMS.
THE MIDDLE ZONE CAN BE USED FOR BOULE OR BOCCIA PLAYS AND IS THEREFORE TILED. A GREENED AREA SERVES AS A RELAXING AND GATHERING SPOT.

PLACEMENT

THE BUILDING IS PLACED CENTRALLY ON THE SITE. THE PLOT IS FILLED WITH EXISTING SOIL TO GET ONE LEVEL. THAT RESULTS IN A MORE DEROGATORY TERRAIN IN THE NORTH. A STAIRCASE LEADS DOWN TO THE MOHOLT LIBRARY AND GYM.

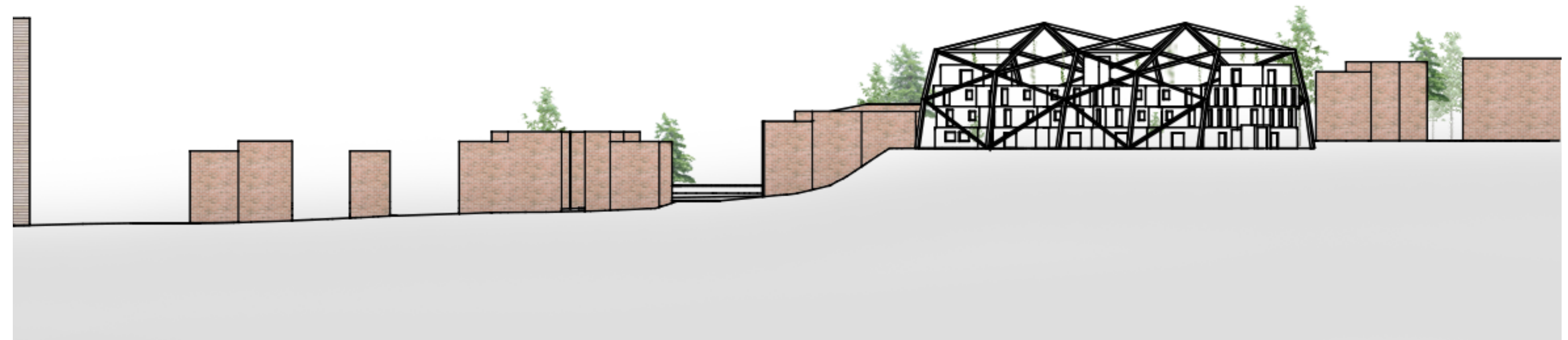


FIG 27. SITE SECTION 1:1000

RADIATION ANALYSIS

SOLAR STUDIES WERE MADE TO SHOW THE MOST EFFICIENT PLACEMENT OF THE PV PANELS ON THE ROOF OF THE GREENHOUSE. FIGURE 28 SHOWS THE SOUTH FACING SURFACES RECEIVE AROUND 1000 kWh PER m2 PER YEAR.

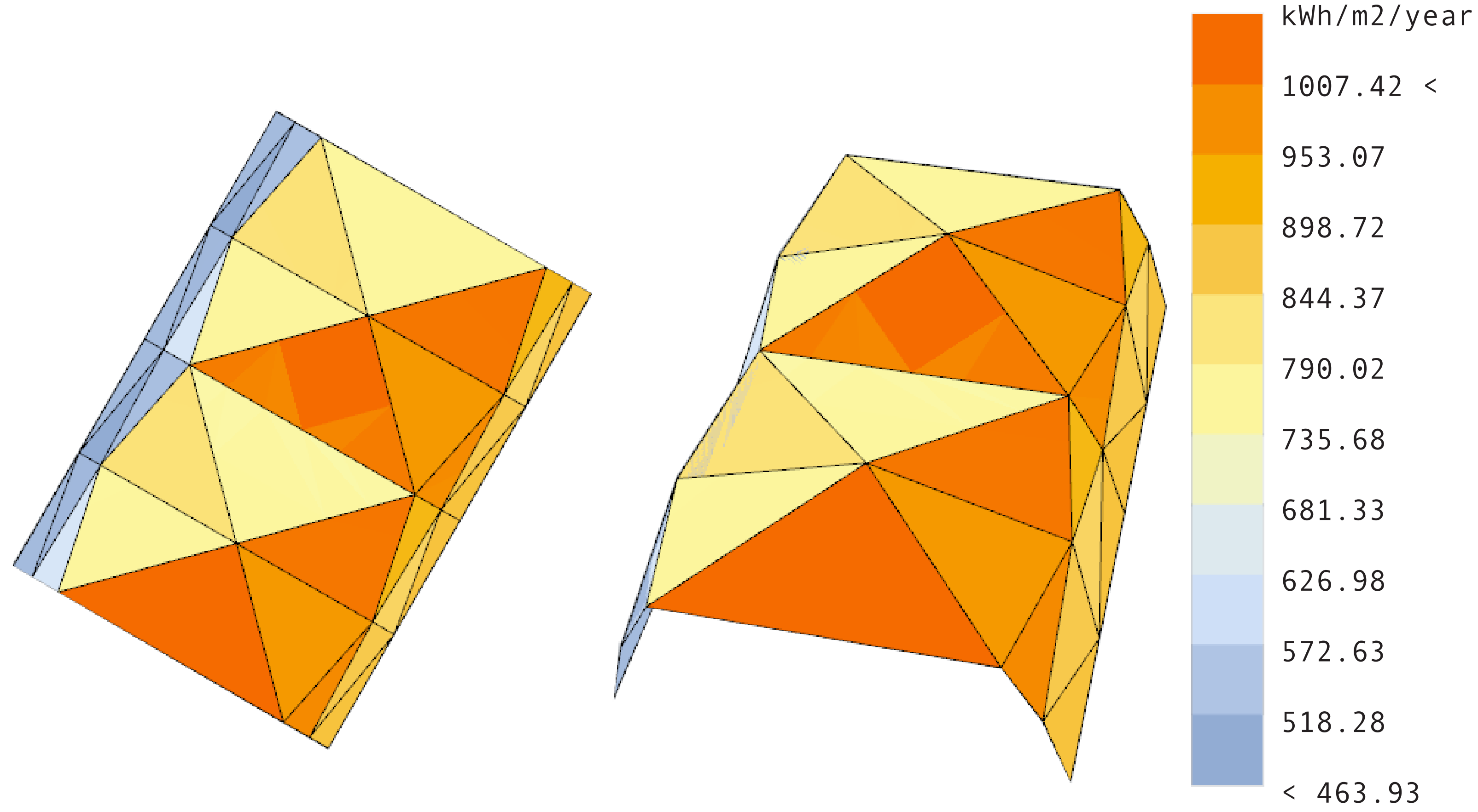


FIG 28. SOLAR ANALYSIS

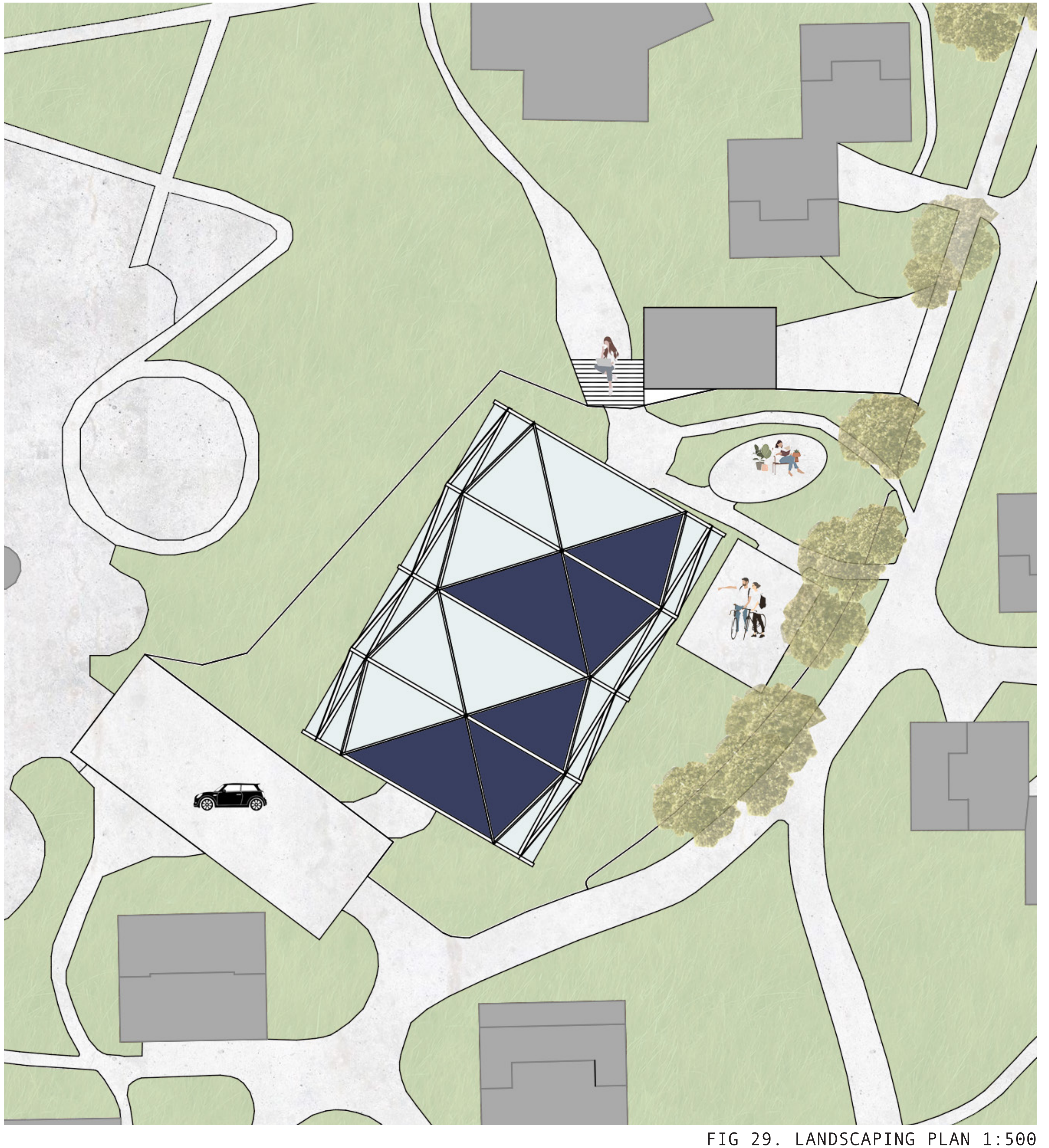


FIG 29. LANDSCAPING PLAN 1:500

LANDSCAPING

THE FORECOURT OF THE MAIN ENTRANCE IS MOSTLY GREEN. IN THE MIDDLE IS AN ISLAND AREA WITH SEATING OPPORTUNITIES. THE STAIRCASE THAT LEADS TO THE MOHOLT LIBRARY AND CONNECTS HAUGENHUSET WITH THE REST OF MOHOLT STUDENTBY IS A SPACIOUS STAIRCASE THAT CAN ALSO BE USED FOR SEATING.

ON THE EAST OF THE BUILDING, BIKE PARKING IS PROVIDED. THE PARKING SPACES ON THE SOUTH SIDE OF THE BUILDING HAVE BEEN RETAINED AND CAN BE USED BY BOTH KINDERGARTEN STAFF AND RESIDENTS OF HAUGENHUSET.

PASSIVE STRATEGIES

NATURAL VENTILATION GREENHOUSE

AS A PASSIVE STRATEGY TO COOL THE GREENHOUSE IN SUMMER AND PROVIDE FRESH AIR IN WINTER, NATURAL VENTILATION IS USED. ON THE LOWER PART OF THE FACADE, TILT WINDOWS ARE USED TO LET OUTSIDE AIR IN. ON THE HIGHEST PARTS OF THE ROOF CONSTRUCTION, PUSH WINDOWS ARE PLACED TO LET WARM AIR OUT OF THE GREENHOUSE. THIS TYPE OF OPENING WAS CHOSEN TO AVOID RAINWATER INSIDE THE GREENHOUSE. THEREFORE BUILDING MATERIALS ON THE BOXES HAVE BEEN SAVED SINCE THE FACADE OF THE BOXES WILL NOT BE EXPOSED TO OUTSIDE WEATHER.

