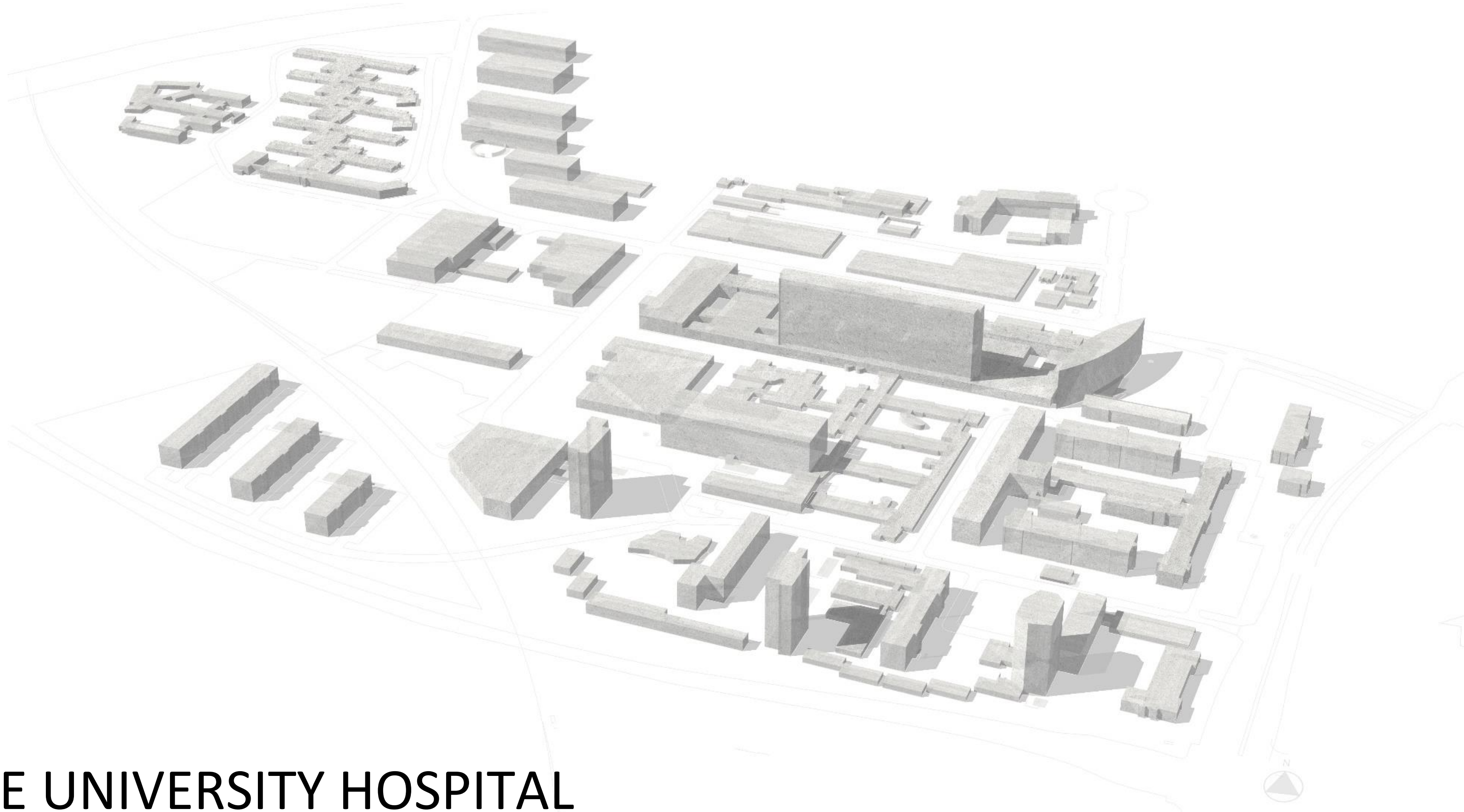

ODENSE UNIVERSITY HOSPITAL

BUILDING REFURBISHMENT AND URBAN RENEWAL OF COMPLEX AND DIVERSE BUILDING STOCKS
- INTEGRATION OF LCA IN ANALYSIS AND DESIGN PROCESSES - *PART 2*

TECHNICAL UNIVERSITY OF DENMARK, DTU

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ABSTRACT

This project contains the investigation and suggestions for renovation and transformation of Odense University Hospital (OUH), Denmark. The idea for the project originated from the knowledge of the establishment of a new Super Hospital and the following concern of what was supposed to happen to the original hospital area.

A study of possibilities for renovation and transformation of both the urban area and a specific building is performed. The urban proposal is overall and for contextual purposes, whereas the proposal for a single building is more in detail.

The proposal for the urban area is based on functional considerations on the city together with results from the first part of the project, which evaluated all buildings and their potential to help decide what buildings to preserve and which to demolish. The design proposal suggests a center of innovation and development for the site which should in general be open and inviting to the public and operate as an integrated part of Odense city.

Four scenarios are considered for the single building design. They differ in the amounts of measures taken to renovation. The first proposal suggests removal of the entire building and building new. The second proposal concerns renewal of building elements in the existing building which are outdated (maintenance). This is also included in the third proposal which also includes additional insulation of the building envelope to reduce transmission loss. The fourth and final proposal addresses a more severe renovation of the existing building. The proposal includes renewal of materials and additional insulation as the third proposal but also a new expression and interior composition of the building.

In order to decide which proposal is preferable an assessment by use of a multi-criteria decision making (MCDM) analysis is carried out. The analysis includes environmental considerations along with other criteria such as energy consumption, daylight, lifetime and architectural qualities.

Through the MCDM analysis the scenario involving a major renovation with preservation of 71% of the original construction was preferred. The scenario is an update of the original construction with improved energy consumption and daylight. The scenario has qualities of the original building and preserves historic value, while getting a transformation which enhance functionality in connection with the overall area.

The multi-criteria decision making tool has proven useful and for more than one subject. For Odense University Hospital it has proven the ability to help decide what is to happen to the existing site as the hospital functions move out in 2022, including environmental concerns. The evaluation which is to be made is very complicated as the site consists of large variations within many criteria. The MCDM tool has in this case shown that we should preserve quality and resources when they have the ability to preserve or create value for future purposes.

PREFACE

This report is made through cooperation by three students at DTU during an individual course for investigating the potential for renovation and transformation of Odense University Hospital (OUH) during the spring and summer semester 2016. The course is nominated to 10 ECTS points and consists of two stages, a macro phase and a micro phase. This report revolves around the micro stage and is the second part of the entire project.

In connection with this project will be given a big thanks to the Facility Management department at OUH, including special thanks to Ivan Schjødt Nielsen, Section Manager, for helpful background knowledge and an inspirational tour of the hospital and to Kirsten Skytte, Technical Assistant, for being helpful providing countless drawings of the different building types.

Finally, big thanks are given to Lotte Bjerregaard Jensen, Associate Professor at DTU Civil Engineering – Architectural Engineering and Morten Birkved, Associate Professor at DTU Management Engineering - QSA, for professional guidance and references to good tools during the project.

CONTENTS

1 INTRODUCTION

This project contains the investigation and suggestions for renovation and transformation thoughts of Odense University Hospital (OUH), Denmark. The idea for the project originated from the knowledge of the establishment of a new super hospital and the following concern of what was supposed to happen to the original hospital area.

Throughout the spring semester of 2016 several analyses of the existing buildings at Odense University Hospital have been made. The results of the different analyses are presented in the booklet and described in details in the related report which contains technical information on the analysis made:

"Odense University Hospital – Mapping – Building refurbishment and urban renewal of complex and diverse building stocks – Integration of LCA in analysis and design processes – part 1"

"Odense University Hospital – Report – Building refurbishment and urban renewal of complex and diverse building stocks – Integration of LCA in analysis and design processes – part 1"

This report revolves around an overall design proposal for the site and proposals for a single building design. The overall site proposal takes considerations on Odense city, and the context of which the site is situated, into account. For the single building design four scenarios are considered, each with smaller or greater amounts of renovation measures.

The building designs are developed through holistic considerations and with specific focus on energy optimization, indoor environment, life cycle assessments and theory on renovation and building transformation. An evaluation on the four scenarios are carried out through a multi-criteria analysis, giving suggestion on which design is more preferable. The analysis is also referred to as multi-criteria-decision-making (MCDM) and is a numerical method.

Evaluation of environmental impacts are included in both the first and second part of the entire course. In the first part LCA was preferred with high impact in order to preserve the already used building materials. In this second part environmental impacts are evaluated and preferred as low as possible to minimize the impact to transform the building.

The report is structured by first giving an introduction to the site and context of the hospital, followed by an overall proposal also including results from the first part of the entire course. Hereafter various analysis of a building on the site are made, of which renovation proposals are designed for, to introduce the building and evaluate strengths and weaknesses of the building. Four scenarios are presented for renovation and transformation of the building. A MCDM analysis is carried out helping decide which scenario is preferable. Finally, a preferred proposal for the building is discussed and evaluated through a holistic approach taking into account the results of the MCDM together with all evaluations made throughout the entire project.

2 SITE

2.1 BACKGROUND AND CONTEXT

The existing Odense University Hospital (OUH) is situated in the centre of Odense partly surrounded by dwellings and green areas. The layout consists of an established floor area of around 300.000 square meters built in the period of 1912 till 2014. Figure 1 shows an overview of the development.

The buildings within OUH functionality are somatic care facilities, offices, facility management and residential apartments for doctors. The buildings which are not within the hospital functions are university buildings used by The University of Southern Denmark, The Danish Cancer Society and psychiatric care facilities. The mapping on Figure 2 shows an overview of the functions on site.

Today OUH is the largest stand-alone workplace on Funen with over 8000 full-time workers. The Hospital treats more than 1.100.000 outpatients and 100.000 discharged patients a year, which roughly means more than 13.000 people visits the hospital on a daily basis. [1]

Figure 1: Development of site

Figure 2: Overview of functions for the existing hospital

In order to cope with the high number of daily visitors, large parts of the previously green and undeveloped area are converted into parking spaces. Today green areas are limited within the site, however the majority of the surroundings are green areas. On Figure 4 is shown an overview of green areas near and within the site.

The area is also connected to a local train station as well as a couple of bus stops in order to ease the heavy car traffic. According to the district plan the coefficient of utilization must not exceed 0.85. With a ground area of around 400.000 square meters this means that additional 40.000 square meters' floor area can be added to the existing [2]. As a result of the limited space to expand the building area, and several other factors as e.g. outdated facilities, a new hospital area is planned. The first sod was cut the 28th of April 2016, and the new hospital ('Nyt OUH'), is expected to be finished by 2022 [3]. The new hospital will be placed in elongation of the relatively new built university area, Cortex Park. The vision is, by placing these instances beside each other, all will benefit from this by creating common projects and research and over time this will give societal and knowledgeable gains. On the images on Figure 3 are shown reference images from the proposal of the new hospital.

Figure 4: Green areas in and around the area

Figure 3: Reference images of the new hospital

Figure 5: Overview of construction types

Figure 6: Tunnelsystem

As said the existing hospital was constructed throughout longer periods of time. This is also evident in the different building types found on site. The main parts are concrete and masonry buildings.

On the map in Figure 5 the distribution of building types is shown, according to construction and materials. These divisions are based on registration and the main construction materials.

The existing hospital also has a great tunnel system connecting the majority of the buildings on the site. On Figure 6 is shown an overview of the tunnel system.

2.2 NEW SITE

2.2.1 RESULTS - PART 1

In part 1 of the project was made a multi-criteria decision making of the entire site. This evaluation took into account architectural, cultural historic, environmental and originality qualities, together with condition, floor areas and environmental impact of materials. The results of this multi criteria evaluation is shown on Figure 7. The results are evaluated according to the “distance” towards an ideal solution, which means that buildings with short distance have better quality than those with long distance.

These results were compared to building types and this comparison can be seen in Figure 8. The color references on the following figure can be correlated to colors in Figure 5, which shows an overview of the construction types.

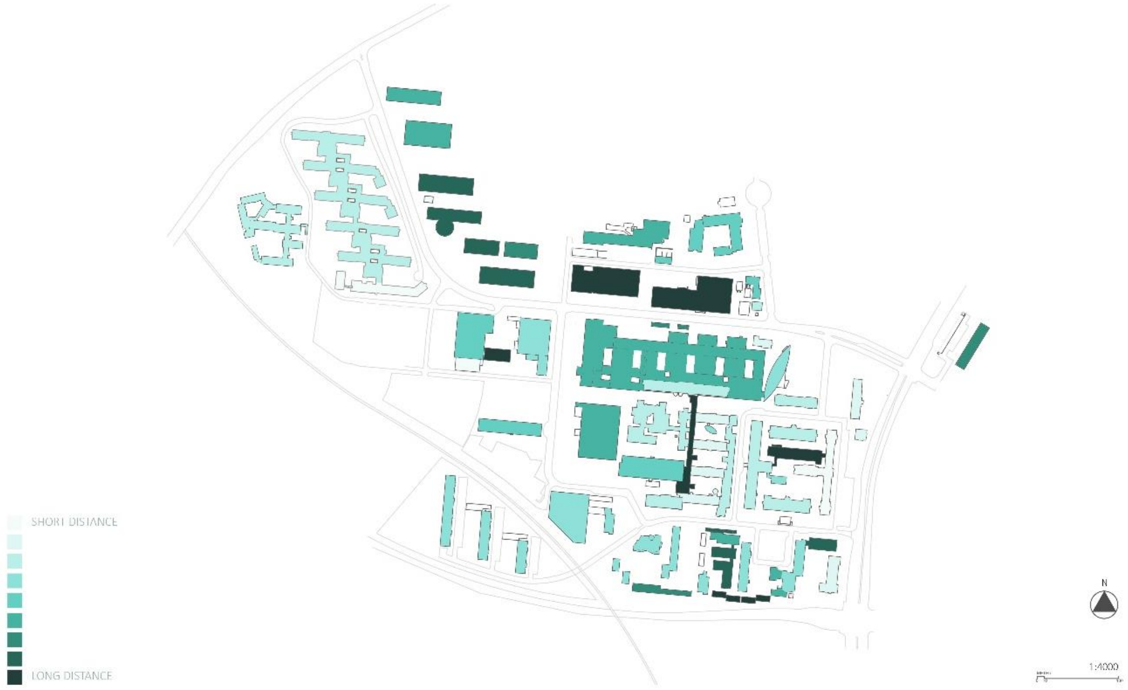


Figure 7: Results of MCDM analysis in part 1 of the entire project

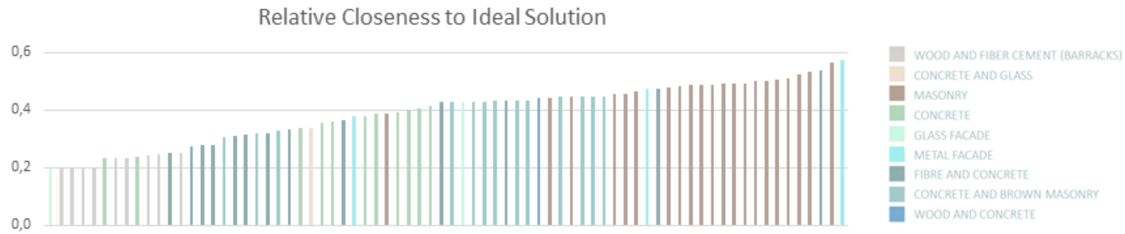


Figure 8: Overview of results from MCDM analysis of part 1 according to construction types

Figure 9: Overview of building numbers

Figure 10: Overview of area with removal of buildings

These results have been taken into considerations when designing a proposal for the new site. Some of the demolishing conclusions made include removal of barracks together with the connecting glass hallway (pathway) and thereby giving the connecting buildings opportunities for functioning individually. Also the big apothecary (building 35, see building numbering in Figure 9 and kitchen/laundry (building 34, see building numbering in Figure 9) buildings should be taken away. The site would then look like the map shown in Figure 10

Some of the university buildings (U3-U7) also had a rather low score/long distance towards the ideal solution but are rather new and are assumed to possible have similar functional use and therefore only limited renovation is needed.

2.2.2 PROPOSAL

A conceptual proposal for the entire site has been designed. The design and considerations are inspired by Jan Gehl's "12 quality Criteria" [4]. Today the existing hospital functions as an individual part of the city and this new concept suggest opening the site and merging it with the rest of the surrounding city. It is placed near the city center where development is taken place these days. Roads are closed, buildings are constructed and an urban environment interacting with everyday life and attractions along with decreased traffic is emerging. A similar approach is contemplated for this new city area. The city Odense has great potential and could with more opportunities, both private and public, possibly invite more inhabitants and tourists. This new site should open up to the public and act as a new center for innovation and development. Diversity is also desired and all sorts of people are invited into the site through various functions attracting and inspiring creativity, activity, culturality, curiosity with means and reasons to enjoy life.

To ensure attractiveness and an inviting atmosphere public functions should be present especially on street level. Public functions should be active both during night and day to hold a living environment and create a protected environment where people can feel safe and comfortable. Some of the measures thought of to create an environment like this include transparent surfaces on street level, giving people a chance to establish a good viewpoint and giving the ability to look around the next corner. This as the existing buildings are rather tall and might appear as closed/massive blocks. Also good lighting throughout the entire day is essential, avoiding dark places and heavy traffic should be diverted away and minimized to create a safe environment.

Figure 11: Inspiration from Grøndby Strand

Figure 12: Reference image: streetfood

The site is, as described, placed within the city where stressful and busy workdays are present. The site should include calming atmospheres with vegetation, soothing accommodations and chances to get away from the everyday feel. This could be created through, vegetation, green sceneries, attractive views, comfortable scales and both seating and standing furniture and corners inviting people to pause, take a break and enjoy a peaceful moment. Also a comforting climate is essential with focus and combinations on sunlight, shades, shelter, light breezes and low noise levels. Ways of reducing noise, sun and wind is through vegetation, hich can also help downscaling the big building blocks together with terraces, sheds, densification and in general a breakup of the vertical tall facades, by terraces and edged surfaces.

Besides above ground level the area has a rather large and connecting tunnel and basement system. These areas have potential for being parking areas and thereby removing traffic from street level. Further the basements can be utilized as playgrounds, exhibition spaces, underground bars where local bands can give concerts, ball courts, etc. Bringing life down together with light in these otherwise dark spaces will enhance protection and safety avoiding unattractive spaces.

The functions considered for the entire site include ground, basement and rooftop spots with cafés, study spaces, library, restaurants, galleries, fitness, parkour, crossfit, ball courts, fablab, knowledge center, shopping, specialties, studios with exhibition spaces, offices, residential apartments and terrace houses. These functions should invite all sorts of people creating a diverse environment with variation, quality and life while cultivating and nurturing

Figure 14: Reference image: Green pathway

Figure 13: Reference image: Green pathway

knowledge, inspiration, development of ideas, skills, etc., and all together be an attractive new part of the city where everyone has an excuse to visit. On Figure 19 is given a proposal for an outlay of the site. The proposal includes additional removal of an ending part of building 1 (main building, dark purple) to give an opening and central spot for the site.

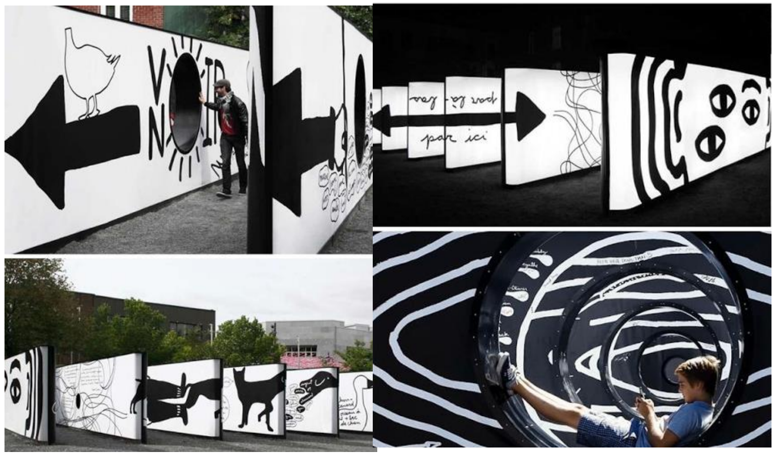


Figure 15: Reference images: installations

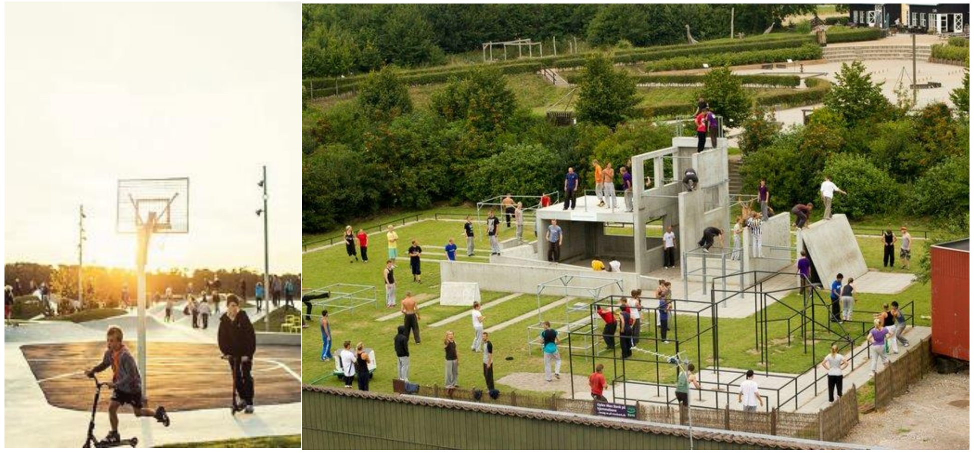


Figure 18: reference images: Activities

Figure 16: Reference image: Urban furniture

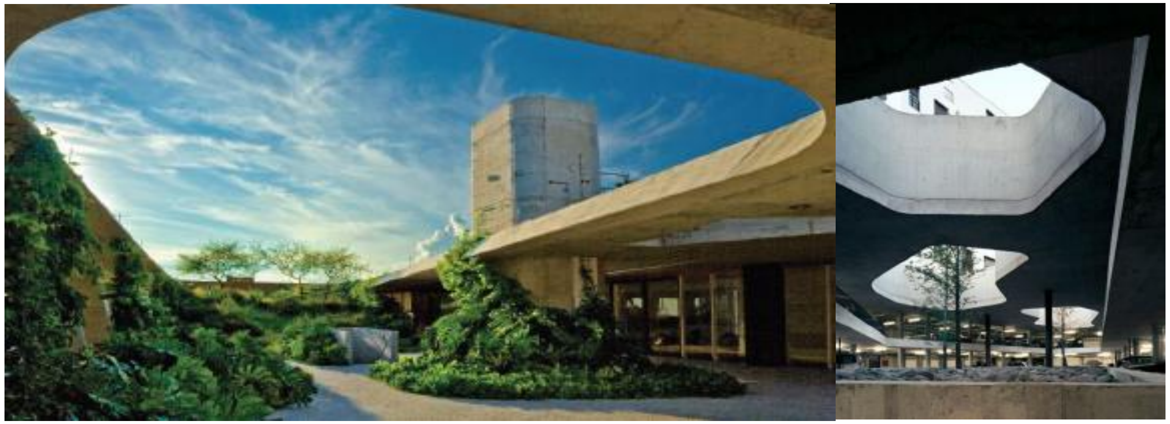


Figure 17: Reference images: Connection to basement level

Figure 19: Overview of site proposal

3 BUILDING

Building 40 of OUH is a concrete construction from 1980s. It has 8 storeys including basement and installations on the top floor. Its facades consist of about 44% glazing compared to total wall area, ignoring the installation floor. Figure 20 shows two photos of the building.

Building 40 is constructed via a columns and beams system with columns in the facades and two rows in the center. Concrete decks are carried by beams, which connect the facade and center columns and neighbouring center columns. Furthermore, supporting concrete shafts in the center and at the ends are used for stabilization. These shafts operate as staircases and lifts. Figure 22 shows an illustration of the construction with basement. The construction is illustrated with comparison to the building body for understanding purposes.

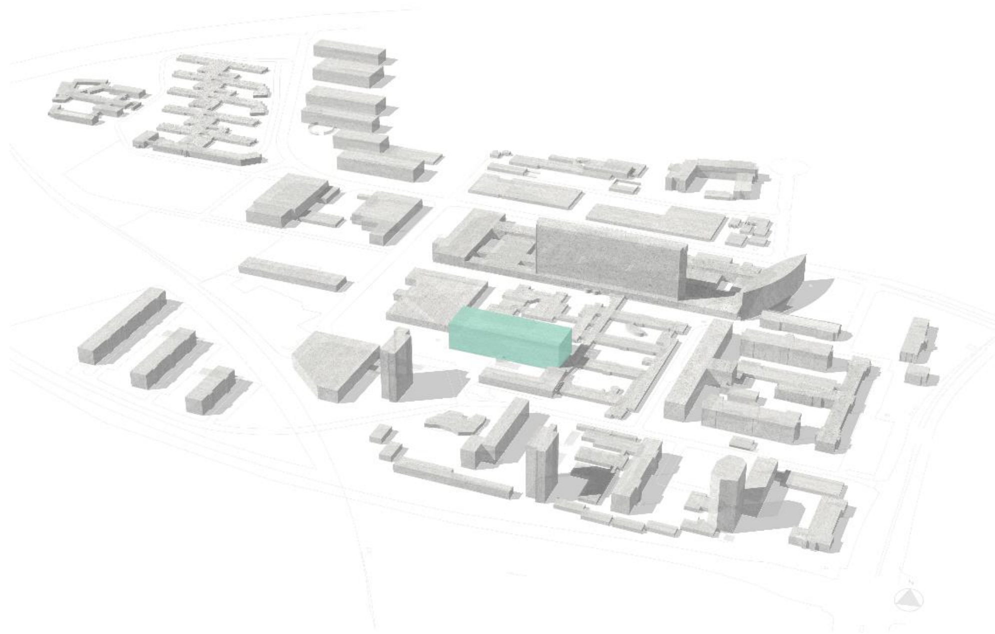


Figure 21: 3D illustration of area with highlight of building 40

Figure 20: Photos of building 40

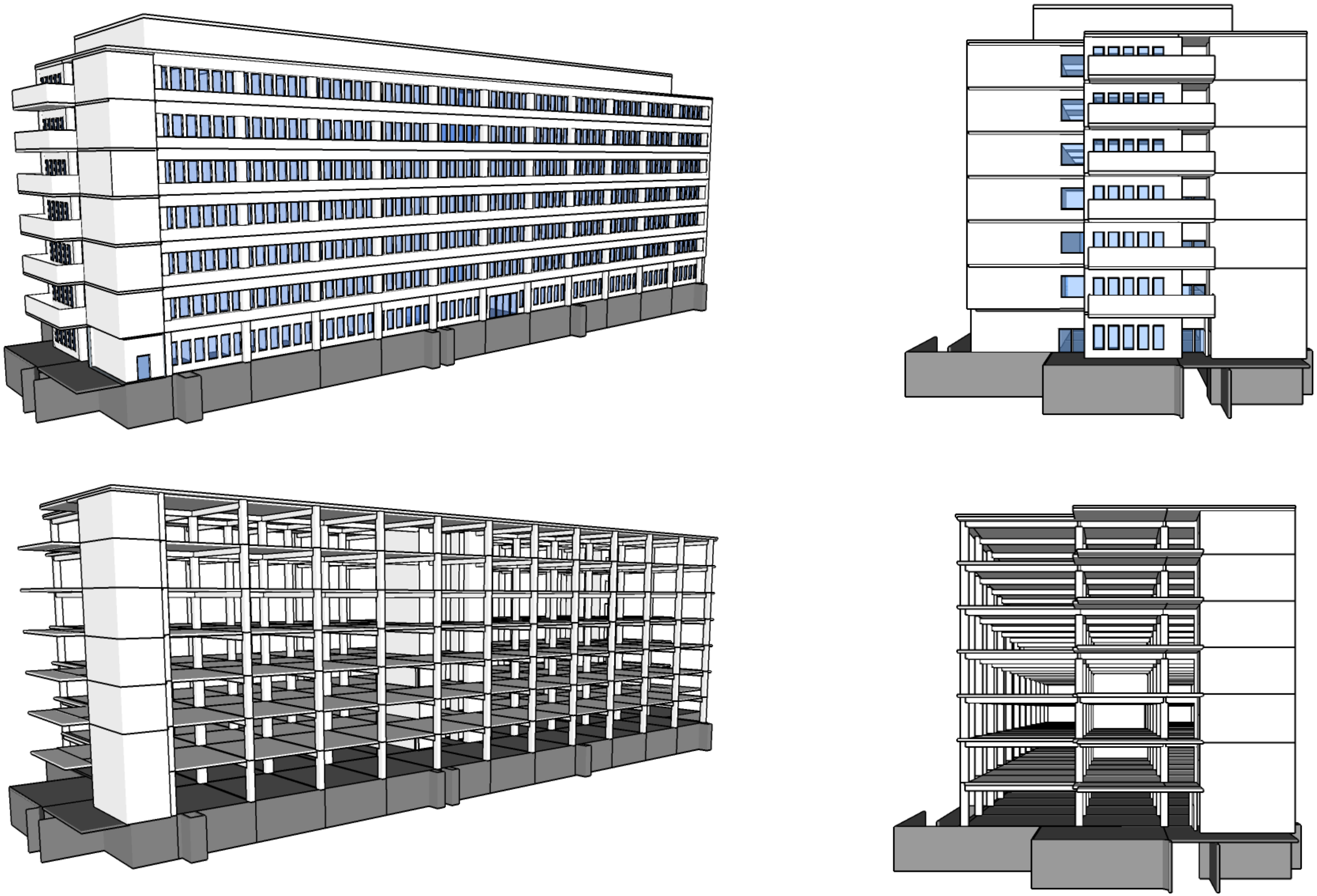


Figure 22: Illustrations of building 40 and the load carrying structure

The total floor area is about 17851 m^2, including basement, and consists of somatic functions which include examinations rooms, operating rooms on one storey, toilets, baths, staff rooms, offices, conference rooms, kitchenettes, storage and technician rooms. The flow within the building is shaped like a ‘H’. The centre is based on vertical movement and connecting the floors and the sides are hallways with access to all rooms, mainly with examination rooms near the facades and storage and technical installation rooms towards the middle. These flows are illustrated on Figure 24 and Figure 23