IN WINTER, THE HEATED AIR IN THE TOP PART OF THE ROOF WILL BE GATHERED AND SUCKED IN THROUGH FLOOR SHAFTS IN THE MIDDLE ZONE OF THE BUILDING. THE HEAT WILL BE REUSED.

NATURAL VENTILATION BOXES

ALL ROOMS, BESIDES THE BATHROOMS, ARE DESIGNED TO WORK BY CROSS VENTILATION. THEREFORE, NATURAL VENTILATION IS ENSURED BY MANUAL WINDOWS OPENING.

ROOF-TO-CEILING HIGH WINDOWS PROVIDE SUFFICIENT DAYLIGHT TO ALL ROOMS. THEREFORE, ARTIFICIAL LIGHT USAGE CAN BE REDUCED TO A MINIMUM.

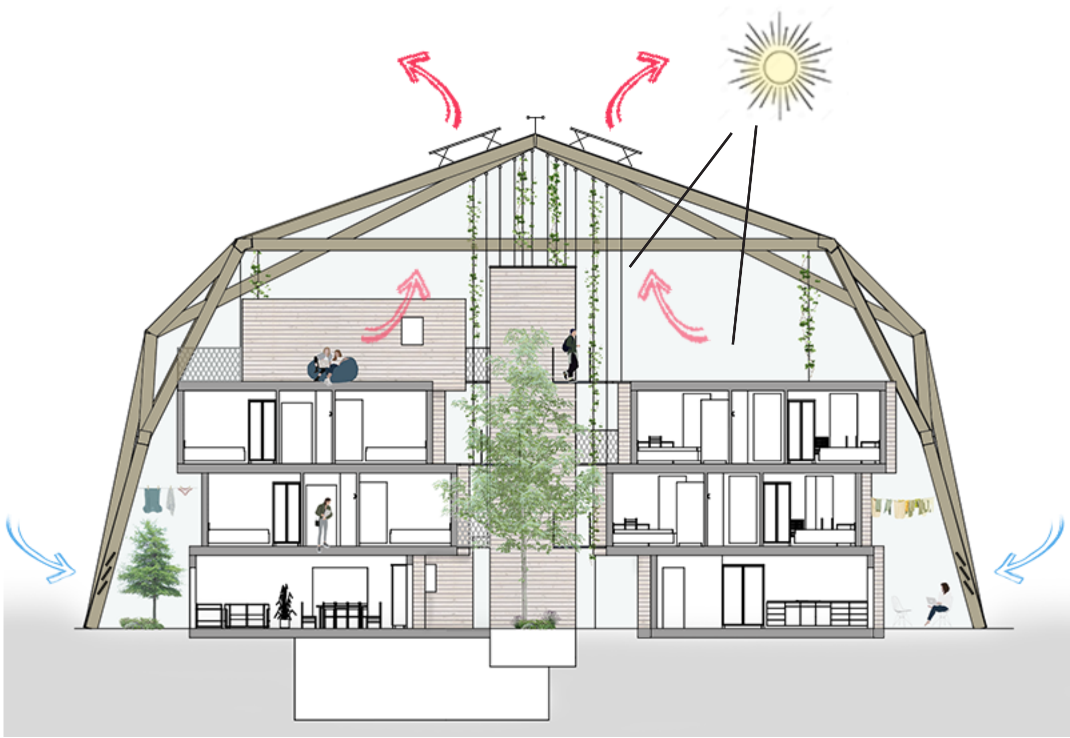


FIG 30. BIOCLIMATIC SECTION B-B GREENHOUSE SUMMER

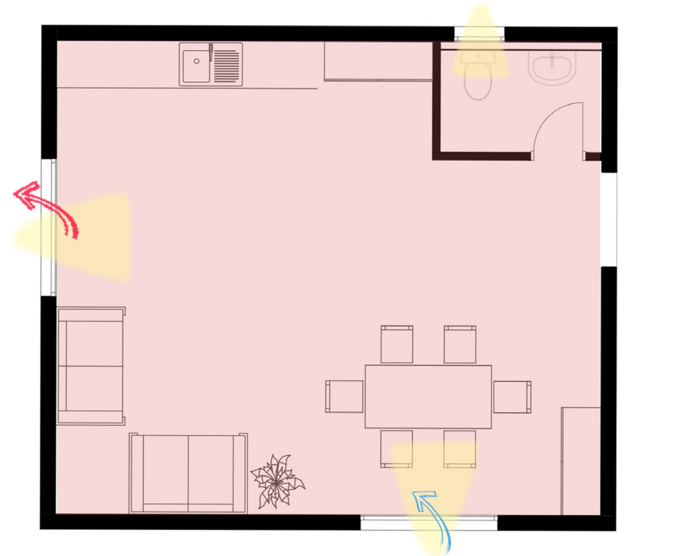


FIG 32.PASSIVE STRATEGIES LIVINGROOM

FIG 33. PASSIVE STRATEGIES STUDIEROOM

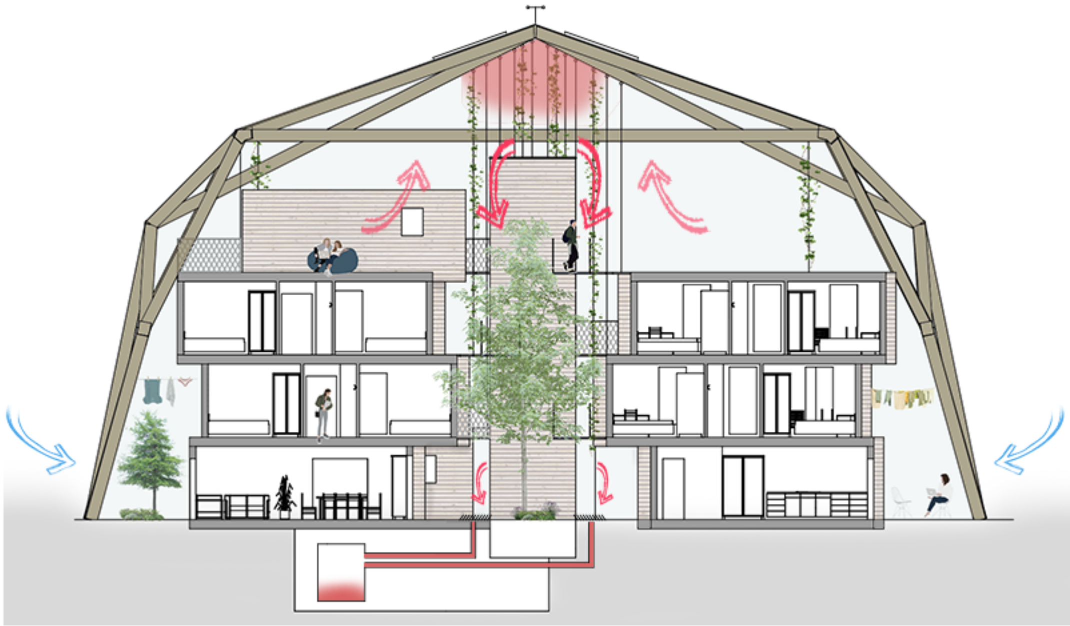


FIG 31. BIOCLIMATIC SECTION B-B GREENHOUSE WINTER

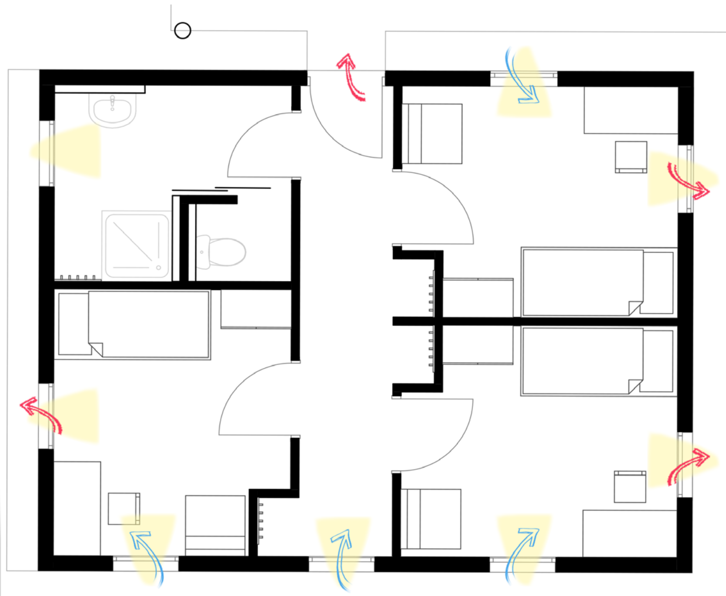


FIG 34. PASSIVE STRATEGIES DORMROOM

DAYLIGHT

THE WINDOWS OF THE FOUR DIFFERENT BOX TYPOLOGIES ARE DESIGNED TO PROVIDE THE ROOM WITH AS MUCH DAYLIGHT AS POSSIBLE IN ADDITION TO FUNCTIONALITY AND NATURAL VENTILATION.

LIVING ROOMS

THE LIVING ROOMS ON THE GROUND FLOOR AND THIRD FLOOR ARE EQUIPPED WITH TWO FLOOR-TO-CEILING WINDOWS TO PROVIDE AS MUCH DAYLIGHT INTO THE LIVING AREA AND TO USE THE WEST AND EAST-FACING WINDOWS AS A BALCONY DOOR. IN ADDITION TO THE TWO 1800mm x 2000mm WINDOWS, THE ENTRANCE DOOR IS GLAZED. IN THE BATHROOM, A SMALLER WINDOW FOR FRESH AIR IS PLACED (700 x 900 MM).

DORM ROOMS

THE DORMROOMS ARE DESIGNED WITH TWO FLOOR-TO-CEILING WINDOWS (900 MM x 2200 MM) TO ENSURE CROSS VENTILATION AND TO ENLARGE THE DAYLIGHT IN THE ROOMS. AS AN EXCEPTION, THE ROOM FACING THE WALKWAYS HAS ONE SMALLER WINDOW (900 MM x 1200 MM) FOR MORE PRIVACY. THE BATHROOM HAS A 900 MM x 1200 MM WINDOW FACING TO THE WEST OR EAST OF THE BUILDING. THEREFORE THE DAYLIGHT FACTOR IN THE BATHROOM IS LOWER THAN IN THE DORM ROOMS. TO ENSURE DAYLIGHT IN THE HALLWAY, THE ENTRANCE DOOR IS GLAZED AND MIRRORS WITH THE WINDOWS ON THE OPPOSITE SIDE.

STUDIEROOM

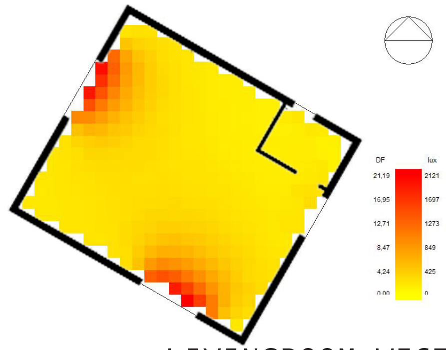
THE STUDY AREAS OF THE BUILDING HAVE WINDOWS FACING TO THE NORTH AND WEST / SOUTH AND EAST. IN ADDITION TO THE FLOOR-TO-CEILING WINDOWS TO THE NORTH / EAST (1800 MM x 2000 MM) AND THE TWO WINDOWS FACING WEST / EAST (1500 MM x 1200 MM), BOTH OF THE RESTROOMS ARE EQUIPPED WITH A WINDOW.

THERMAL MASS

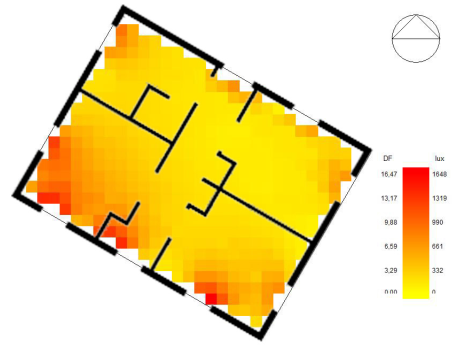
THERMAL MASS INSIDE THE GREENHOUSE IS CREATED BY USING BRICK TILES FOR THE PATHWAYS THAT LEADS TO THE ENTRANCE DOORS OF THE LIVING ROOMS.