3.1 EVALUATION/ANALYSIS

3.1.1 SOCIAL AND APPEARANCE

The building is part of a busy hospital environment and is connected through its basement with tunnels to other buildings as well as its connection on the ground floor through a connecting hallway. The building is accommodating many people every day and has for many years. It is operating in a busy environment and through the smaller interior scale it has a comforting atmosphere which has the ability to slow down the surrounding actions in an otherwise hectic and emotional environment. This also gives individuals more private spots to feel safe and protected. Its architectural qualities include good proportions and interactions between elements in their

Figure 24: Plan illustration of ground floor

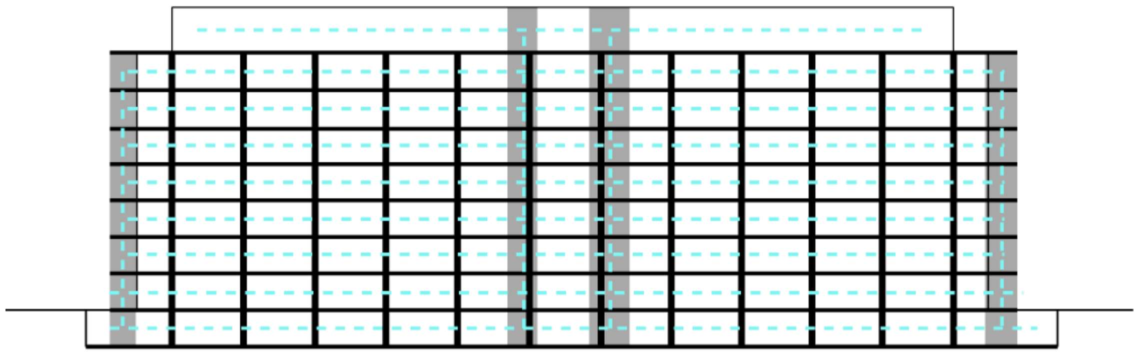


Figure 23: Vertical illustration of flows through stabilizing shafts

shapes and materials. The facades have rhythmical patterns through continuous windows and concrete columns. These elements are also features given the building its characteristic and raw, appealing appearance. The original expression of the building is kept throughout the years and only North oriented concrete surfaces on the façade has been polished. The building is rather tall around smaller buildings but taken the entire site into account the building creates connections to the taller surrounding buildings and softening their scale in the overall environment.

3.1.2 TECHNICAL AND FUNCTIONAL

3.1.2.1 ENERGY & INDOOR ENVIRONMENT

The building has a rather high transmission loss due to minimal insulation, concrete columns, old windows, large air change rate and an old ventilation system. A large air change rate is necessary in hospital functions to optimize the air quality and limit especially bacteria and particles [4]. Concrete also has rather high heat conductivity making it insufficient to insulate, however concrete is diffusion open allowing vapour transmission and thereby helps avoid potential mold damages together with the efficient ventilation. The energy consumption of the building is determined through a BE15 calculation to 152,8 kWh/m^2 per year. The analysis also concludes that no overheat is present which is helped by the great heat loss.

3.1.2.2 DAYLIGHT

In general, the daylight in the building is surrounded near the facades and non-existing in the middle. The building is about 28m wide giving difficulties for bringing the light into the middle and despite this rooms are placed around the facades cutting off any potential light for travelling into the middle. On the ground floor in the center where lifts are placed a minimal amount of light is present. In the rooms along the facades on all floors however the light is sufficient with around 2 % in half the room[5]. Daylight analysis are made for the ground floor (Figure 25) and third floor (Figure 26) as windows are different between ground floor and all other floors. Analysis of the third floor are representing floors 1-6.

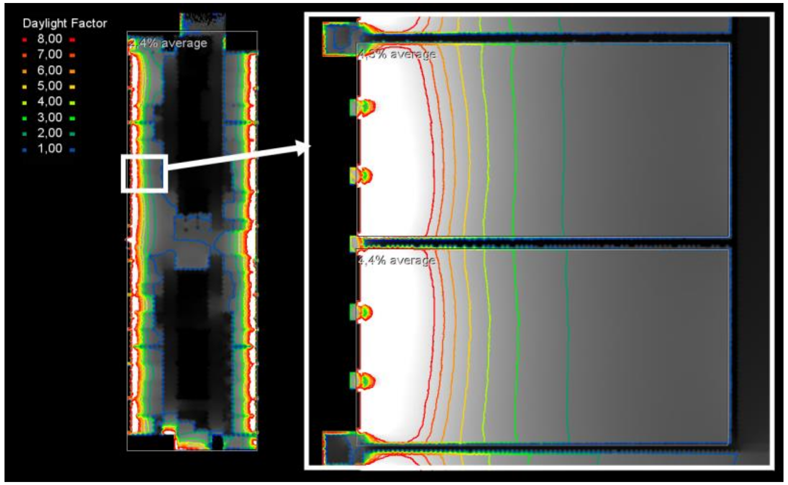


Figure 25: Daylight factor on entire ground floor and detail of two offices

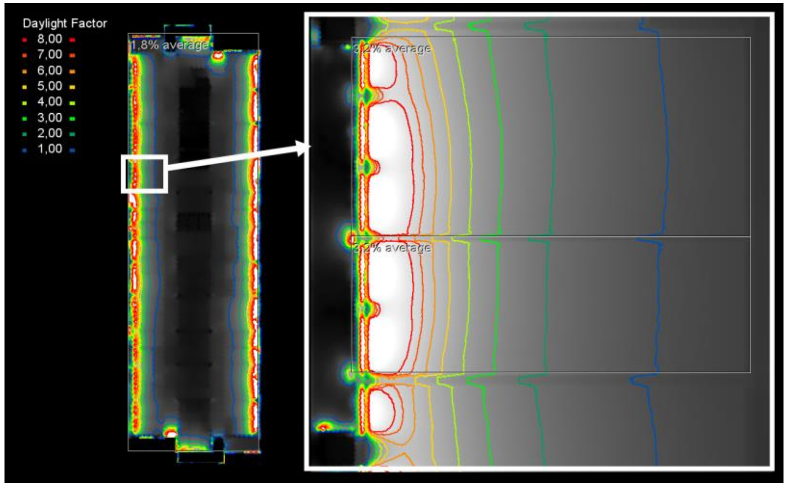


Figure 26: Daylight factor on entire 3rd floor and detail of two offices

3.1.3 CONDITION

Building 40 was built in the 1980s. To get an idea of the state of the materials within the building a simple evaluation of each material has been made with reference values on material life time from among other SBi [6]. For simplification the building is assumed constructed in 1985 and to be redeveloped in 2022 as the new superhospital supposedly should be finished. An overview of the lifetime of building materials is shown in Table 1.

It is a concrete building with the qualities of concrete including fire resistance, diffusion openness and a rather long lifetime. The building has many installations which might be able to be reutilized in case of renovation. The ventilation system is big in order for the hospital to operate in a healthy environment. This large system might need cleaning to improve its effect and quality. It is assumed that the aggregate is outdated and could be changed given a better heat recovery and effectiveness.

3.1.4 ENVIRONMENTAL

An evaluation on embodied carbon in the existing building materials has been carried out. This analysis is made in order to evaluate the amount of embodied carbon preserved when renovating, hence a recycling rate. The evaluation includes embodied carbon-dioxide equivalents (CO2-eqv) for production of materials. Transportation to construction site is

Table 1: Lifetime of building materials

Material	**Lifetime**	**Remaining life years**	**Comments**
Concrete	100	63	
Light concrete	> 100	> 63	
Windows	80	0	In general windows are however assumed to be changed after 30 years due to performance decrease [8] [9]
Insulation	Unlimited	-	Insulation might slump down which decreases its insulation capacity and therefore might need additional material
Roofing felt (<10°)	30	0	
Fiber cladding	30	0	Eternit without asbestos is assumed as it is constructed in the 1980s [10] [11].
Vinyl (flooring)	50	13	
Gypsum	60	23	

ignored, hence it is assumed that 95-98% of the impacts are accounted for by this method[1]. The impact data is gathered from Ecoinvent and processed in GaBi. The LCIA methodology used is ReCiPe 1.08 (Hierarchist). Embodied carbon results (kg Co2-eq) are shown in Figure 27.

In Appendix A detailed calculations for embodied carbon can be found. In Table 2 below is listed the building materials of each building component used for calculations.

In general floors, which includes concrete decks, have the greatest impact followed by interior walls, beams and exterior walls. All these building elements are rather heavy and hence the large impact.

The existing building is also used as scenario 0, and is the basis for the following four scenarios/proposals for renovation of the building.

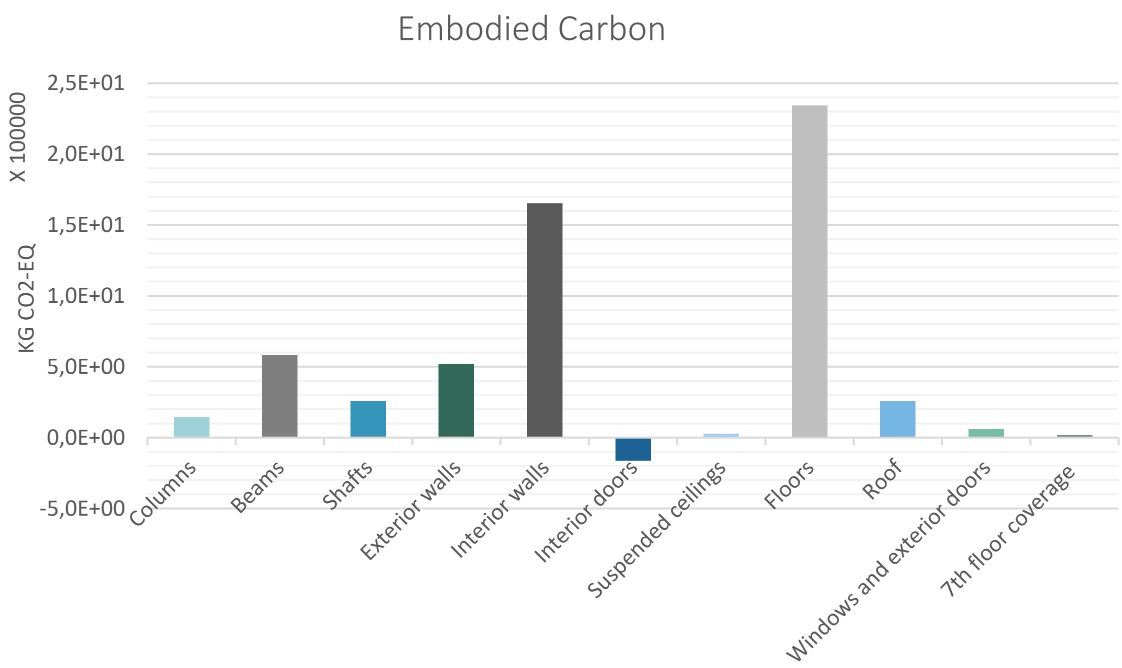


Figure 27: Diagram showing amount of embodied carbon in the existing building

Table 2: List of building components and materials

Building part	**Material**
Load carrying columns	Concrete
Load carrying beams	Reinforced concrete
Stabilizing shafts	Concrete
Floors	Solid reinforced concrete
	Vinyl floor coverage
Exterior walls	Light concrete
	Insulation (Rockwool)
Interior walls	Light concrete
Windows and exterior doors	Glass
	Wood and steel frame
Interior doors	Wood
Roof	Solid reinforced concrete
	Bitumen (roofing felt)
	Insulation
Suspended ceilings	Gypsum
7th floor coverage	Eternit

[1] According to guidance by Morten Birkved, Associate Professor at the Technical University of Denmark.

3.2 SOLUTION/DESIGN

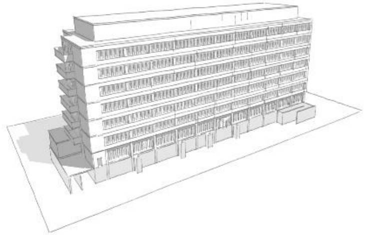
3.2.1 STRATEGY

There are different scenarios to consider for building 40 and for each scenario a number of criteria is taken into account in the evaluation. In order to decide which solution is the better one a long-term and holistic approach through Multi-Criteria-Decision-Making (MCDM) analysis is carried out. The MCDM is based on TOPSIS theory. The method is a mathematical system where a number of solutions are assessed through various criteria. A detailed description of the execution of this MCDM analysis is given in section *X MCDM*. The solutions compared are the scenarios considered for the building. Short descriptions of each scenario is given to the right.

The criteria of which each scenario is evaluated could include functionality, energy consumption, material consumption, recycling rate, quality on indoor environment, cost of renovation and much more. In this project the cost of renovation is however not included. The criteria assessed in this project are listed on the opposite page with related descriptions. Also evaluation unit or value is listed for each criteria.

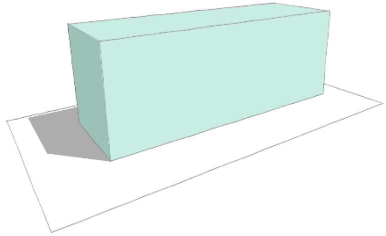
0 The existing building (case for comparison and not part of MCDM)

This case represents the existing building and its state today and where no renovation is considered. This case is listed for comparison and evaluation on improvements or aggravation in the other cases. Criteria assessed for this case is found in section X Evaluation/Analysis.



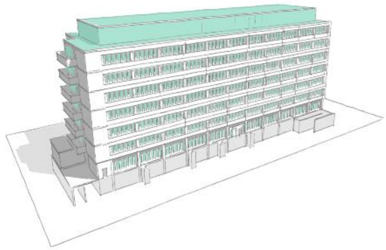
1 Demolish and build new

The existing building is assumed demolished and a new standard office building is constructed.



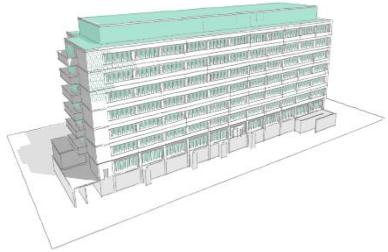
2 Maintenance

In this case only necessary elements are renewed. These elements include windows, roofing felt and eternit coverage on the 7th floor with installations. No maintenance on installation systems is considered and therefore not taken into account.



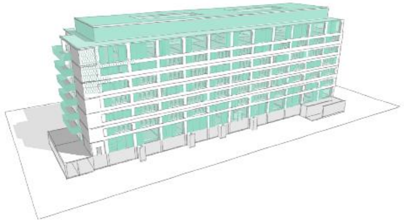
3 Maintenance and facade optimization

All elements of case 2 are renewed and then additional insulation is added to the external walls and around external concrete columns, which results in a slight reduction on the width of new windows. Again no measures on technical installations are considered.



4 Major renovation

In this case larger parts of the building is removed. A new design for the building is presented giving the building a new interior composition and function with studios and exhibition rooms for entrepreneurship. The basic maintenance from case 2 and 3 is still implemented. As well as in case 2 and 3 no actions are considered for the technical installations.



Energy Consumption	The energy consumption of the building calculated by use of BE15. *[kWh/m^2,year]*
Overheat	The thermal indoor environment is evaluated according to overheat which is found through the BE15 calculation representing the cooling energy needed to lower the temperature. *[kWh/m^2,year]*
Daylight	Evaluated through results of daylight analysis carried out by VELUX daylight Visualizer. *[1 good daylight, 2 sufficient daylight, 3 bad daylight]*
Floor area	Size of floor area. *[m^2]*
Environmental impact of materials	Ratio of global warming impacts [kg CO_2-eq/m^2/year] on measures taken (production of new components and disposal of existing materials which are either worn out or disposed of for transformation purposes) for each scenario compared to global warming impacts of a reference building (production and disposal of a new office building).* The LCA analysis and comparison does not take into account future maintenance, energy use and disposal so as not to extrapolate future strategies for disposal as well as the quality of future elements and their potential change in lifetime. When calculating the impacts for the scenarios, transportation to and from construction site is ignored, hence it is assumed that 95-98% of the impact is accounted for by this method. ** *[-] (Ratio)*
Recycling rate	The remaining embodied carbon [kg CO_2-eq] from the existing building in each scenario compared to the total embodied carbon of the existing building (scenario 0). ** *[-] (Ratio)*
Remaining life years	Superficial evaluations of remaining life years through assumptions and standard lifetimes. *[years]*
Architectural quality	Each scenario is evaluated on its aesthetics and architectural quality based on arguments/theory from the SAVE method. *[Points 1-9, where 1 is high quality]*
Interaction with surrounding site	An evaluation of the building's ability to interact and give quality to its surroundings. *[Points 1-9, where 1 is high quality]*

*The reference building utilized for comparison is NN1 [7]

**The environmental impacts and calculations for embodied energy to find recycling rates are gathered from EcoInvent and processed in GaBi. The LCIA methodology

3.2.2 PROPOSALS

In this section a short description of each scenario is given with images for illustration and understanding purposes. After each scenario has been presented and described a summary and comparison of all results will be made. All scenarios and their related calculations are carried out with assumptions from observations and general traditions. The main purpose of the project is to use the MCDM tool and hence detailing on each scenario are ignored.

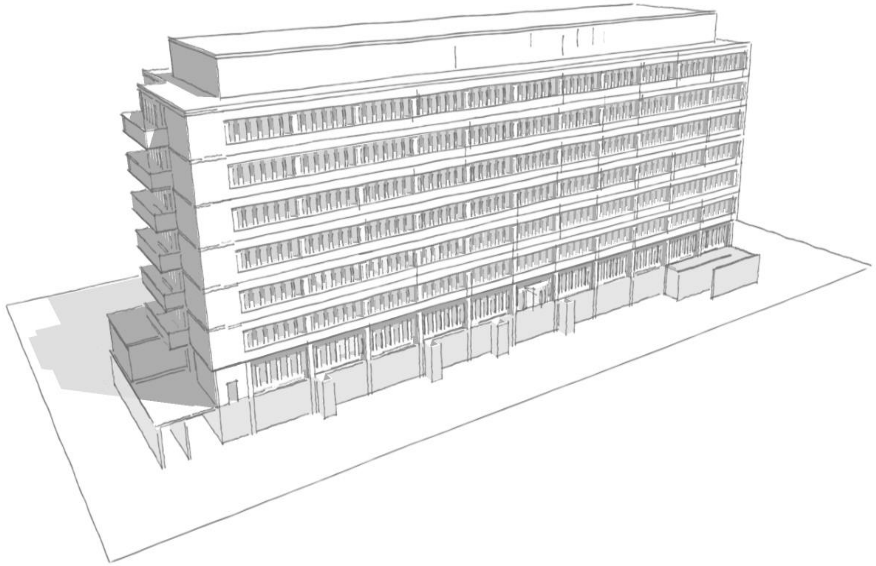


Figure 28: Illustration of the existing building

3.2.2.1 SCENARIO 0 - THE EXISTING BUILDING

(Summary from section 3.1 Building 40)

The existing building 40 is evaluated according to energy performance and daylight with results of 152,8 kWh/m^2 per year and 0 kWh/m^2 per year of overheating and an acceptable daylight of 2% in half the room which is recommended in the Danish Building Regulation. The total floor area is 17851 m^2 including basement. The embodied carbon of the building materials production is 5,7E6 kg CO2-eq. The building should have 63 years left where maintenance on some materials is needed but not accounted for in the environmental impacts calculations as different options are explored in the following four scenarios.

Scores for each criteria (which are not used in MCDM but given for comparison purpose):
Energy consumption: 152,8 kWh/m^2
Overheat: 0 kWh/m^2
Daylight: 2 (sufficient daylight)
Floor area: 17851 m^2
Environmental impact of materials: (not calculated)
Recycling rate: 100%
Remaining life years: 63 years
Architectural quality: 3
Interaction with new surrounding site: 7

3.2.2.2 SCENARIO 1 - DEMOLISH AND BUILD NEW

The existing building is demolished and replaced by a new office building. The new office building is assumed to be similar to the NN1 building and environmental impacts from this case is used [7]. This new building is assumed to meet the energy requirements of 2015 as well as recommendations for daylight. The building is further assumed to consist of 15000m^2 floor area.

The environmental impact for disposal of the existing building materials and the production of the new standard building materials are taken into account. The impacts of disposal of existing materials and production of new building compared to LCA impacts of a reference building is 109%. In Figure 31 can be seen the in- and output for the calculation. In Appendix A can be found details and calculations for the disposal and production impacts respectively. The division of impacts between materials and processes are shown in Figure 30. Maintenance is not included in the environmental impacts. The recycling rate is zero as no materials of the existing building are preserved.

The architectural value is difficult to evaluate as it is an imagined case. An assumption however is made affected by thoughts that a new building at this spot would only be built with high quality to give this new site attractional value, including architectural quality. Quality on interaction with surrounding site and concept is assumed relatively high. This is assumed since efforts and investments are made for the building and probably designed *for* the site.

Scores for each criteria to use in MCDM:
Energy consumption: 41,1 kWh/m^2
Overheat: 0 kWh/m^2
Daylight: 1 (good daylight)
Floor area: 15000 m^2
Environmental impact of materials: 109%
Recycling rate: 0%
Remaining life years: 100 years
Architectural quality: 1 (high quality)
Interaction with new surrounding site: 1 (high quality)

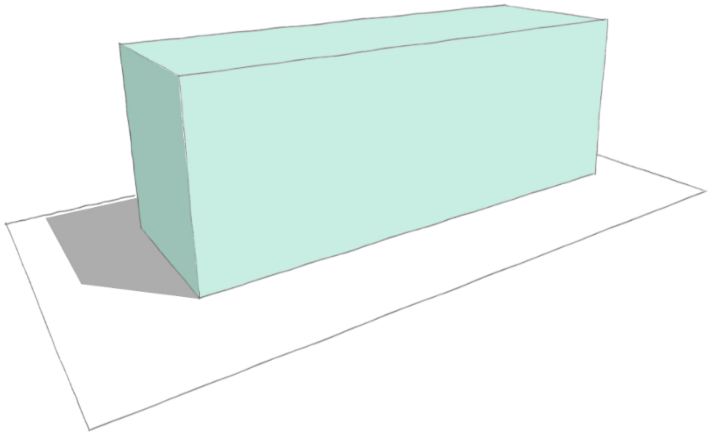


Figure 29: Building block representing the new fictional building

Figure 31: Black Box: in and outputs in environmental impacts evaluation

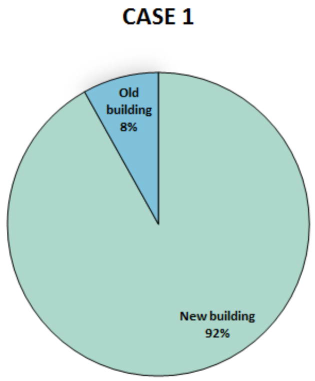


Figure 30: Pie chart showing the production and disposal

3.2.2.3 SCENARIO 2 – MAINTENANCE

In scenario 2 the existing building is renovated by renewal of building materials which are worn out - regular maintenance. The materials included in this renewal are windows, roofing felt and eternit plates. The existing windows are assumed to be 2-layered in a frame of wood and steel and to be replaced by 3-layered windows in a similar frame. These new windows are assumed with a light transmittance of 0,75 compared to the original with transmittance 0,8. The calculation can be found in Appendix B and C. The daylight is slightly decreased overall but still supplying a sufficient daylight in the facade/office rooms. See Figure 33 and Figure 34 for daylight analysis on the ground and third floor. Eternit plates on the upper floor, where installations are placed, are renewed. Roofing felt is also renewed in its original type and form. The renovated building has a better energy performance as the new 3-layered windows has a lower U-value, hence lower heat loss. The energy use is calculated to 112,7 kWh/m^2 per year. This is a 26% reduction from the existing building of scenario 0. The overheat is 3 kWh/m^2 per year.

The environmental impact of the elimination of existing materials and production of new elements are summarized to 4% compared to the LCA of a new building. An overview of the materials accounted for are shown in Figure 35, illustrated by the black box principle. The division between impacts for material and phases can be seen in Figure 36. The recycling rate is at 94%.

The floor area is equal to scenario 0 of 17851 m^2. Architectural quality and quality of interaction to surrounding site is unchanged from scenario 0 as the qualities are preserved despite the renewal of the building elements. The score of each criteria can be seen below.

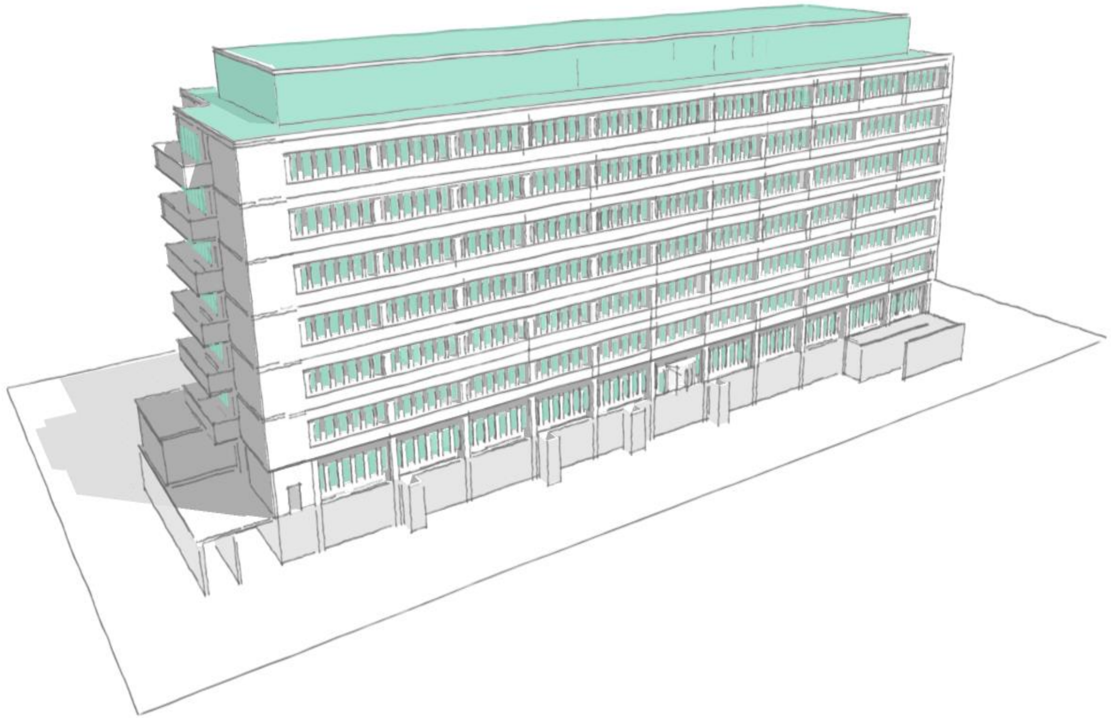


Figure 32: Illustration of the building highlighting the renovated elements

Scores for each criteria to use in MCDM:
Energy consumption: 112,7 kWh/m^2
Overheat: 3 kWh/m^2
Daylight: 2 (sufficient)
Floor area: 17851 m^2
Environmental impact of materials: 4%
Recycling rate: 94%
Remaining life years: 63 years
Architectural quality: 3 (rather good quality)
Interaction with new surrounding site: 7 (rather bad quality)

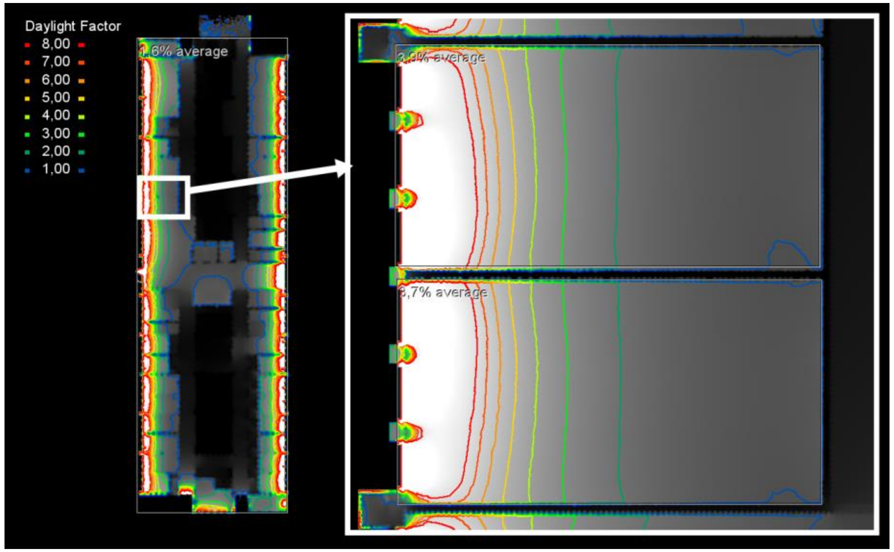


Figure 33: Daylight factor at ground floor

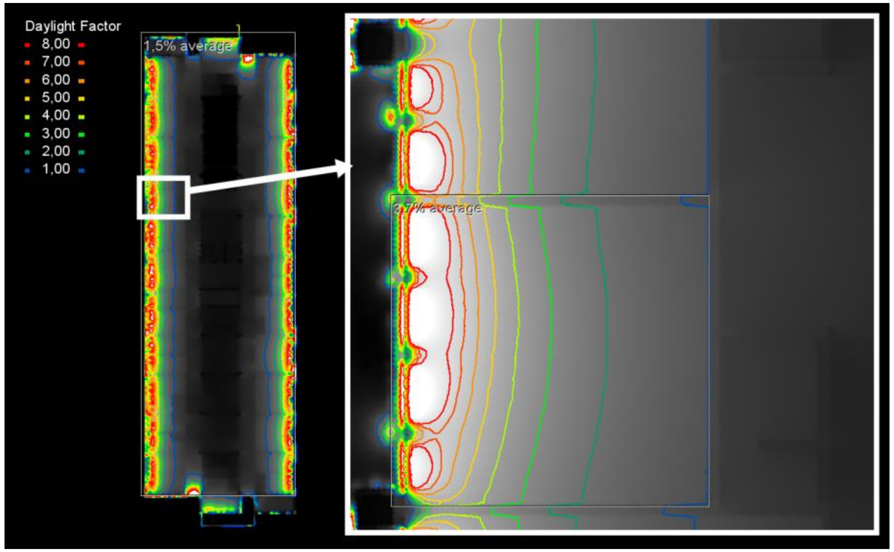


Figure 34: Daylight factor on third floor

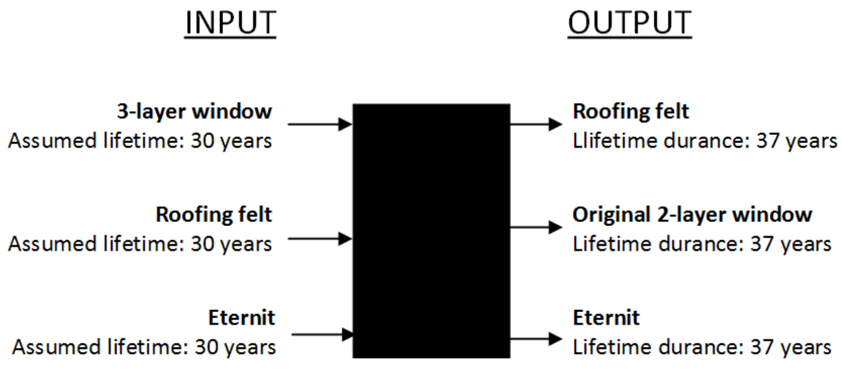


Figure 35: Black box: overview of in and outputs in environmental impacts evaluation