INSIDE THE LIVING ROOM, EXPOSED CONCRETE FLOORS PROVIDE THERMAL MASS TO STORE HEAT. THE EXPOSED CONCRETE FLOORING IS SHOWN IN RED IN FIGURE 32 AND 33.

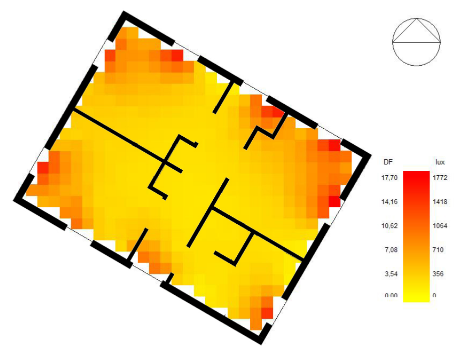
FIG 35. DAYLIGHT FACTORS OF THE FOUR BOX TYPOLOGIES



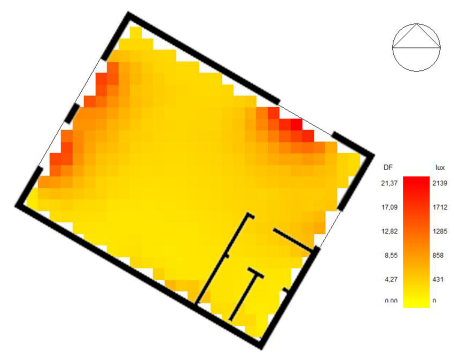
LIVINGROOM WEST



1.FLOOR DORMROOMS



2.FLOOR DORMROOMS



STUDIEROOM WEST

TAB 2. AVERAGE DAYLIGHT FACTOR PER BOX

ROOM	DAYLIGHT FACTOR
GROUNDFLOOR	
WEST	
LIVINGROOM 1	3,584
LIVINGROOM 2	1,594
LIVINGROOM 3	2,232
LIVINGROOM 4	1,817
STUDIEROOM	4,469
EAST	
STUDIEROOM	4,204
LIVINGROOM 1	2,333
LIVINGROOM 2	1,536
LIVINGROOM 3	1,915
LIVINGROOM 4	2,298

ROOM	DAYLIGHT FACTOR
1. FLOOR	
WEST	
DORMROOM 1	3,493
DORMROOM 2	3,069
DORMROOM 3	1,972
DORMROOM 4	2,142
DORMROOM 5	2,903
EAST	
DORMROOM 1	3,416
DORMROOM 2	1,825
DORMROOM 3	1,929
DORMROOM 4	1,930
DORMROOM 5	3,053

ROOM	DAYLIGHT FACTOR
2. FLOOR	
WEST	
DORMROOM 1	3,828
DORMROOM 2	3,069
DORMROOM 3	3,459
DORMROOM 4	3,939
DORMROOM 5	3,400
EAST	
DORMROOM 1	3,485
DORMROOM 2	3,673
DORMROOM 3	3,181
DORMROOM 4	3,295
DORMROOM 5	4,233

ROOM	DAYLIGHT FACTOR
3. FLOOR	
WEST	
LIVINGROOM	3,585
EAST	
LIVINGROOM	3,539

ACTIVE STRATEGIES

GROUND SOURCE ENERGY

IN THE COURSE OF THE PROJECT MOHOLT 50/50, THE AREA WAS EQUIPPED WITH A GROUND-SOURCE HEAT PUMP. THE HEAT PUMP PROVIDES HEATING AND COOLING TO THE NEW TOWER BUILDINGS.
THE SYSTEM CONTAINS THREE 84 kW UNITS.
FOR THIS PROJECT IT WAS ASSUMED THAT THE SYSTEM HAS ENOUGH SPARE CAPACITY TO PROVIDE DOMESTIC HOT WATER AND SPACE HEATING.

Effekt- og energibehov og varmetilskudd fra belysning, utstyr, varmtvann og personer

	Driftstid timer/døgn/uker	Netto effektbehov (i driftstiden) W/m^2	Årlig netto energibehov $kWh/(m^2 \cdot år)$	Varmetilskudd (i driftstiden) W/m^2
Belysning	16/7/52	1,95	11,4	1,95
Utstyr	16/7/52	3,00	17,5	1,80
Varmtvann	16/7/52	5,10	29,8	0,00
Personer	24/7/52	–	–	1,50
Sum	–	–	58,7	–

MERKNAD Det er forutsatt at 100 % av effekt- og energibruken til belysning og 60 % av effekt og energibruken til utstyr går over til varme i bygningen, og resten av varmen går tapt i sluk og avluft ved bruk av utstyr som vaskemaskin, oppvaskmaskin og tørketrommel.

FIG 36. EXTRACT FROM NS-3700

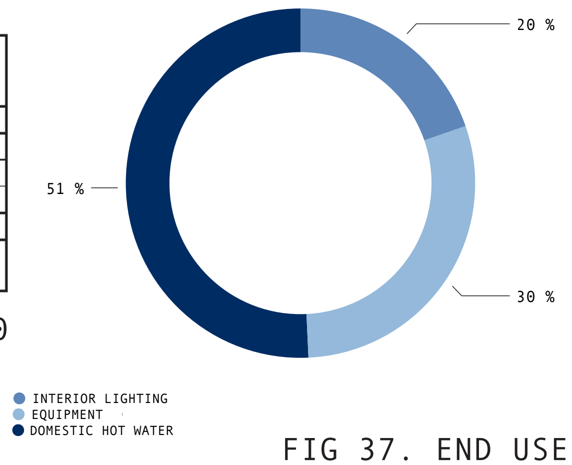


FIG 37. END USES

END USES	kWh
INTERIOR LIGHTING	15617,50
EQUIPMENT	23449,53
DOMESTIC HOT WATER	40222,68
TOTAL OF PEOPLE	60

TAB 3. END USES IN kWh

RENEWABLE ENERGY

THE GREENHOUSE STRUCTURE SERVES AS A PHOTOVOLTAIC PANEL SUBSTRUCTURE TO PRODUCE RENEWABLE ELECTRICITY ON SITE. TO ENSURE A HIGH IRRADIATION LEVEL (kWh/m2), THE ROOF IS SHAPED WITH A 18 DEGREE ANGLE. THE SURFACES ARE USED FOR PV ARE CHOSEN DEPENDING ON THE RADIATION STUDIES, DISCUSSED ABOVE. THE TOTAL PV AREA USED IS 509,9 M2.

THE MODULES USE IN THIS MASTER THESIS PROJECT ARE SCHÜCO 50+ FROM THE COMPANY SCHÜCO. GLASS PANELS ARE CHOSEN TO ENSURE AN EVEN FINISH AND A SIMILAR CONSTRUCTION TO THE REMAINING GLASS PANELS OF THE GREENHOUSE. THE PRODUCT REACHES AN EFFICIENCY OF 10 PERCENT.

THE GREENHOUSE WAS MODELLED IN DESIGN BUILDER AND THE PHOTOVOLTAIC PRODUCTION WAS CALCULATED IN THE SAME SOFTWARE.
THE BUILDING GENERATES 68,27 kWh/m2. THEREFORE THE BUILDING GENERATES A TOTAL OF 34810.527 kWh PER YEAR.

AS SHOWN IN TABLE 4, THE ENERGY LOSSES OF THE PV PANELS ARE 1832,13 kWh.

PHOTOVOLTAIK POWER	36642,660
POWER CONVERSION	-1832,13
TOTAL ON-SITE ELECTRIC SOURCES	34810,527

TAB 4. ELECTRIC LOADS IN kWh

FIG 38. SOLAR PANEL TYPE SCHÜCO 50+

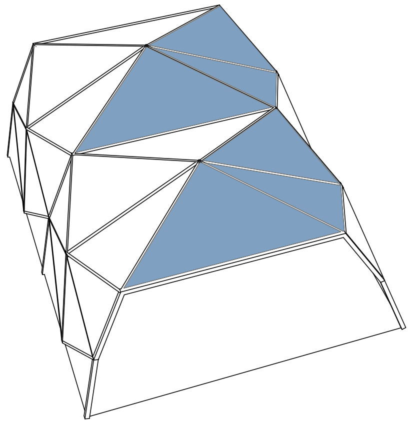


FIG 39. PV POSITIONING

DOMESTIC HOT WATER

THE DOMESTIC HOT WATER WAS CALCULATED BY FOLLOWING THE NS-3700 STANDARD OF RESIDENTIAL PASSIVE HOUSES. THEREFORE IT WAS ASSUMED A WATER CONSUMPTION OF 35 LITERS PER PERSON PER DAY, LIVING IN THE BUILDING.

60 PERSONS x 35 LITER = 2.100 LITERS PER DAY

THE MOHOLT 50/50 PROJECT USES A GREYWATER HEAT RECOVERY SYSTEM. A SIMILAR SYSTEM CAN BE USED FOR THIS PROJECT AS WELL TO REDUCE THE ENERGY FOR HEATING THE WATER.
EACH GROUNDFLOOR BOX, EXCEPT THE STUDIEROOMS, HAS ITS HOT WATER TANK. IN THAT CASE, ONE TANK CAN SERVE ONE KITCHEN AND TWO BATHROOMS. HAVING THE WATER TANKS CENTRAL SAVES WATER PIPE LENGTH AND ALSO HELPS THE WATER TO REACH THE DESIRED TEMPERATURE FASTER.

HEATING

THE STUDIEROOM HAS A HOT WATER BOILER IN THE BATHROOM. FROM THERE, 3 RADIATORS ARE SERVED. ONE IN THE MEETING ROOM AND TWO IN THE ACTUAL STUDIEROOM.
IN THE LIVING ROOM, A HOT WATER BOILER IS PLACED IN THE KITCHEN TO SUPPLY DHW TO THE KITCHEN AND TOILET. THE RADIATOR IN THE LIVING ROOM GETS SERVED FROM IT.
THE BATHROOM AND TOILET IN THE DORM ROOMS ARE EQUIPPED WITH A UNDERFLOOR HEATING. A PIPE FROM THE KITCHEN BELOW SERVES IT.
EACH STUDENT ROOM IS HEATED BY A RADIATOR.

WATER REUSE

TO FULFILL THE SUSTAINABLE CONCEPT OF THE PROJECT, THE GREYWATER WILL BE FILTERED IN THE TECHNICAL ROOM OF THE BUILDING AND WILL AFTERWARDS BE USED TO WATER THE PLANTS IN THE GREENHOUSE.

IN ADDITION TO THAT, THE WATER USED FOR THE PLANTS, ALSO HELPS TO ACHIEVE A COMFORTABLE CLIMATE INSIDE THE GREENHOUSE.

FIG 40. HEATING SUPPLY STUDIEROOMS

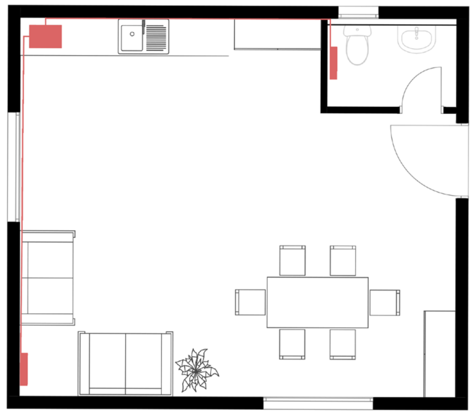


FIG 41. HEATING SUPPLY LIVINGROOMS

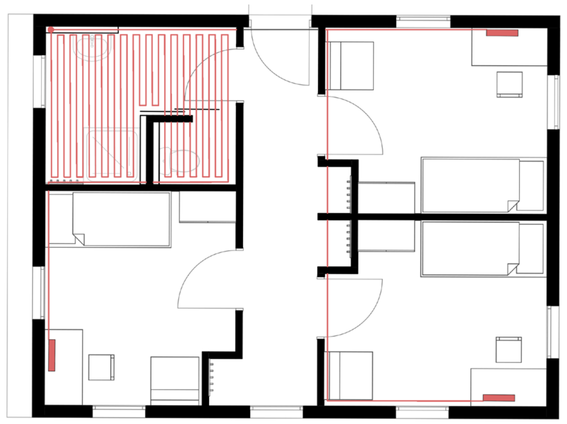


FIG 42. HEATING SUPPLY DORMROOMS

MATERIALS + DETAILS

MATERIALS

THE PROJECTS MAIN VISIBLE MATERIALS ARE WOOD, GLASS, PHOTOVOLTAIC PANELS, AND METAL GRILLES.

THE GREENHOUSE IS CONSTRUCTED WITH 400 MM x 400 MM BEAMS, THAT ARE TOPPED WITH A GLASS CONSTRUCTION AND GLAZED PV PANELS.

THE INNER LIVING AREA ARE PREFABRICATED WOOD-FRAME BOXES, THAT ARE STACKED ON TOP OF EACH OTHER. TO IMPROVE THE ACOUSTICS INSIDE THE GREENHOUSE, A WOODEN CLADDING IS ADDED TO THE FACADES OF THE BOXES.

THE WALKWAYS IN THE GREENHOUSE, THAT CONNECT THE BOXES WITH EACH OTHER, ARE OUT OF METAL GRILLES TO ENSURE AS MUCH DAYLIGHT TO THE BOXES BELOW AS POSSIBLE. THE BRIDGES ARE ATTACHED TO THE GREENHOUSE STRUCTURE BY METAL CABLES, THAT ARE GREENED WITH CLIMBING PLANTS.

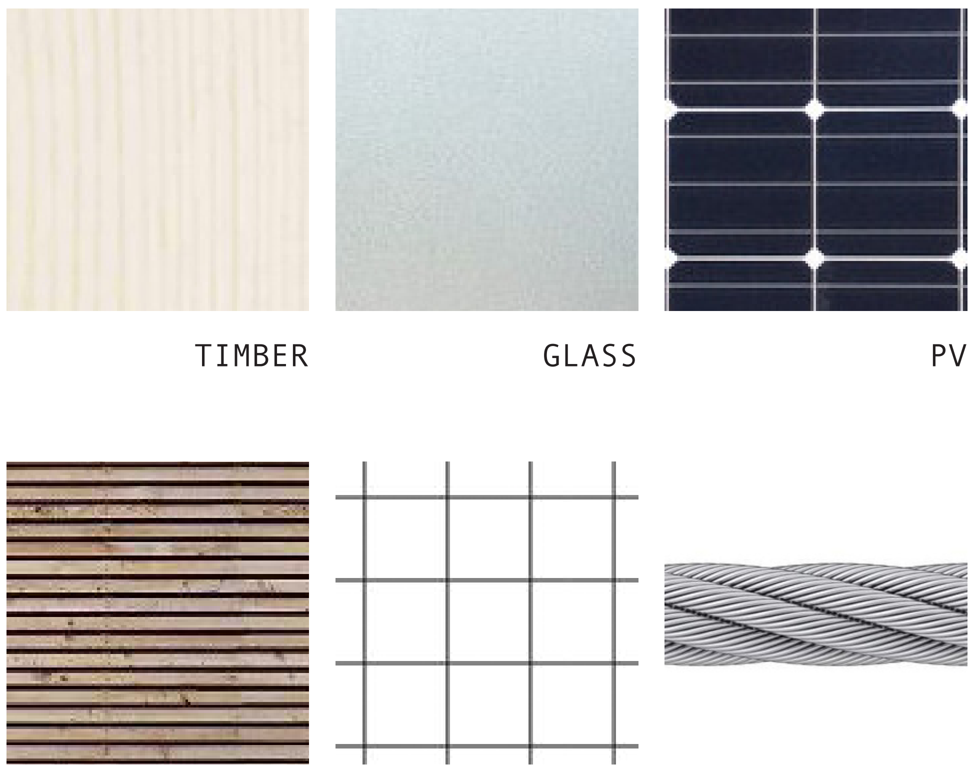


FIG 43. MATERIALS

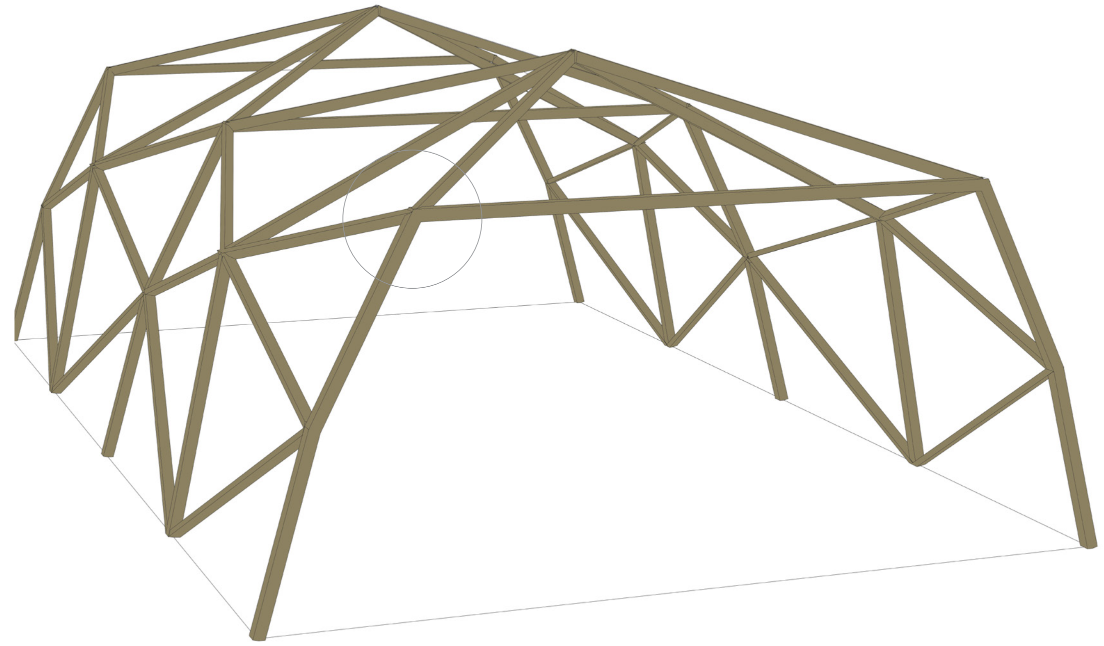


FIG 44. PERSPECTIVE GREENHOUSE WOODEN CONSTRUCTION

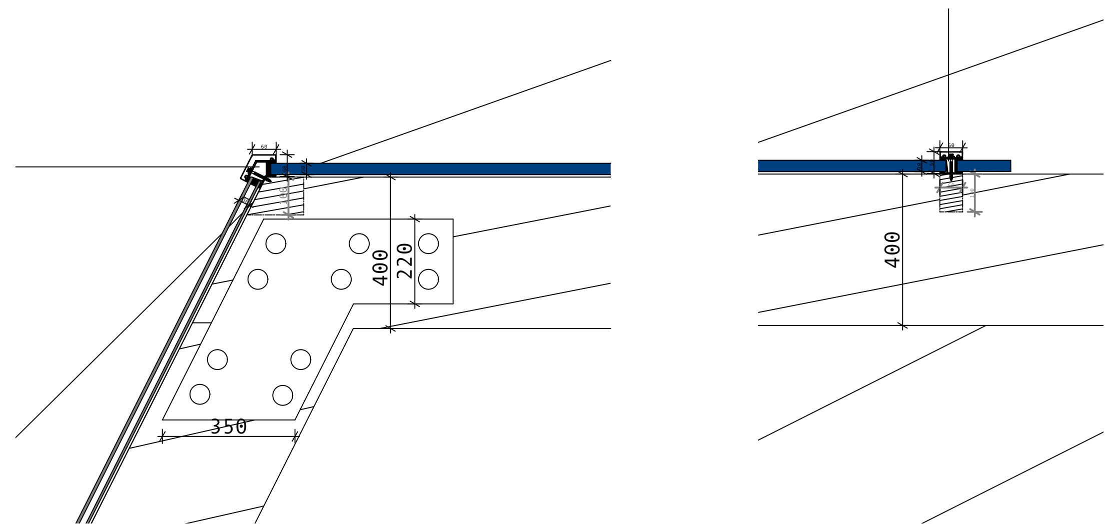


FIG 45. DETAIL 1 GREENHOUSE CONSTRUCTION 1:20

GREENHOUSE

THE GREENHOUSES MAIN CONSTRUCTION IS A CROSS LAMINATED TIMBER CONSTRUCTION WITH BEAMS OF 400 x 400 MM. AS A SUBSTRUCTURE FOR THE GLASS AND PV PANELS, SMALLER BATTENS OF 60x100 MM WITH A DISTANCE OF 2000 MM ARE PLACED. THESE BATTENS ARE ALSO ON THE NORTH AND SOUTH GLASS FRONT FACADE.

STRUCTURE

THE BOXES ARE OUT OF PREFABRICATED ELEMENTS. THE WALLS AND SLABS ARE WOODEN FRAME ELEMENTS WITH INSULATION IN BETWEEN. THE INSIDE IS COVERED WITH A PLASTER BOARD. TO GIVE THE BOXES AN EVEN FINISH, THE FACADES ARE COVERED WITH WOODEN CLADDING.

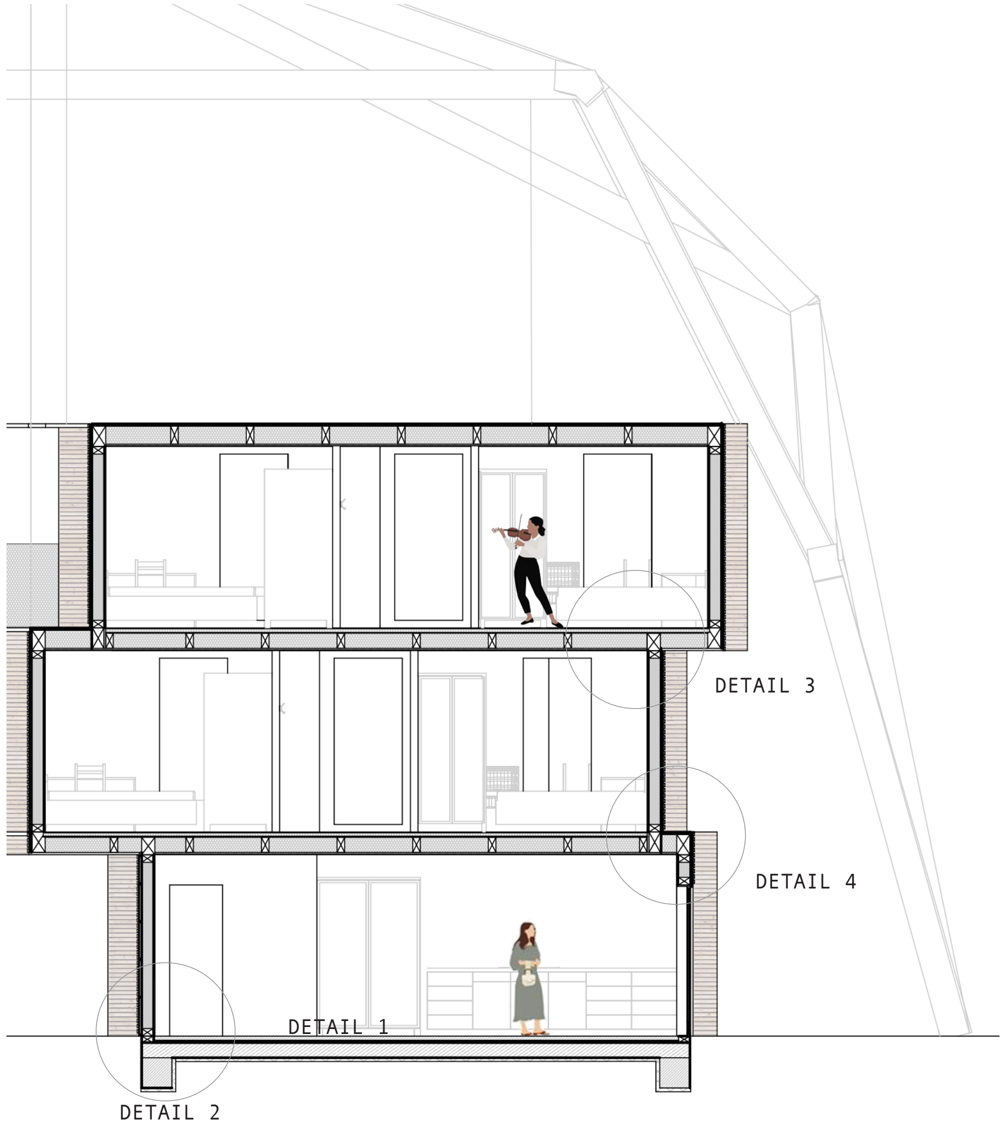


FIG 46. CONSTRUCTION SECTION OVERVIEW

FLOOR
- WOODEN FLOORING 10MM
-IMPACT SOUND INSULATION 50MM
-PLYWOOD 10MM
- JOIST 100 X 200MM
-EPS INSULATION 200MM
-PLYWOOD 20MM
-PLASTER BOARD 10MM