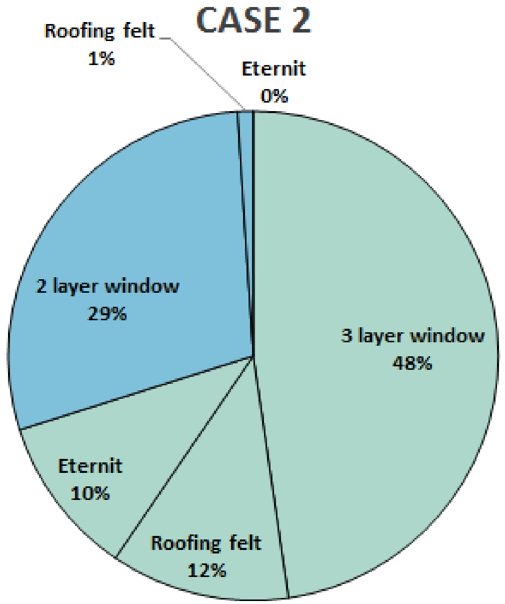


Figure 36: Pie chart showing the production and disposal

3.2.2.4 SCENARIO 3 - MAINTENANCE AND FACADE OPTIMIZATION

This scenario is similar to scenario 2 and an adding of additional insulation material to decrease the heat loss of the building. Insulation is added within external concrete wall elements and on the exterior side of the concrete columns. The insulation around the columns overlaps the original windows and the new energy efficient windows will then be 20 cm narrower, still keeping the expression and characteristic of the building.

The energy consumption is calculated to 109,3 kWh/m^2 per year and hence only reduced a little compared to scenario 2. The overheat is increased to 3,8 kWh/m^2 due to lower heat loss as the building is now better insulated. With decrease in window area the daylight factor in the building is decreased, but only slightly and there is no actual difference. In Figure 39 and Figure 41 the daylight of respectively the ground and third floor can be seen.

As additional material is applied, the environmental impact is 7% compared to the impacts of a new office building. The measures taken into account in the LCA are shown in Figure 38. The division between impacts are shown in the pie chart of Figure 40. The recycling rate is 94% and equal to scenario 2 as the same existing materials are renewed and only additional insulation is added, still reusing the old.

Architectural quality and quality on interaction with surroundings are equal to case 2, as the qualities are retained. Despite the fact that smaller modifications are made the building still preserves the original architectural qualities.

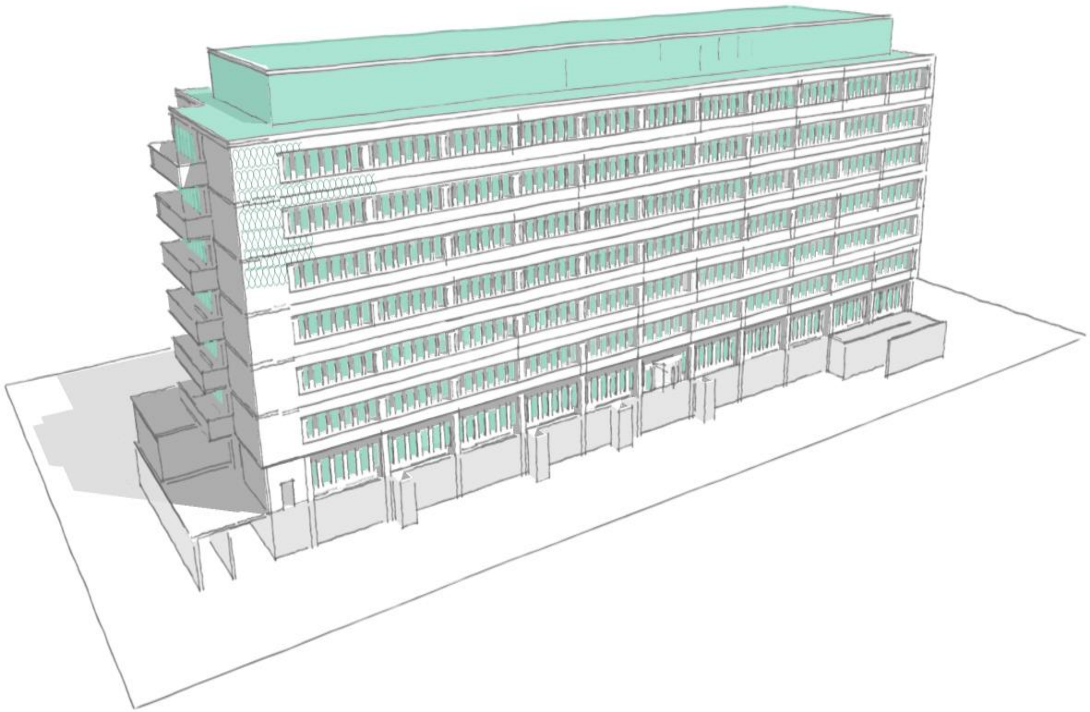


Figure 37: Illustration of the building highlighting renovation elements

Scores for each criteria to use in MCDM:
Energy consumption: 109,3 kWh/m^2
Overheat: 3,8 kWh/m^2
Daylight: 2 (sufficient daylight)
Floor area: 17851 m^2
Environmental impact of materials: 7%
Recycling rate: 94%
Remaining life years: 63
Architectural quality: 3 (rather high quality)
Interaction with new surrounding site: 7 (rather low quality)

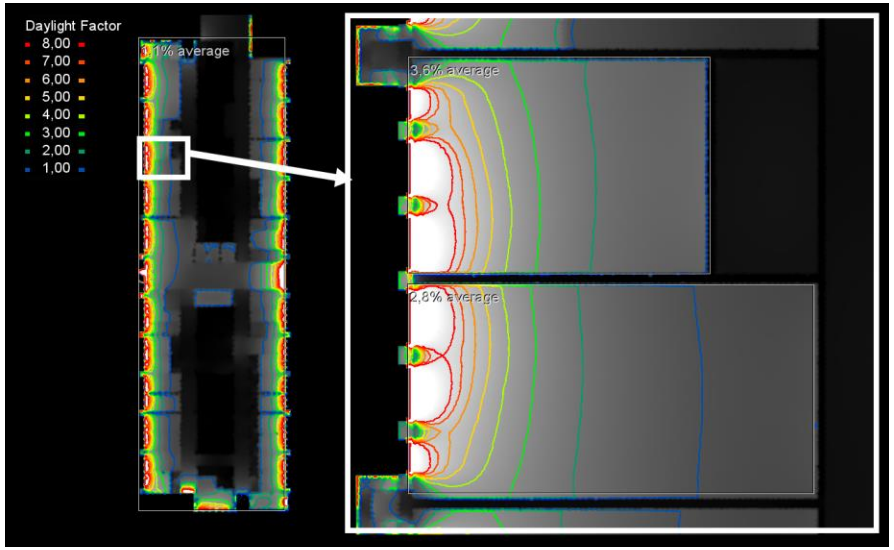


Figure 39: Daylight factor at ground floor

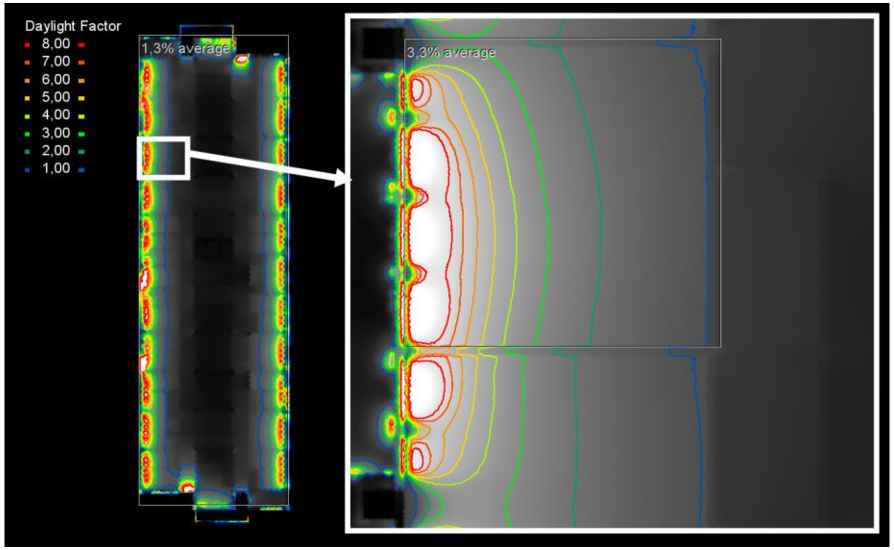


Figure 41: Daylight factor at third floor

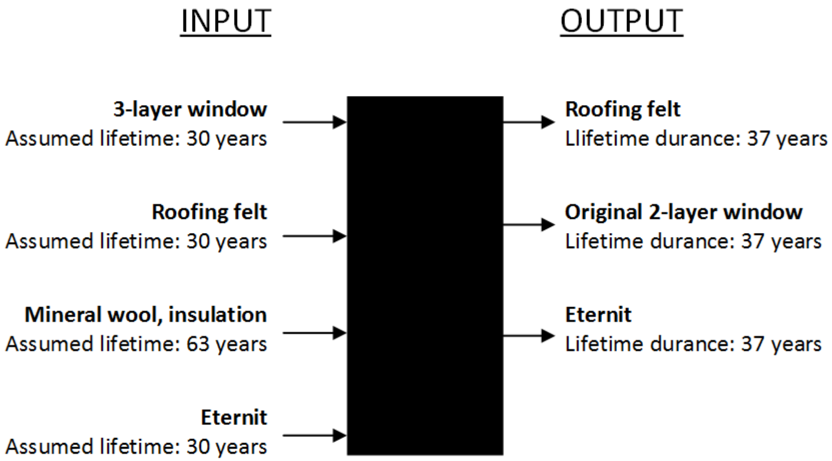


Figure 38: Black box: overview of in and outputs in environmental impacts evaluation

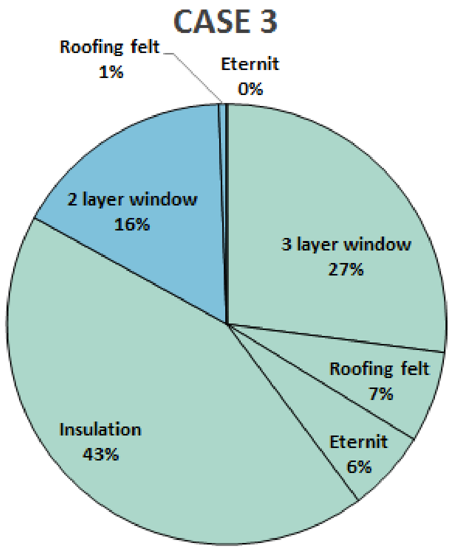


Figure 40: Pie chart showing the production and disposal

3.2.2.5 SCENARIO 4 - MAJOR RENOVATION

In this scenario a larger renovation is carried out. The building is assumed to be used for entrepreneurship and development. The building will consist of studios and workshops for individuals and smaller companies with joined and individual exhibition opportunities and a public restaurant on the top floor. A large horizontal exhibition space combined with a cafe will be found on the ground and basement floors. In the middle of the building large openings/atriums in decks will be giving opportunities to look up on other floors from the ground floor. The load carrying beams in these openings will be kept to preserve the original load carrying system and for exhibition spots. This will further enhance the original architectural qualities with raw concrete. This open interspace will, beside exhibition spots, provide an actual view up through the building. The studios can utilize this view for display through transparent walls creating a vertical exhibition space. An illustration of the interior design can be seen in Figure 44. The transparent walls for the studios can be used for display and exhibition and potentially be equipped with interior curtains if a more private atmosphere is needed.