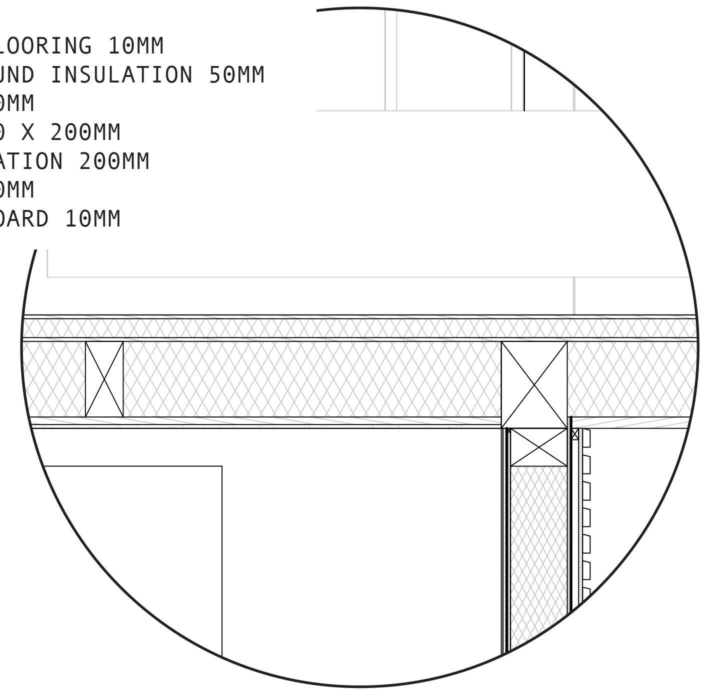


FIG 48. DETAIL 3 OVERHANG TO WALL 1:20

WALL
-EXTERIOR CLADDING 20MM
-VERTICAL BATTENS 10MM
-HORIZONTAL BATTENS 20MM
-FIBER BOARD INSULATION 10MM
-WINDBARRIER
-JOIST 150 X 200MM
-EPS INSULATION 150MM
-FIBER BOARD INSULATION 10MM
-PLYWOOD 10MM
-PLASTER BOARD 10MM

FOUNDATION
-EXPOSED CONCRETE FLOOR 60MM
-PLYWOOD 10MM
-CONCRETE FLOOR SLAB 200MM

-CONCRETE RINGWALL 400MM
-EPS INSULATION 50MM

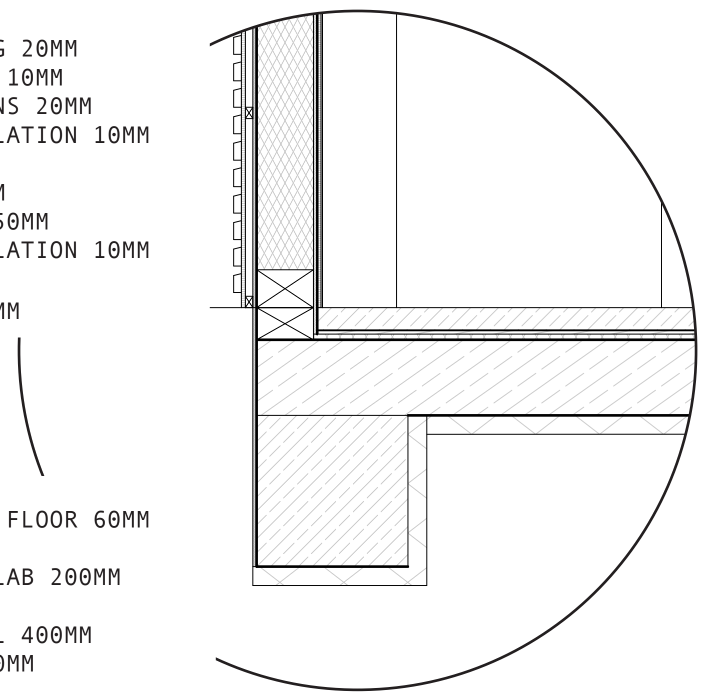


FIG 47. DETAIL 2 WALL TO FOUNDATION 1:20

OVERHANG ROOF
-WOOD BOARD 10MM
-HORIZONTAL BATTENS 20 X 30MM
-VAPOUR BARRIER
-FIBER BOARD INSULATION 10MM
-EPS INSULATION 240MM
-PLYWOOD 20MM
-PLASTER BOARD 10MM

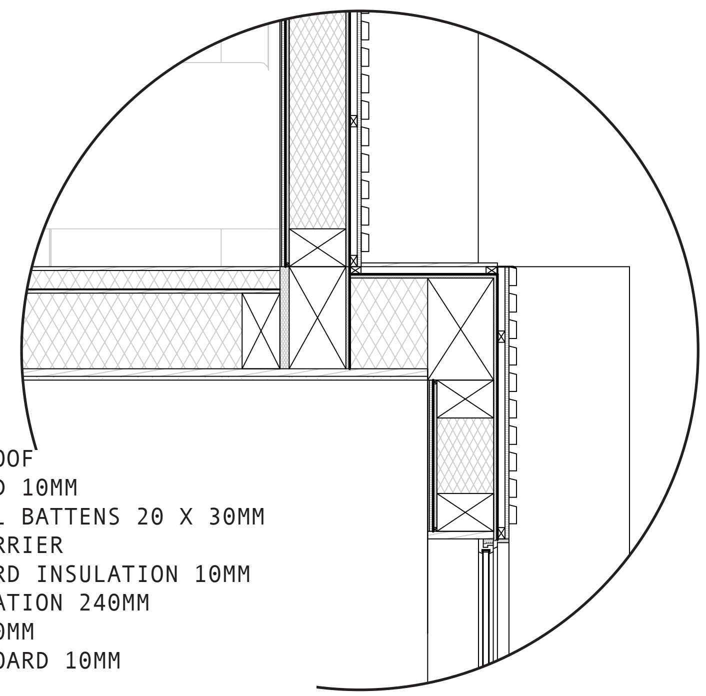


FIG 49. DETAIL 4 WALL TO ROOF 1:20

ACOUSTICS

TO IMPROVE THE ACOUSTICS INSIDE THE GREENHOUSE, WOODEN CLADDING AS FACADE MATERIAL ON THE BOXES IS USED.

ACCORDING TO TEK 17, A NUMBER OF AT LEAST 45 DECIBELS BETWEEN ROOMS IN STUDENT HOUSINGS ARE REQUIRED. AS OPPOSED TO OTHER RESIDENTIAL BUILDINGS, WHERE THE REQUIREMENT IS 54 DECIBEL (NORSK STANDARD NS-8175:2019 SOUND CLASS C), IN STUDENT HOUSING THE REGULATION IS LOWER.
ACCORDING TO TEK 17 STANDARD, THE INDOOR WALLS WERE DESIGNED TO ENSURE A NOISE REDUCTION LEVEL OF 45 DECIBELS.
TO REACH THIS GOAL, THE PARTITION WALLS ARE FILLED WITH INSULATION OF 100 MM.

FOUNDATIONS

GROUNDWORK AND FOUNDATIONS ARE COMMON IN CONCRETE. CONCRETE ACCOUNTS FOR A LARGE PART OF A BUILDINGS EMISSIONS. IN THIS THESIS, THE REGULATIONS FROM BYGGFORSK, A SLAB ON GRADE FOUNDATION WAS CHOSEN.
TO FINALIZE THE FOUNDATIONS DIMENSION, FURTHER RESEARCH ABOUT THE GROUND ON THE SITE NEEDS TO BE DONE. IN THE SCOPE OF THIS THESIS, THE DIMENSIONS ARE ESTIMATED ACCORDING TO THE BUILDINGS SIZES.
THE FOUNDATION OF THE BUILDING EXISTS OUT OF A 400 MM RING WALL, INSULATED FROM THE OUTSIDE WITH A 50 MM EPS INSULATION, ACCORDING TO THE INSULATION DIMENSIONS OF TRONDHEIM. A CONCRETE SLAB OF 200 MM ON THE GROUND FLOOR IS USED TO SUPPORT LOADS OF THE WALLS AND FURNITURE. OTHER THAN THAT, THE EXPOSED CONCRETE FLOOR OF 60MM SERVES AS THERMAL MASS AND REDUCES THE FLOORING MATERIAL.

WINDOWS + DOORS

FOR THIS PROJECT, DOUBLE GLAZED WINDOWS WITH A U-VALUE OF 1,493 W/M2-K ARE USED. A DOUBLE GLAZED WINDOW IS SUFFICIENT, IN ORDER TO THE GREENHOUSE.

THE DOORS ARE GLAZED WOODEN FRAME DOORS TO ENSURE A HIGHER DAYLIGHT FACTOR INSIDE THE ROOMS AND ALSO ENCOURAGE INTERACTIONS BETWEEN STUDENTS LIVING IN THE BUILDING.