In the center will be utilized the existing lifts and staircases as well as staircases at the ends of the building. All staircases and lifts are surrounded

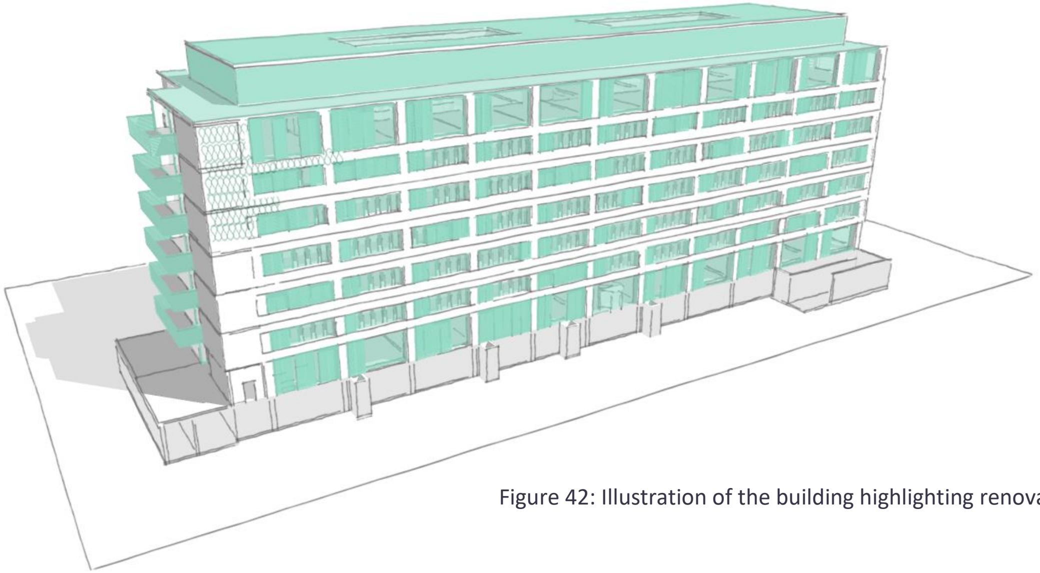


Figure 42: Illustration of the building highlighting renovation elements

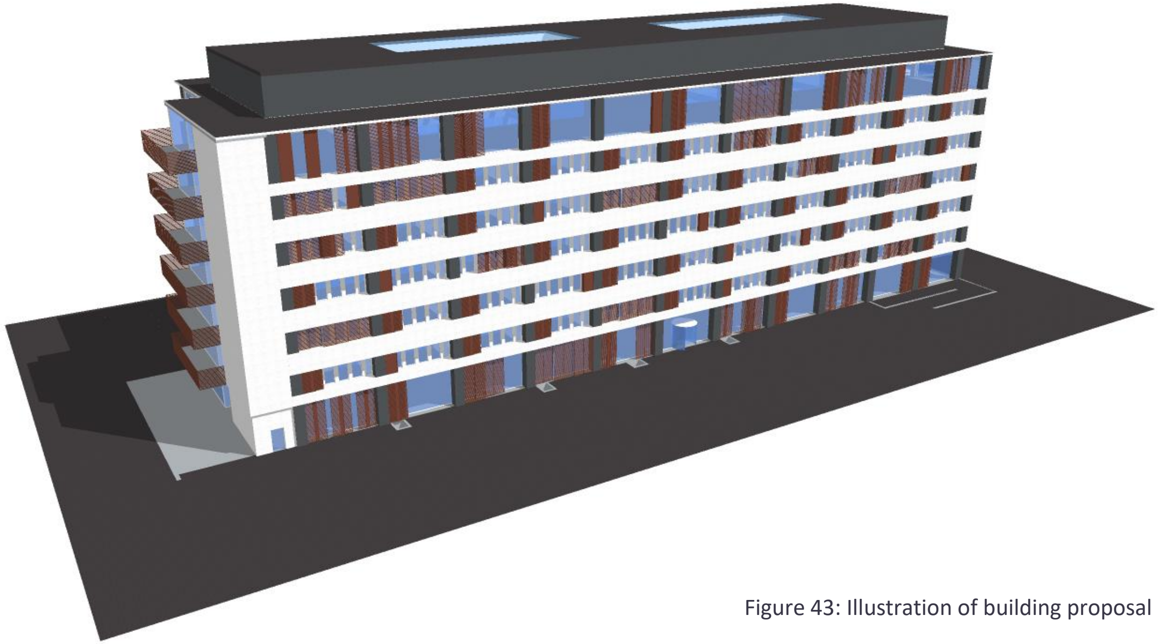


Figure 43: Illustration of building proposal

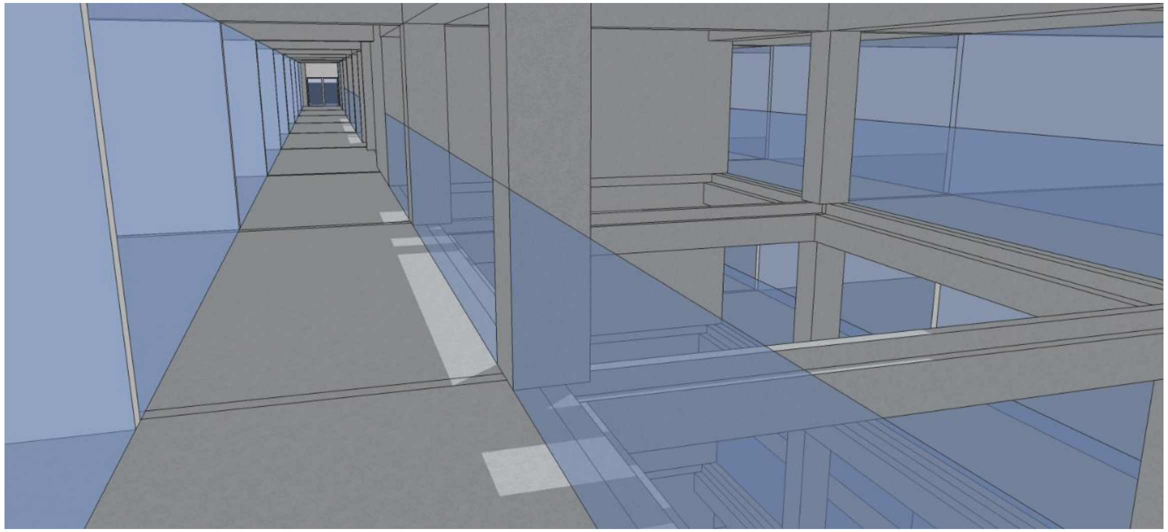


Figure 44: Detail of open interspace in the middle of the building

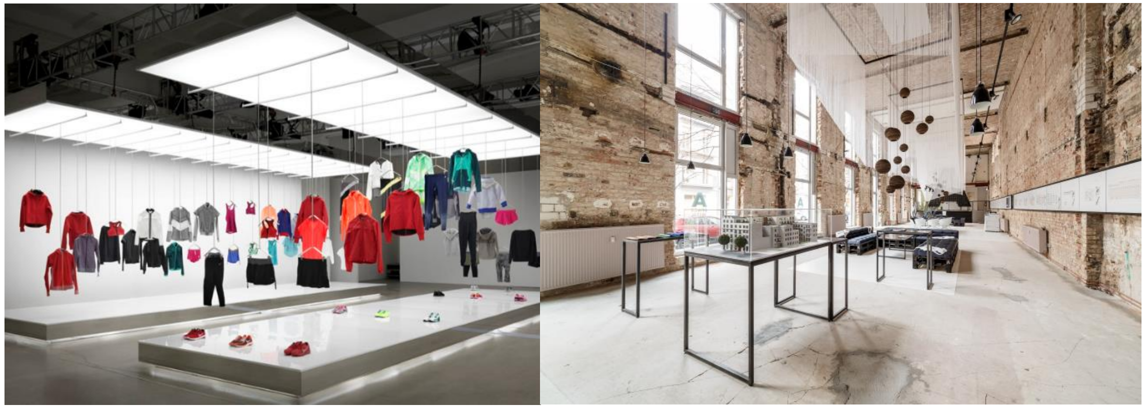


Figure 46: Reference images: Exhibition ideas

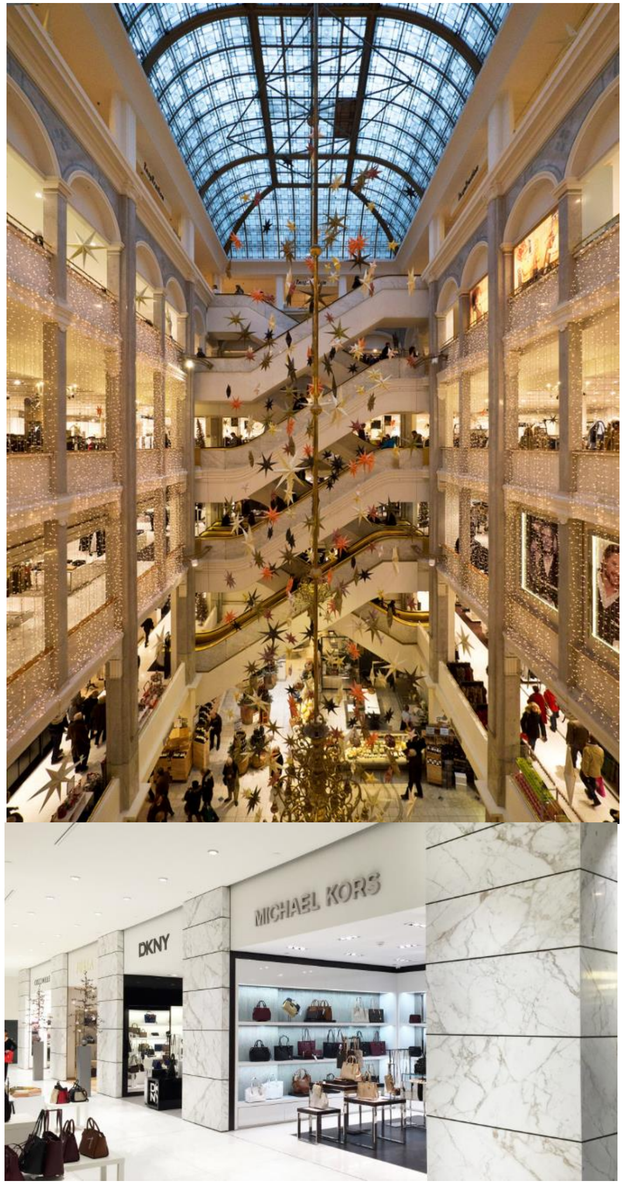


Figure 45: Reference images: views through several storeys, Illum, Copenhagen

by stabilizing concrete walls which will be preserved in the load carrying system. On Figure 47 can be seen a plan of 3rd floor.

The staircase in the center should be attractive and interesting inviting people to use it despite the fact that it is closed in a concrete shaft adjacent to elevators. Ideas to accomplish this include lighting installations creating and experience in the otherwise dark and closed off space. Also small exhibition and display spots could be used giving quality and value to utilize the stairs and giving it life. With the restaurant on the top floor and transparent walls for display on each floor the public is invited to visit all floors and enjoy the surroundings in this open space, which furthermore helps joining all storeys. This design has similarities to big shopping malls such as Illum and Magasin in Copenhagen with openings in the middle of each floor providing a view up through all storeys. Reference images are shown in Figure 45.