LOCATION	THICKNESS mm
BELOW FOUNDATION	50
INSIDE OUTDOOR WALLS	150
INSIDE ROOF	240
INSIDE FLOOR	200

TAB 5. DIMENSIONS OF INSULATION

LCA BALANCE

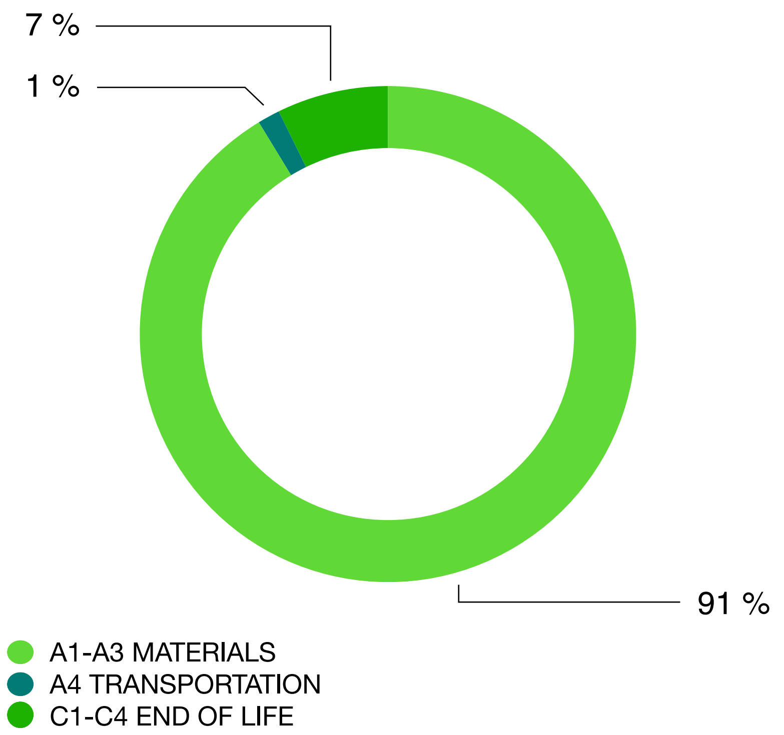


FIG 50. LIFE CYCLE STAGES

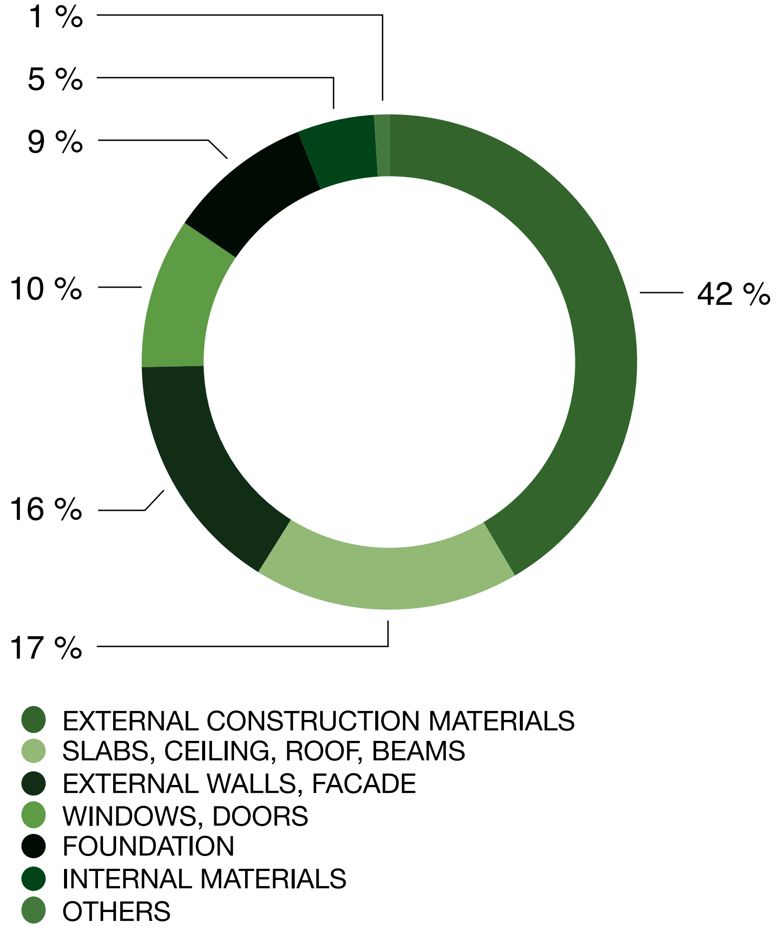


FIG 51. CLASSIFICATIONS

LCA

THE TOTAL EMBODIED EMISSIONS FROM REPLACEMENT AN MATERIAL PRODUCTION IS 48.6663,36 KGCO.

91% OF THE EMISSIONS ARE FROM MATERIALS. TRANSPORTING THE GOODS TO THE SITE MAKES A TOTAL OF 7%. THE REPLACEMENT AT THE END OF LIFE MARKS 1%.

MOST EMISSIONS ARE COMING FROM EXTERNAL CONSTRUCTION MATERIALS SUCH AS THE GLASS FACADE FOR THE GREENHOUSE, PV PANELS, AND THE METALL STAIRCASES AND BRIDGES. 17% RESULTS FROM SLABS, CEILINGS, AND ROOFS. NEARLY THE SAME AMOUNT IS FROM EXTERNAL WALLS AND FACADES.
THE FOUNDATIONS ARE RESPONSIBLE FOR 9% OF THE TOTAL EMISSIONS. 10% ARE FROM WINDOWS AND DOORS. THIS NUMBER DOES NOT INCLUDE THE GLASS FACADE OF THE GREENHOUSE.

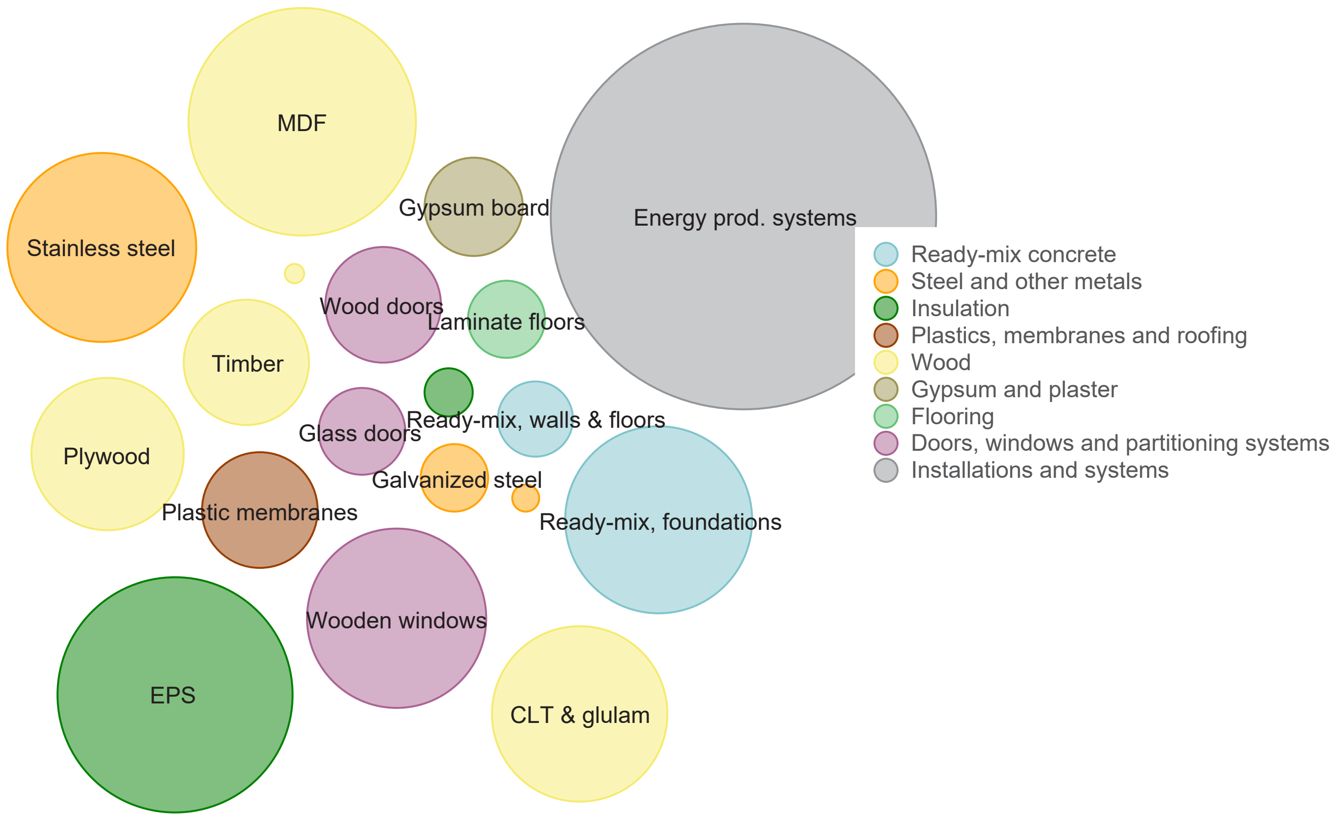


FIG 52. TOTAL LIFE CYCLE IMPACT BY RESOURCE

FIG 53. LCA BALANCE

Section	Resource	User input	Unit	Global warming kg CO	Acidification kg
A1-A3	Stainless steel products, 7850 kg/m3 (Øglænd System)	0,02	m3	731,62	9,64
A1-A3	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	91,77	m3	8286,83	41,3
A1-A3	Solar panel photovoltaic system, EU average	509,9	m2	91881,72	542,23
A1-A3	Galvanized steel staircase, indoor use (Lonbakken)	630	kg	1688,4	4,42
A1-A3	Aluminium window system, per m2, 1230 x 1480 mm, 76.54 kg/unit, 42.05 kg/m2, AWS 90.SI+ (Schüco)	1289,4	m2	195206,6	581,98
A1-A3	Stainless steel products, 7850 kg/m3 (Øglænd System)	4113,76	kg	19170,12	252,58
A4	Stainless steel products, 7850 kg/m3 (Øglænd System)	0,02	m3	0,3	0,0014
A4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	91,77	m3	619,89	2,85
A4	Solar panel photovoltaic system, EU average	509,9	m2	567,56	2,3
A4	Galvanized steel staircase, indoor use (Lonbakken)	630	kg	8,93	0,041
A4	Aluminium window system, per m2, 1230 x 1480 mm, 76.54 kg/unit, 42.05 kg/m2, AWS 90.SI+ (Schüco)	1289,4	m2	124,56	0,57
A4	Stainless steel products, 7850 kg/m3 (Øglænd System)	4113,76	kg	7,88	0,036
C1-C4	Stainless steel products, 7850 kg/m3 (Øglænd System)	0,02	m3	0,13	0,00075
C1-C4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	91,77	m3	4838,13	6,56
C1-C4	Solar panel photovoltaic system, EU average	509,9	m2	376,92	2,03
C1-C4	Galvanized steel staircase, indoor use (Lonbakken)	630	kg	0,51	0,003
C1-C4	Aluminium window system, per m2, 1230 x 1480 mm, 76.54 kg/unit, 42.05 kg/m2, AWS 90.SI+ (Schüco)	1289,4	m2	147,96	1,16
C1-C4	Stainless steel products, 7850 kg/m3 (Øglænd System)	4113,76	kg	3,32	0,02
D	Stainless steel products, 7850 kg/m3 (Øglænd System)	0,02	m3	-441,74	-2,45
D	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	91,77	m3	-28639,53	-30,49
D	Galvanized steel staircase, indoor use (Lonbakken)	630	kg	-92,48	-0,36
D	Stainless steel products, 7850 kg/m3 (Øglænd System)	4113,76	kg	-11574,58	-64,1
				323661,37	**1447,72**
A1-A3	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	60,71	m3	5482,11	27,32
A1-A3	Solid wood cladding, 600 kg/m3, 19x120 [mm], Moistr. 15%, (Foreningen Norske Lauvtrebruk)	1044,8	m2	5418,55	7,32
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	741,47	2,66
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	741,47	2,66
A1-A3	Plastic vapour control layer, 0.15 mm (Tommen Gram)	1044,8	m2	328,07	1,25
A1-A3	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	1044,8	m2	3041,46	66,15
A1-A3	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	1044,8	m2	1979,61	1,76
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1718	m2	18288,39	65,67
A4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	60,71	m3	410,08	1,89
A4	Solid wood cladding, 600 kg/m3, 19x120 [mm], Moistr. 15%, (Foreningen Norske Lauvtrebruk)	1044,8	m2	377,26	1,74
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	2,02	0,0093
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	2,02	0,0093
A4	Plastic vapour control layer, 0.15 mm (Tommen Gram)	1044,8	m2	0,083	0,00038
A4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	1044,8	m2	4,74	0,022
A4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	1044,8	m2	166,77	0,77
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1718	m2	49,73	0,23
C1-C4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	60,71	m3	3200,64	4,34
C1-C4	Solid wood cladding, 600 kg/m3, 19x120 [mm], Moistr. 15%, (Foreningen Norske Lauvtrebruk)	1044,8	m2	2061,09	2,8
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	2,26	0,014
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1044,8	m2	2,26	0,014
C1-C4	Plastic vapour control layer, 0.15 mm (Tommen Gram)	1044,8	m2	6,33	0,012
C1-C4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	1044,8	m2	1036,07	1,41
C1-C4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	1044,8	m2	107,19	0,66
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	1718	m2	55,82	0,35
D	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	60,71	m3	-18946,34	-20,17
D	Solid wood cladding, 600 kg/m3, 19x120 [mm], Moistr. 15%, (Foreningen Norske Lauvtrebruk)	1044,8	m2	-12373,94	-13,17
D	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	1044,8	m2	-4840,13	-5,15
				43505,49	**189,06**
A1-A3	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	29,46	m3	5008,27	11,87
A1-A3	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	44,35	m3	7539,84	17,87
A1-A3	Reinforcement steel (rebar), generic, 80% recycled content, A615	88,38	kg	76,97	0,3
A1-A3	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	112,2	m2	3814,8	9,04
A1-A3	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	112,2	m2	2524,5	8,74
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	147,3	m2	522,68	1,88
A1-A3	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	147,3	m2	3314,3	11,48
A1-A3	Steel reinforcement mesh, 7850 kg/m3 (Norsk Stål)	154,67	kg	59,86	0,1
A4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	29,46	m3	91,92	0,13
A4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	44,35	m3	138,38	0,2
A4	Reinforcement steel (rebar), generic, 80% recycled content, A615	88,38	kg	0,034	0,00016
A4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	112,2	m2	70,01	0,1
A4	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	112,2	m2	4,33	0,02
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	147,3	m2	1,42	0,0065
A4	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	147,3	m2	5,69	0,026
A4	Steel reinforcement mesh, 7850 kg/m3 (Norsk Stål)	154,67	kg	0,059	0,00027
C1-C4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	29,46	m3	784,13	2,53
C1-C4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	44,35	m3	1180,5	3,81
C1-C4	Reinforcement steel (rebar), generic, 80% recycled content, A615	88,38	kg	0,68	0,0027
C1-C4	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	112,2	m2	597,27	1,93
C1-C4	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	112,2	m2	44,81	0,086
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	147,3	m2	1,6	0,0099
C1-C4	Radon and moisture membrane for site construction, PP, 1.2 mm (Icopal)	147,3	m2	58,83	0,11
C1-C4	Steel reinforcement mesh, 7850 kg/m3 (Norsk Stål)	154,67	kg	0,12	0,00074
D	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	29,46	m3	-13419,8	-27,94
D	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	44,35	m3	-20203,22	-42,07
D	Reinforcement steel (rebar), generic, 80% recycled content, A615	88,38	kg	-26,14	-0,11
D	Concrete (Norwegian low-carbon), B20 M90, lavkarbonklass A (2015 NB37)	112,2	m2	-10221,87	-21,28
D	Steel reinforcement mesh, 7850 kg/m3 (Norsk Stål)	154,67	kg	-31,8	-0,12
				25841,02	**70,23**
A1-A3	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	19,2	m3	1733,76	8,64
A1-A3	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	23,04	m3	2080,51	10,37
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	33,89	m2	577,22	2,07
A1-A3	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	56,93	m2	331,47	7,21
A1-A3	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	56,93	m2	107,87	0,096
A1-A3	Spruce cladding, surface treated with Jotun Drygolin Extreme paint, 19 mm, 8.50 kg/m2 (Moelven)	56,93	m2	68,32	0,38
A1-A3	Plastic vapour control layer, 0.15 mm (Tommen Gram)	56,93	m2	17,88	0,068
A1-A3	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	60	m2	220	0,6
A1-A3	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	784	m2	11127,74	39,96
A1-A3	Engineered wood flooring, 3-layered, 15 mm, 8.3 kg/m2 (Kährs)	880	m2	1490,13	6,16
A1-A3	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	880	m2	16133,33	43,63
A1-A3	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	2561,72	55,72
A1-A3	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	2561,72	55,72
A1-A3	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	880	m2	1667,36	1,48
A4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	19,2	m3	129,69	0,6
A4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	23,04	m3	155,63	0,72
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	33,89	m2	1,57	0,0072
A4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	56,93	m2	0,52	0,0024
A4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	56,93	m2	9,09	0,042
A4	Spruce cladding, surface treated with Jotun Drygolin Extreme paint, 19 mm, 8.50 kg/m2 (Moelven)	56,93	m2	0,15	0,00067
A4	Plastic vapour control layer, 0.15 mm (Tommen Gram)	56,93	m2	0,0045	0,000021
A4	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	60	m2	2,3	0,011
A4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	784	m2	30,26	0,14
A4	Engineered wood flooring, 3-layered, 15 mm, 8.3 kg/m2 (Kährs)	880	m2	186,46	0,86
A4	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	880	m2	168,49	0,78
A4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	3,99	0,018
A4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	3,99	0,018
A4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	880	m2	140,46	0,65
C1-C4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	19,2	m3	1012,23	1,37
C1-C4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	23,04	m3	1214,67	1,65
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	33,89	m2	1,76	0,011
C1-C4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	56,93	m2	112,92	0,15
C1-C4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	56,93	m2	5,84	0,036
C1-C4	Spruce cladding, surface treated with Jotun Drygolin Extreme paint, 19 mm, 8.50 kg/m2 (Moelven)	56,93	m2	31,97	0,043
C1-C4	Plastic vapour control layer, 0.15 mm (Tommen Gram)	56,93	m2	0,34	0,00066
C1-C4	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	60	m2	18,83	0,026
C1-C4	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 (EPS-gruppen)	784	m2	33,96	0,21
C1-C4	Engineered wood flooring, 3-layered, 15 mm, 8.3 kg/m2 (Kährs)	880	m2	611,22	0,83
C1-C4	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	880	m2	1380,77	1,87
C1-C4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	872,64	1,18
C1-C4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	872,64	1,18
C1-C4	Gypsum plasterboard, 7.2 kg/m2, 9.5 mm +/-0.5 mm, Windliner - X/Utvendig - X type EH2 (GU-X) (Norgips)	880	m2	90,28	0,56
D	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	19,2	m3	-5991,92	-6,38
D	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	23,04	m3	-7190,31	-7,65
D	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	56,93	m2	-527,5	-0,56
D	Spruce cladding, surface treated with Jotun Drygolin Extreme paint, 19 mm, 8.50 kg/m2 (Moelven)	56,93	m2	-149,36	-0,16
D	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	60	m2	-78,99	-0,084
D	Engineered wood flooring, 3-layered, 15 mm, 8.3 kg/m2 (Kährs)	880	m2	-2684,07	-2,86
D	Fiberboard, sound absorbing, 36 mm, 9 kg/m2, 250kg/m3, Silencio Thermo (Hunton Fiber AS)	880	m2	-5792,49	-6,16
D	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	-4076,68	-4,34
D	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	880	m2	-4076,68	-4,34
				47771,74	**245,07**
A1-A3	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	7,57	m3	683,57	3,41
A1-A3	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3	1125,74	m2	517,82	1,81
A1-A3	Fiberboard (MDF), for interior walls and ceilings, painted, 11 mm, 9.2 kg/m2, 836.36 kg/m3 (Huntonit)	2251,48	m2	9108,26	39,5
A4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	7,57	m3	51,13	0,24
A4	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3	1125,74	m2	7,54	0,035
A4	Fiberboard (MDF), for interior walls and ceilings, painted, 11 mm, 9.2 kg/m2, 836.36 kg/m3 (Huntonit)	2251,48	m2	576,85	2,66
C1-C4	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	7,57	m3	399,09	0,54
C1-C4	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3	1125,74	m2	122,63	0,23
C1-C4	Fiberboard (MDF), for interior walls and ceilings, painted, 11 mm, 9.2 kg/m2, 836.36 kg/m3 (Huntonit)	2251,48	m2	2363,68	3,21
D	Cross-laminated timber (CLT), 420 kg/m3 (Splitkon)	7,57	m3	-2362,44	-2,51
D	Fiberboard (MDF), for interior walls and ceilings, painted, 11 mm, 9.2 kg/m2, 836.36 kg/m3 (Huntonit)	2251,48	m2	-10766,2	-11,45
				13830,58	**51,63**
A1-A3	Concrete (Norwegian low-carbon), B35 M45/MF45, lavkarbonklass A (2015 NB37)	8,84	m3	1856,4	4,37
A1-A3	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	147	m2	436,48	9,49
A4	Concrete (Norwegian low-carbon), B35 M45/MF45, lavkarbonklass A (2015 NB37)	8,84	m3	27,58	0,04
A4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	147	m2	0,68	0,0031
C1-C4	Concrete (Norwegian low-carbon), B35 M45/MF45, lavkarbonklass A (2015 NB37)	8,84	m3	235,29	0,76
C1-C4	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	147	m2	148,69	0,2
D	Concrete (Norwegian low-carbon), B35 M45/MF45, lavkarbonklass A (2015 NB37)	8,84	m3	-3097,54	-6,45
D	Laminated plywood, waterproof, 10.2 mm (Fibo Trespo)	147	m2	-694,61	-0,74
				2705,12	**14,86**
A1-A3	Balcony Door, 0.78 W/m2K, 65.15 kg, 1.23x1.48 m (Norgesvinduet Kompetanse)	76,8	m2	3093,31	24,95
A1-A3	Wooden interior door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf (Nordic Dørfabrikk)	160,8	m2	5421,71	35,53
A1-A3	2 Way Inward Opening Window, Frame: 105 mm, 64.4 kg, 1.23x1.48 m (Lian Trevarefabrikk)	366,3	m2	17345,12	189,35
A4	Balcony Door, 0.78 W/m2K, 65.15 kg, 1.23x1.48 m (Norgesvinduet Kompetanse)	76,8	m2	35,02	0,16
A4	Wooden interior door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf (Nordic Dørfabrikk)	160,8	m2	196,96	0,91
A4	2 Way Inward Opening Window, Frame: 105 mm, 64.4 kg, 1.23x1.48 m (Lian Trevarefabrikk)	366,3	m2	49,63	0,23
C1-C4	Balcony Door, 0.78 W/m2K, 65.15 kg, 1.23x1.48 m (Norgesvinduet Kompetanse)	76,8	m2	25,26	0,16
C1-C4	Wooden interior door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf (Nordic Dørfabrikk)	160,8	m2	733,66	1
C1-C4	2 Way Inward Opening Window, Frame: 105 mm, 64.4 kg, 1.23x1.48 m (Lian Trevarefabrikk)	366,3	m2	175,43	1,08
D	Wooden interior door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf (Nordic Dørfabrikk)	160,8	m2	-3112,09	-3,31
				27076,11	**253,36**
TOTAL				**484391,43**	**2271,93**

BUILDING ENERGY PERFORMANCE

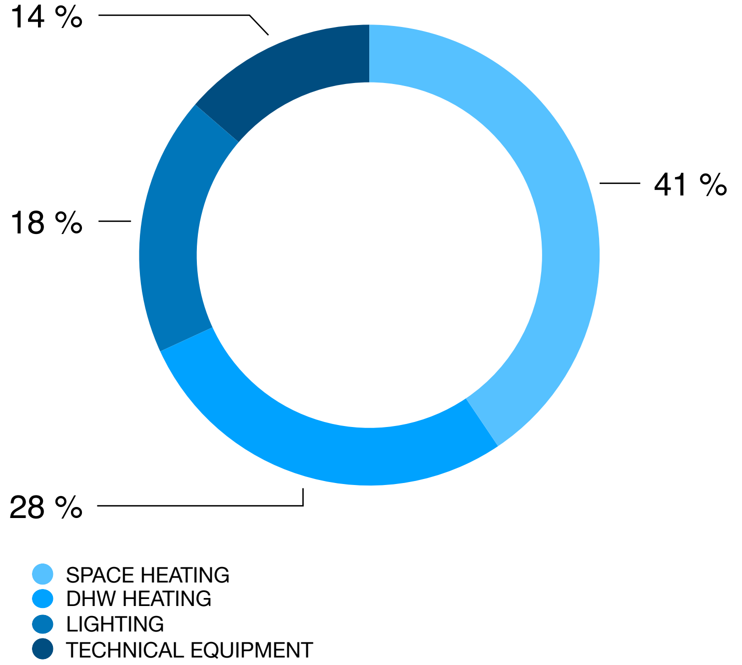


FIG 54. ENERGY DEMAND PER END-USE

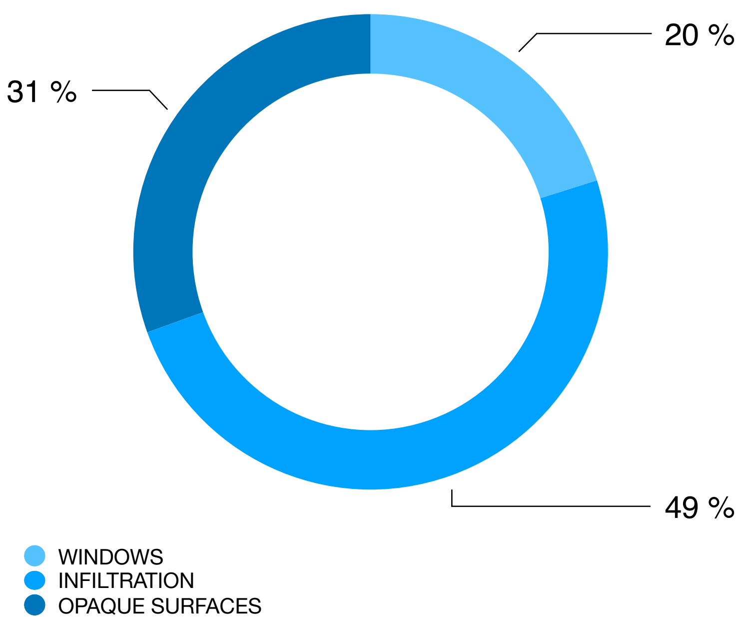


FIG 55. HEAT LOSS PER PARAMETER

MONTH	kWh
JANUARY	383,149
FEBRUARY	1223,653
MARCH	2978,725
APRIL	4370,169
MAY	5633,825
JUNE	5663,18
JULY	5602,577
AUGUST	4262,162
SEPTEMBER	2742,499
OCTOBER	1344,686
NOVEMBER	404,3029
DECEMBER	201,5994
TOTAL	34810,527