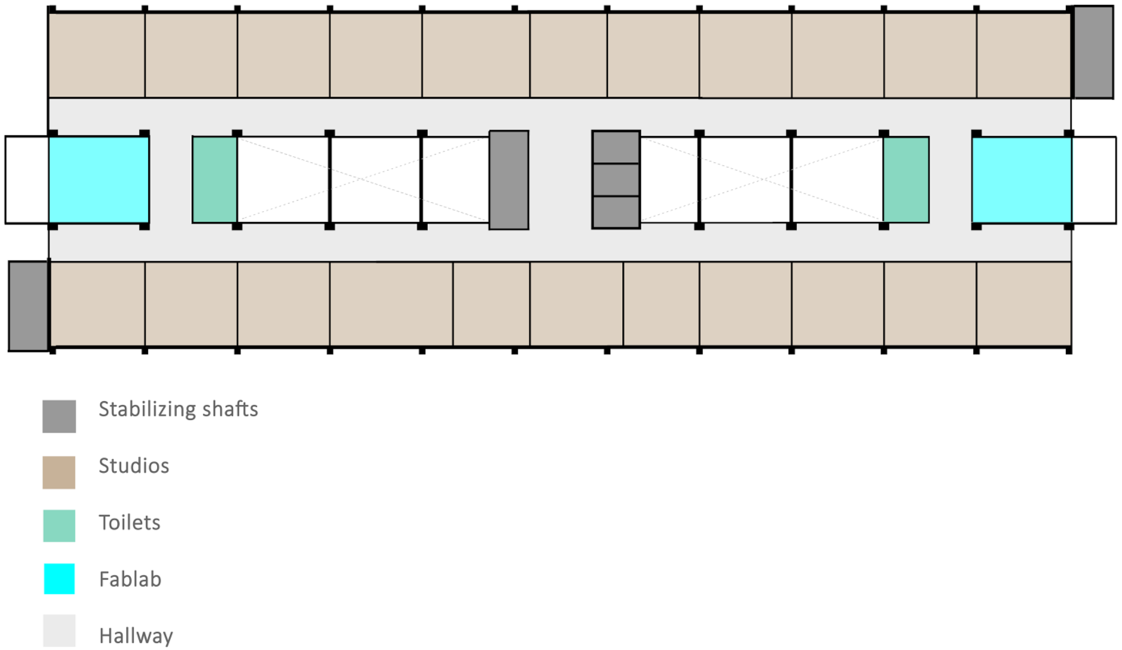


Figure 47: Plan of the 3rd floor

Figure 48: Lighting installations for main staircase

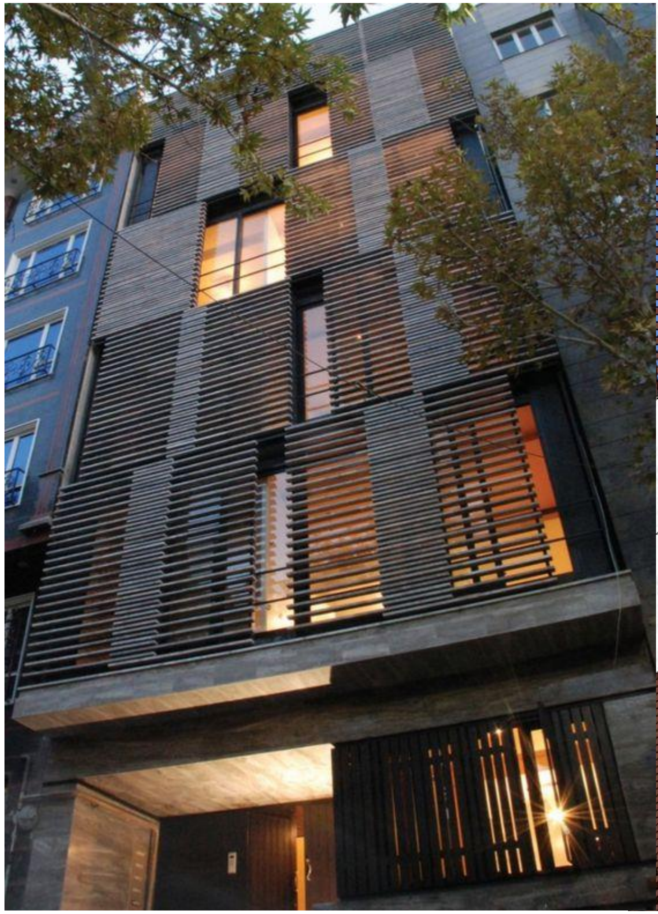


Figure 50: Reference image: external shading

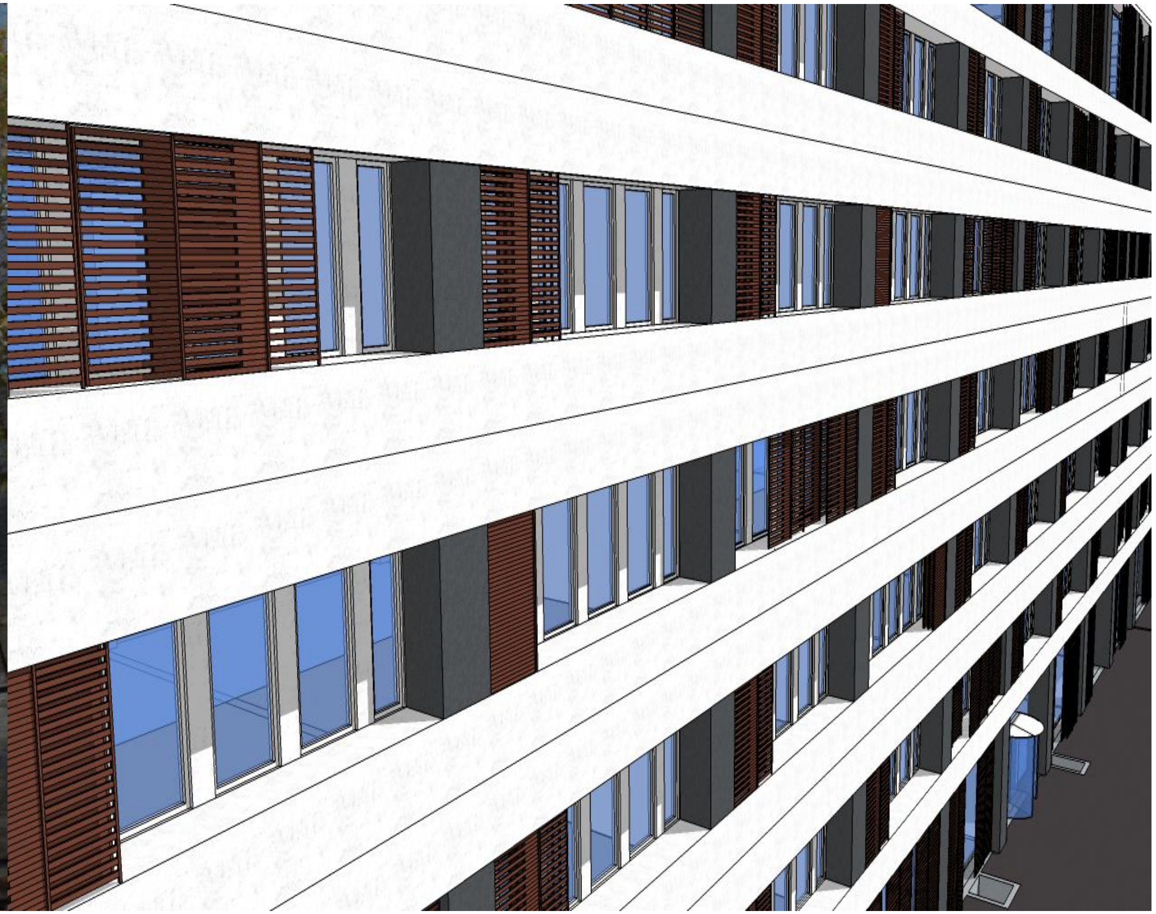


Figure 49: External shading on building

The building has an energy consumption of 67,8 kWh/m^2 per year, which is a reduction of 56% compared to the original building. The energy consumption fulfills requirements for both *Renoveringsklasse 1* and *2* (Renovation classes 1 and 2 of the Danish Building Regulation) and has 0 kWh/m^2 per year of overheating. The overheat has been reduced by use of external shading. This external shading is made through wooden panels. These should be movable providing a flexible system to use as preferred by the users. The shades will furthermore bring warmth and softness to the otherwise cold and adamant design of raw concrete. An illustration of how the shading could look is shown in Figure 50.

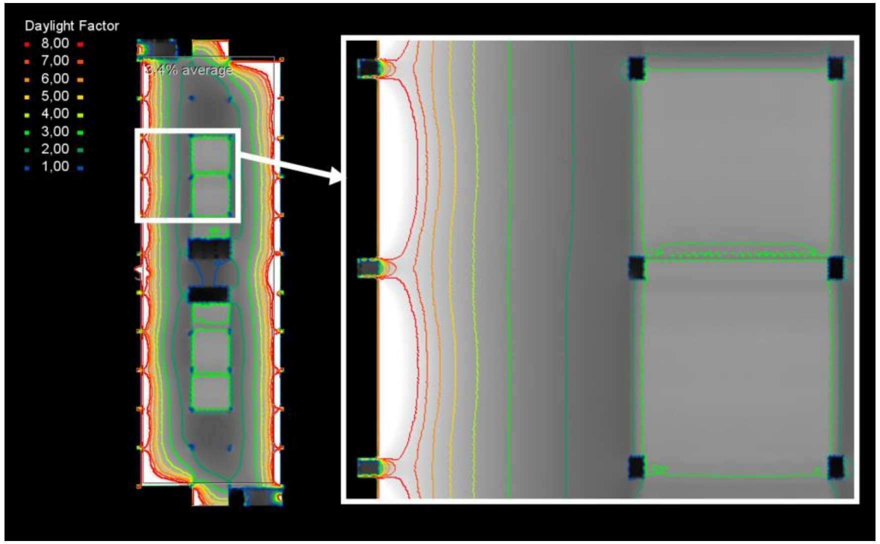


Figure 52: Daylight factor at ground floor

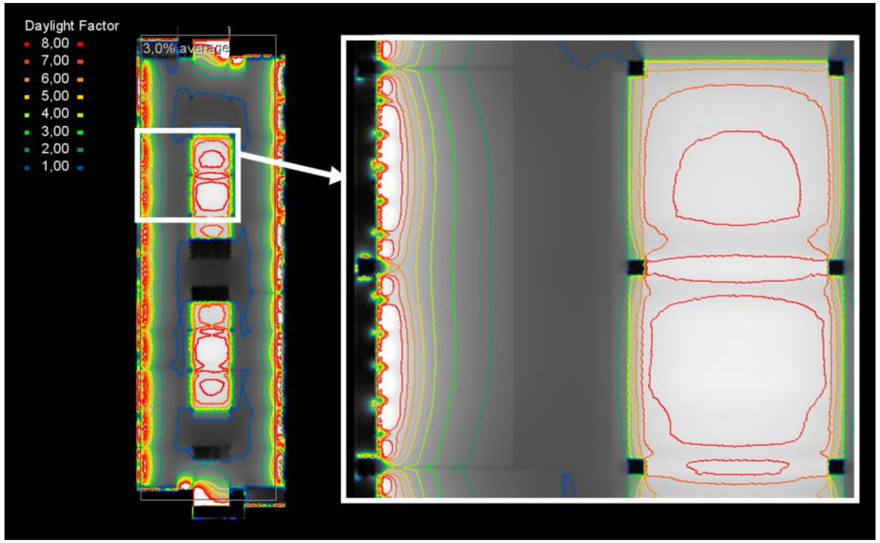


Figure 51: Daylight factor at third floor

To improve daylight in the center of the building/the new atrium's, roof openings through the installation storey and restaurant will be installed. This will, besides improving the daylight, supply an opportunity to experience all floors and hence join these through the openings as visitors in the restaurant can look directly down through glass walls surrounding the openings. The daylight factor analysis can be seen on Figure 51 and Figure 52 for ground and third floor respectively.

In general, the daylight has been greatly improved especially in the middle of the building since daylight is now present in the center of the building through the roof opening.

On the ground and top floor external walls and windows are renewed by complete glass facades. These glass walls have a transmittance of 45% so as not to create glare and to avoid overheating as the g-value is low. This is also accommodated through the already mentioned external blinds which are also found on the ground floor.

The total floor area of the building will be 15345 m^2 which is 86% of the existing building due to large openings in decks in the middle. The environmental impact of materials demolished of the original building and production of new materials is 19% compared to that of an entire reference building (new office building). An overview of the in and output of the LCA calculation is shown in Figure 53. The main part (78%) of the environmental impact is due to production of new materials. Figure 54 shows the division of environmental impacts. The recycling rate is 71%.

Some of the original architectural qualities are retained through preservation of concrete columns and wall elements. The raw expression is kept to preserve the identity and the building history. The amended design should support the original qualities while improving the overall building attraction. The building's interaction with its surroundings is assumed high as it is specifically designed and developed with

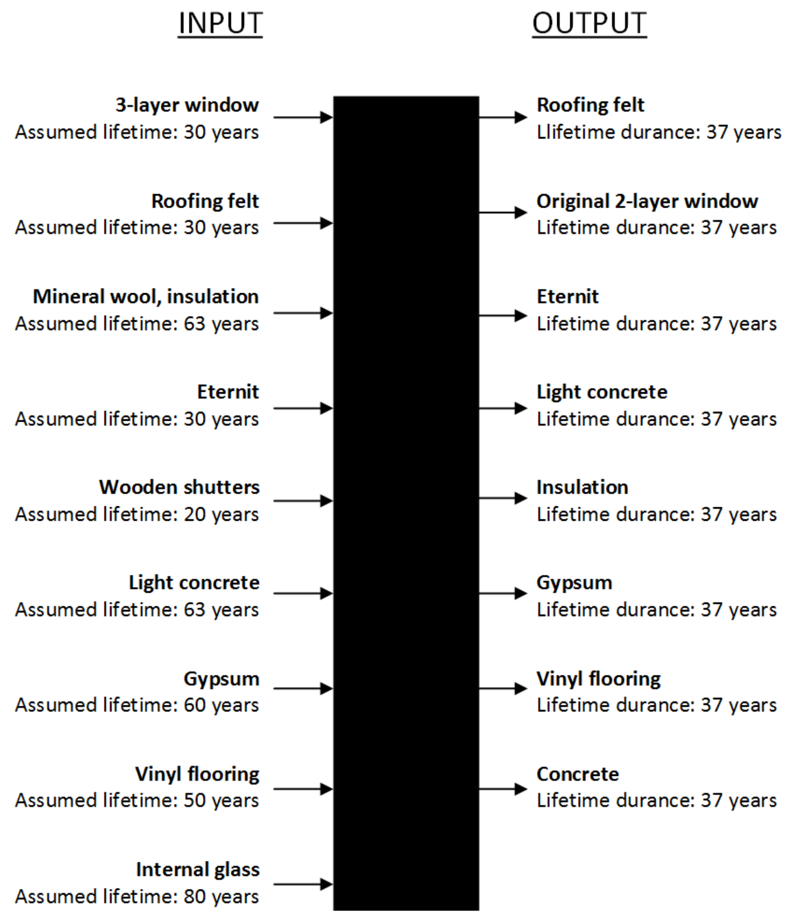


Figure 53: Black box: in and outputs of LCA

thoughts on the surrounding site, giving the building a new life. The building is in this design more open and inviting through among other the higher transmittance on street level.

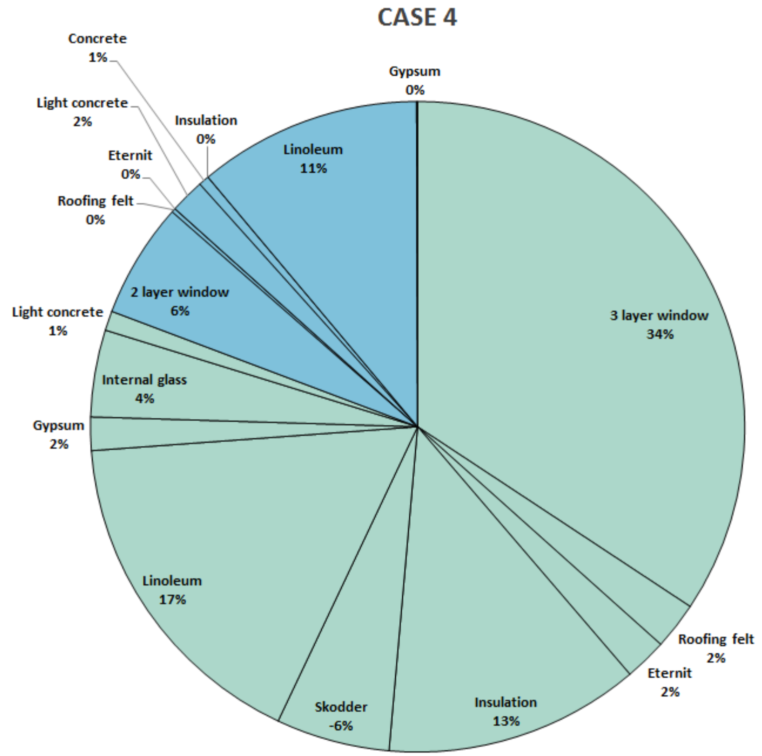


Figure 54: Pie chart showing the production and disposal

Scores for each criteria to use in MCDM:
Energy consumption: 67,8 kWh/m²
Overheat: 0 kWh/m²
Daylight: 1 (good daylight)
Floor area: 15345 m²
Environmental impact of materials: 19%
Recycling rate: 71%
Remaining life years: 63 years
Architectural quality: 1 (high quality)
Interaction with new surrounding site: 1 (high quality)

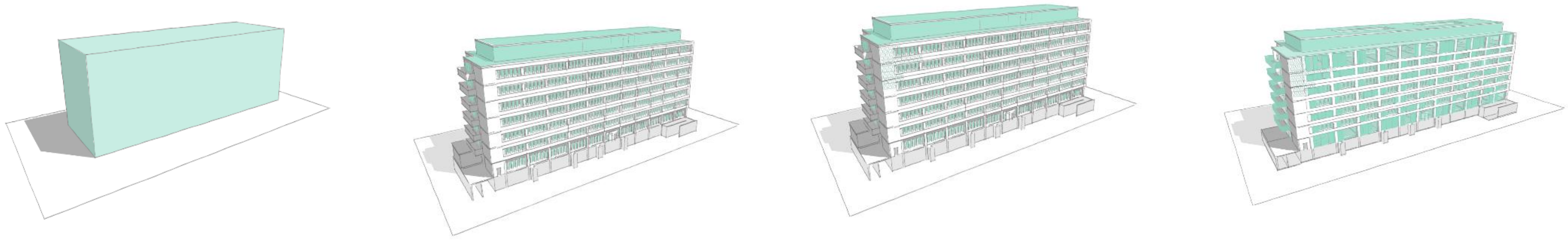
3.2.2.6 SUMMARY

On the opposite page on Figure 55 are shown diagrams for each criteria comparing the scenarios. In general daylight varies but in all scenarios it is sufficient. Energy is rather high for the original building and with the small renovation cases which does decrease with renovation approaches. The decrease in energy however increases the overheat in the building as heat loss is lowered. This is again decreased in case 4 where external blinds are utilized which also helps avoiding glare and lowering the illumination near the window, which could otherwise be prevented by use of internal curtains.

The environmental impact coefficient varies and is larger in the comparison to a standard new office building emission, with larger renovation approaches. The recycling rate is higher as less actions are taken.

The architectural expression varies in cases 1 and 4, where 2 and 3 the building looks more or less the same with only minor changes in case 3. In case 4 the original structure and facade elements are preserved as well as the window pattern on all storeys except the ground and top floor. This preservation helps keeping the architectural qualities of the building. The raw concrete and continuous facade system are characteristic for the building and its history. The overall architectural impression is hence changed in case 4 but still with high quality. In case 1 no knowledge on architectural quality is known. An assumption however is made affected by thoughts that a new building at this spot would only be built with high quality to give this new site attractional value, including architectural quality.