TAB 6. TOTAL ON-SITE ELECTRIC SOURCES

PARAMETER	VALUE
HEATED FLOOR AREA (BRA)	1467,82 m2
HEATED VOLUME	3522,77 m3
EXTERIOR SURFACE GREENHOUSE	1289 m2
U-VALUE	EXTERIOR WALL: 0,22 W/m2-K ROOF: 0,146 W/m2-K SLAB ON GRADE: 0,10 W/m2-K WINDOWS + DOORS: 1,49 W/m2-K
INFILTRATION RATE	0,6 h-1
OPERATIONAL HOURS	VENTILATION: 24 h/d LIGHTING:16 h/d TECHNICAL EQUIPMENT: 16h/d OCCUPANCY: 24h/d
INTERNAL GAINS	LIGHTING: 1,95 W/m2 TECHNICAL EQUIPMENT: 3,00 W/m2 DHW: 5,10 W/m2 PEOPLE: 1,50 W/m2

TAB 7. BUILDING PARAMETERS

	TOTAL ENERGY kWh	ENERGY PER TOTAL BUILDING AREA kWh/m2
TOTAL SITE ENERGY	114304,67	84,95
TOTAL SOURCE ENERGY	395513,63	293,96

TAB 8. SITE AND SOURCE ENERGY CONSUMPTION

ENERGY PERFORMANCE

THE ENERGY SIMULATION FOR THIS PROJECT WAS PERFORMED WITH THE SOFTWARE DESIGN BUILDER. THE SIMULATION WAS DONE TO ESTABLISH THE ANNUAL ENERGY NEED AND ENERGY DELIVERED TO THE BUILDING.

TO ENSURE A SIMULATION OUTCOME THAT IS AS TRUE TO THE ORIGINAL AS POSSIBLE, THE GREENHOUSE AND THE BOXES WERE SIMULATED IN TWO DIFFERENT SIMULATIONS.

THE GREENHOUSE WAS SIMULATED AS ONE ZONE WITHOUT ANY SCHEDULE. TO IMITATE THE HEAT LOSSES OF THE BOXES, A RADIATOR WITH THE EXACT HEAT LOSS DATA WAS PLACED INSIDE THE GREENHOUSE.
TO COOL DOWN THE BUILDING, ONLY NATURAL VENTILATION WAS USED.

WITH THE OUTCOME OF THIS SIMULATION, A NEW EPW FILE WAS CREATED TO BE USED ON THE BOXES. THEREFORE, THE GREENHOUSE THEN SERVED AS THE NEW LOCATION OF THE BOX SIMULATION.

THE ENERGY NEED OF THE BUILDING IS COVERED BY A GROUND-SOURCE HEAT PUMP, THAT IS ALREADY EXISTING AT MOHOLT. THE GROUND-SOURCE HEAT PUMP WAS INSTALLED FOR THE PROJECT MOHOLT 50/50 AND HAS ENOUGH CAPACITY TO COVER THIS PROJECT.
THE BUILDING WAS DESIGNED TO REACH PASSIVE HOUSE STANDARD AND THEREFORE FOLLOWED THE REQUIREMENTS OF NS.3700.
THE TOTAL ENERGY NEED OF THE BUILDING IS 114304,67 kWh PER YEAR / 84,95 kWh PER M2.

ENERGY DEMAND

FIGURE 54 SHOWS THE ENERGY DEMAND PER END-USE. THEREFORE 41% / 69606,96 kW OF THE DEMAND IS USED FOR SPACE HEATING. THE SECOND-LARGEST ENERGY DEMAND IS USED FOR DOMESTIC HOT WATER HEATING. THE DEMAND FOR DHW IS 47320,80 kW, WHAT RESULTS IN 28%.
THE DEMAND FOR SPACE LIGHTING IS 31235,06 kW AND FOR TECHNICAL EQUIPMENT 23449,51 kW ARE NEEDED.

HEAT LOSSES

AS SHOWN IN FIGURE 55, 20% OF THE HEAT LOSSES ARE THROUGH WINDOWS AND DOORS. 31% OF THE LOSSES ARE THROUGH OPAQUE SURFACES LIKE WALLS AND ROOFS. THE BIGGEST HEAT LOSS IS THROUGH INFILTRATION. THAT RESULTS FROM HIGH NATURAL VENTILATION DEMANDS TO PREVENT THE BUILDING FROM OVERHEATING DUE TO THE HIGH GREENHOUSE TEMPERATURES.

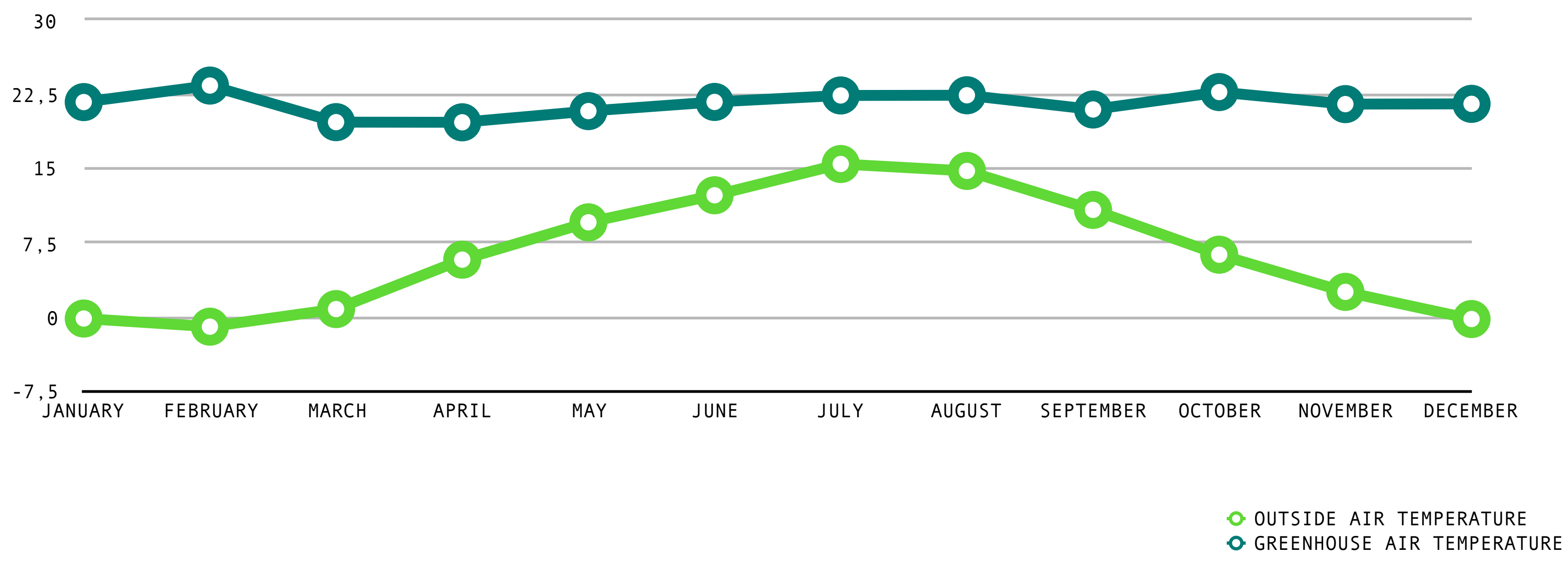


FIG 56. AIR TEMPERATURE GREENHOUSE / OUTSIDE

IMPACT OF GREENHOUSE

AS SHOWN IN FIGURE 56 THE GREENHOUSE HAS A LARGE IMPACT ON THE THERMAL COMFORT OF THE „OUTSIDE AREAS“. BY HAVING AN AVERAGE TEMPERATURE OF 21,49 DEGREES OUTSIDE THE BOXES COMPARED TO THE YEARLY AVERAGE TEMPERATURE IN TRONDHEIM OF 6,40 DEGREES, STUDENTS ARE MORE LIKELY TO USED THE GREEN AREAS INSIDE THE GREENHOUSE.

MORE THAN JUST THE ASPECT OF USING THE OUTSIDE SPACES, THE GREENHOUSE GIVES THE BOXES A MEDITERRANIAN CLIMATE, WHICH LEADS TO FEWER INSULATION MATERIALS. THE HEAT LOSSES OF THE BOXES ARE USED TO HEAT UP THE GREENHOUSE AND THEREFORE BRING A WARMER CLIMATE TO THE BOXES BACK. U-VALUES OF THE WINDOWS, DOORS, AND OUTSIDE SURFACES COULD BE INCREASED, WHICH SAVES MATERIALS AS WELL.

CONCLUSION

CONCLUSION

TO MEET THE INCREASING DEMAND FOR STUDENT DORMITORIES, SIT WILL HAVE TO BUILD MORE STUDENT HOUSING FACILITIES IN THE FUTURE. IN ORDER TO DO JUSTICE TO THIS, IT IS MORE IMPORTANT THAN EVER TO PAY ATTENTION TO THE EMISSIONS FROM NEW BUILDINGS.

STUDENT HOUSING PROVIDERS LIKE SIT MUST FIND LOW-CARBON ALTERNATIVES TO REDUCE EMISSIONS OF THEIR BUILDING STOCK. IN THAT CONTEXT, THIS THESIS WAS MAINLY DRIVEN BY REDUCING BUILDING MATERIALS AND DECREASING OPERATIONAL EMISSIONS.

THE GREENHOUSE PROVIDES A MEDITERRANEAN CLIMATE TO THE INSIDE STUDENT HOUSING. THEREFORE THE HEATING DEMAND IS LOWER THAN ON A BUILDING EXPOSED TO THE CLIMATE IN TRONDHEIM.

THE DESIGN AND CONCEPT OF THE BOXES INSIDE THE GREENHOUSE ARE FOLLOWED BY SIMPLICITY AND RECURRENCE.

THE MAIN LIMITATION OF THIS THESIS WORK WAS TO CALCULATE THE INDOOR CLIMATE OF THE GREENHOUSE. THE GREENHOUSE IS ADDITIONALLY HEATED BY OPERATING THE INNER HOUSES AND THEIR HEAT LOSSES. NEITHER THE SOFTWARE GRASSHOPPER THAN DESIGN BUILDER ALLOWS TO SIMULATE A HOUSE-IN-HOUSE CONCEPT. THEREFORE, THE HEAT LOSSES WERE SIMULATED BY A HEAT SOURCE INSIDE THE GREENHOUSE.

A SECOND LIMITATION WAS THE CALCULATION OF THE EMBODIED EMISSIONS. THE AVAILABILITY OF DOCUMENTATIONS OF THE EMISSION FACTOR (EPD) OF CONSTRUCTION MATERIALS INSIDE THE SOFTWARE ONE CLICK LCA IS LIMITED. CALCULATING THE EMISSIONS OF EACH BUILDING COMPONENT STILL GIVES AN OVERVIEW OF THE CONTRIBUTION TO THAT PROJECT.

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