Quality on interaction with surrounding site and concept is assumed higher for case 1 and 4 where actions are taken to design for the conceptual purpose. For case 2 and 3 it is lower as the building is only maintained and this large possibly office building might lack of attraction quality and inviting atmosphere as this new concept is designed for.



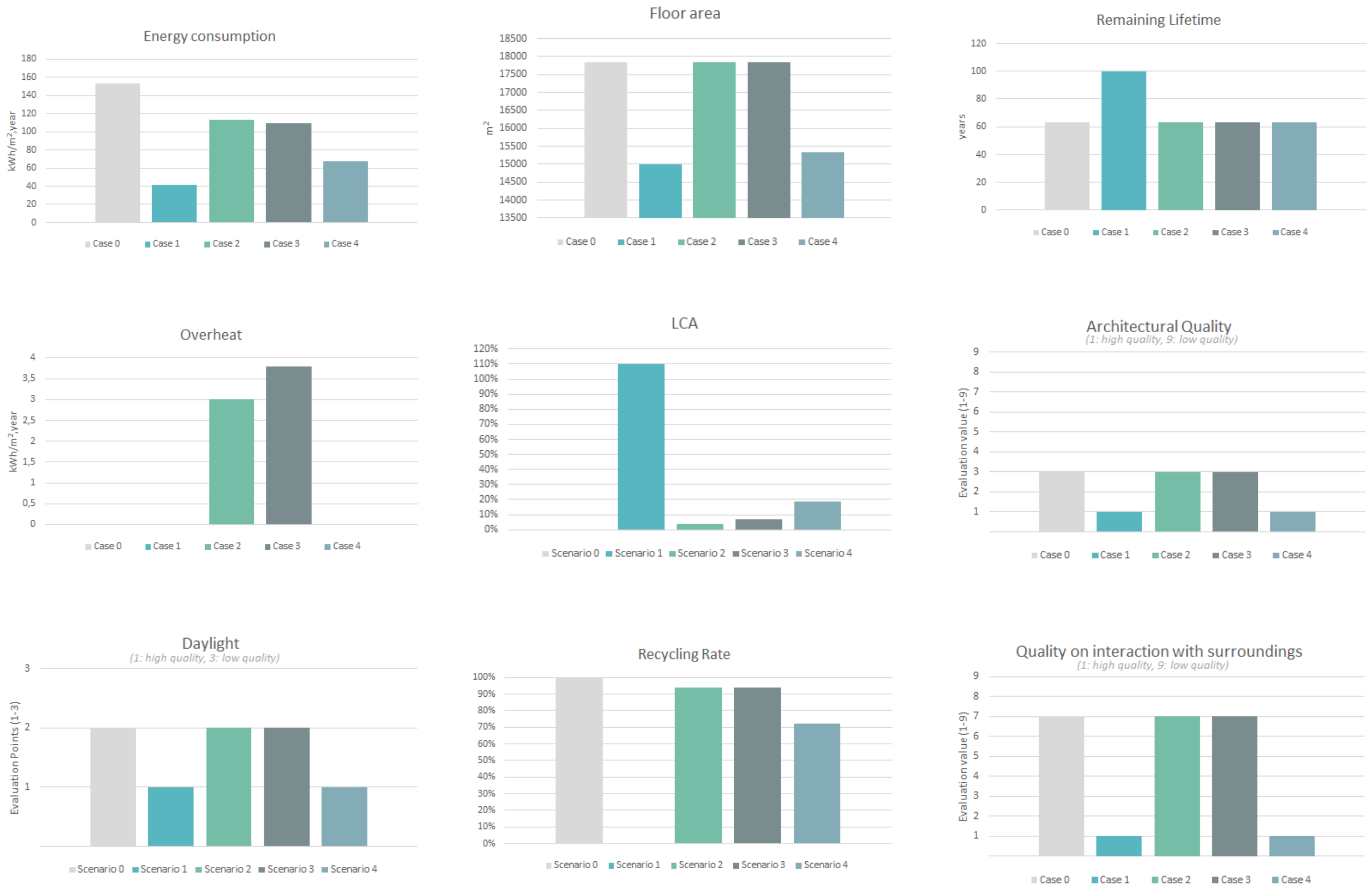


Figure 55: Results for each criteria comparising all five scenarios

The matrix in Table 3 will be used in the MCDM analysis which is described in the following section.

3.2.3 MCDM ANALYSIS

All scenarios have been evaluated according to a number of criteria and an MCDM analysis should help decide which scenario is the better one. MCDM is a mathematical approach and to perform it the TOPSIS method has been used. TOPSIS is short for Technique for Order of Preference by Similarity to Ideal Solution.

3.2.3.1 CALCULATION

The theory of the TOPSIS tool is to evaluate how close a solution of the given problematic, is from the ideal solution. It is built on the assumption of having 'm' alternative solutions (in this case scenarios), and 'n' criteria. The mathematics behind the method consists of linear algebra. The exact calculations can be seen in Appendix D, and below the different steps of the method and mathematics are explained along with the name of the tab where the steps take place in the appendix.

3.2.3.2 WEIGHTING

Each criteria is given a certain "weight" according to its 'importance'). The weights of each criteria are described on page 40. For each criteria is also specified whether a criteria is preferred as high or as low as possible and hence referred to as a beneficial attribute or a negative attribute respectively.

Table 3: Matrix with results of criteria for each scenario to use in MCDM calculation

Scenario	0)	**1**	**2**	**3**	**4**
Energy Consumption [kWh/m²,year]	152,8	41,1	112,7	109,3	67,8
Overheat [kWh/m²,year]	0	0	3	3,8	0
Daylight [-]	2	1	2	2	1
Floor area [m²]	17851	15000	17581	17851	15345
Environmental Impact [%]	0%	110%	4%	7%	19%
Recycling Rate [%]	100%	0%	94%	94%	72%
Remaining lifetime [years]	63	100	63	63	63
Architectural Quality [-]	3	1	3	3	1
Interaction with surroundings [-]	7	1	7	7	1

STEP 1 'Input' tab - Defining the components.

a) When having the alternative solutions (buildings) and the different criteria (mapping types), a matrix can be established, an m*n-matrix, where each component, x_{ij}, is a score dependent on the alternative/buildings, i, and the criteria/mappings, j. These scores are shown in the coherent mappings and explained earlier in the report. The criteria/mappings included in the MCDM are:

1. Architectural quality
2. Cultural quality
3. Environmental quality
4. Originality
5. Condition
6. Area
7. LCA - Embodied Energy
8. LCA - Global warming
9. Years left

b) Then defining 'Y' as a set of beneficial attributes - the more, the better, and defining 'N' as a set of negative attributes - the less the better.

STEP 2 'Normalization' tab - Normalization of the decision matrix (m*n-matrix)

a) By doing this, the different criteria, which are valued differently, are aligned which allows comparison across all criteria, as their sizes are somewhat equal.

b) Mathematically, this is done by

$$n_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \qquad , i = 1, \ldots, m, \qquad j = 1, \ldots, n$$

STEP 3 'Weighting' tab - Weighting of the normalized components

a) Defining a weighting, w[j], for all the different criteria put up and multiplying this weighting with each normalized n_{ij} component from the m*n-matrix

b) Mathematically, this is done by

$$v_{ij} = w_{ij} * n_{ij} \qquad , i = 1, \ldots, m, \qquad j = 1, \ldots, n$$

STEP 4 'Ideal&NegativeIdeal solution' tab - Determining the ideal and negative ideal solution value.

a) The ideal solution can be found by pointing out the maximum v_{ij}'s value of beneficial attributes, when using 'Y', and minimum value from the negative attributes, when using 'N'.

1. Mathematically this is done by
   $A^{+} = \{v_1{}^{+}, \ldots, v_n{}^{+}\} = \{(max_j(v_{ij})|i \in Y), (min_j(v_{ij})|i \in NJ)\}.$
   This gives the maximal distance $v_j{}^{+}$

b) The negative ideal solution can be found by pointing out the minimum v_{ij}'s value of beneficial attributes, when using 'Y', and maximum value from the negative attributes, when using 'N'.

2. Mathematically this is done by:
   $A^{-} = \{v_1{}^{-}, \ldots, v_n{}^{-}\} = \{(min_j(v_{ij})|i \in Y), (max_j(v_{ij})|i \in N)\}.$

This gives the maximal distance $v_j{}^{-}$

STEP 5 'Separation measures' tab - Determining the 'placements' of the alternatives/solutions.

a) Distance from the ideal solution is found by

$$d^{+}{}_{i} = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^{+})^2} \qquad , i = 1, \ldots, m,$$

b) Distance from the negative ideal solution is found by

$$d^{-}{}_{i} = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^{-})^2} \qquad , i = 1, \ldots, m,$$

c) The square root of the summation is however done on the next tab, hence only the subtraction squared are on this exact tab.

STEP 6 'RelativeCloseness to IdealSolut' tab - Determining the relative closeness for each solution (building) to the ideal solution.

a) Mathematically it is done by:

$$R_i = \frac{d_i{}^{-}}{(d_i{}^{+} + d_i{}^{-})}, i = 1, \ldots, m.$$

b) As $d_i{}^{-} \geq 0$ and $d_i{}^{+} \geq 0$, then the result must be within $R_i \in [0,1]$. Hence, the bigger R[i], the closer to the ideal solution.

Energy Consumption	4	Energy consumption is an important factor. Building operation is a large consumer and should preferably be reduced also for security of our environment. This criteria is a negative attribute in the MCDM calculation and should be as low as possible.
Overheat	3	It is deemed important to have comfortable thermal indoor environment as to ensure user satisfaction. Overheat is a negative attribute in the MCDM analysis as it is preferred as low as possible.
Daylight	4	Daylight is an important quality in a building and working environment. A good daylight also minimizes use of artificial lighting and hence minimize energy consumption. Since daylight is given a score of 1 for best quality it is a negative attribute in the MCDM analysis.
Floor area	2	The size of floor area is not a very important factor in this project, where focus has been more on functionality and quality. It is however often an important factor and could in other cases be given a higher weight. It is important though to consider the range between scenarios as this factor might be able to vary a lot. The criteria is preferred as large as possible and therefore a beneficial attribute.
Environmental impact of materials	2	Environmental impacts have been given a rather low weight. It is an important factor but due to large uncertainties in the calculations the weight has been reduced. The calculations have only taken global warming into account as an environmental impact due to lack of reference values on other categories. The impacts should be as low as possible and therefore is a negative attribute.
Recycling rate	4	The rate of recycling is given high weight as preservation of resources has become more and more important for the environment and meaning minimized extraction of raw materials. The recycling rate should be as high as possible and therefore a beneficial attribute.
Remaining life years	3	Remaining life years is rather important and a very low timeframe is to be avoided if great amounts of resources are invested. Remaining life years is a beneficial attribute and should be as high as possible.
Architectural quality	3	Architectural quality for our surroundings is very important for preservation of buildings. In this project however there are some uncertainties as a fictional scenario is included. Therefore, a weight of 3 is given. Architectural quality is evaluated according to the SAVE method where 1 point indicates highest quality, hence this criteria is an negative attribute in the MCDM analysis.
Interaction with surrounding site	4	Interactions with the surrounding site is considered important especially in this case as the quality for the area and its concept is important for the city and the site development. This criteria is evaluated with a scale like architectural quality and is therefore also a negative attribute as it is preferred as low as possible.

3.2.3.3 *RESULTS*

After the score of each scenario has been evaluated in the MCDM tool, the relative closeness to an ideal solution is found. This means that the scenario with the highest score is the 'best' solution according to the MCDM analysis. The results can be seen in the diagram in Figure X. Scenario 4 is hence the best solution for renovation of building 40 according to the MCDM analysis.

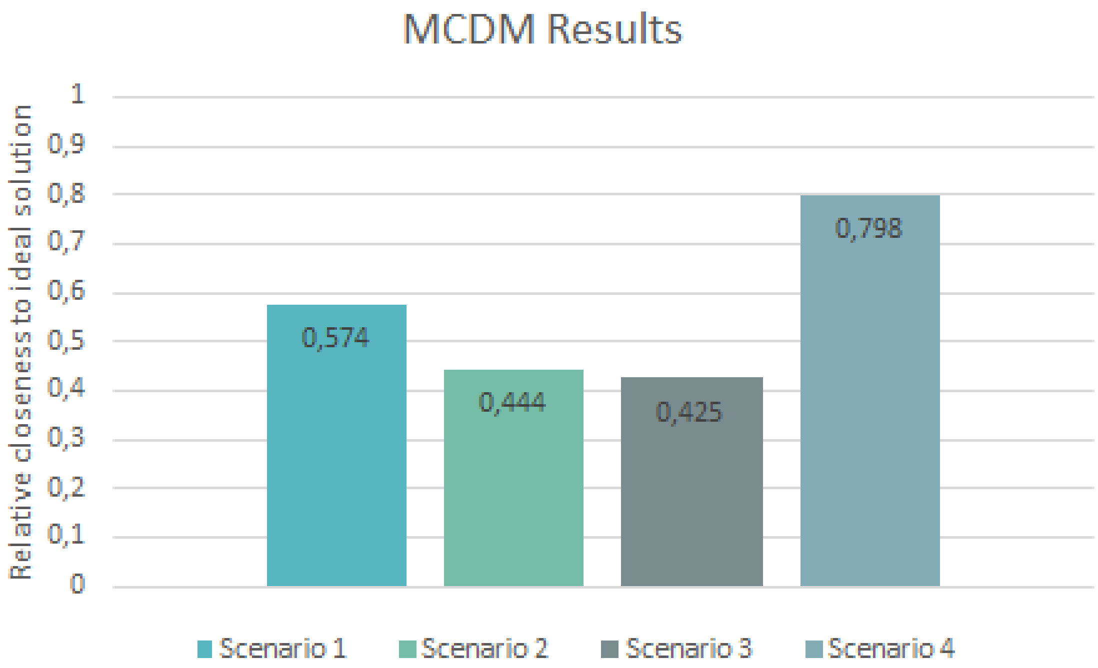


Figure 56: Diagram of MCDM results

4 DISCUSSION

Scenario 4 is evaluated the optimal solution after the MCDM analysis. The scenario revolved around a major renovation with preservation of 71% of the original building and high functional and aesthetic qualities. Hereafter followed scenario 1 with complete disposal and new build. Scenario 1 had higher environmental impact and lower recycling rate but a much reduced energy consumption and high quality on daylight, aesthetics and interaction with site. Without the MCDM analysis a holistic evaluation of all criteria compared to other scenarios would be complicated. The MCDM creates a numerical calculation which takes all criteria included into account. The final two scenarios, scenario 2 and 3 representing the smaller renovations of mainly maintenance and addition of insulation material, had the highest distance towards an ideal solution. The scenarios vary only slightly between them and with the result that additional insulation was not sufficient enough to give a higher score by the MCDM analysis. The two cases only differ on energy consumption and environmental impact and for both criteria only with slight differences. Scenario 2 without insulation is slightly better. These results also state that for this construction issue value creation is preferred and minimal maintenance would not pay off.

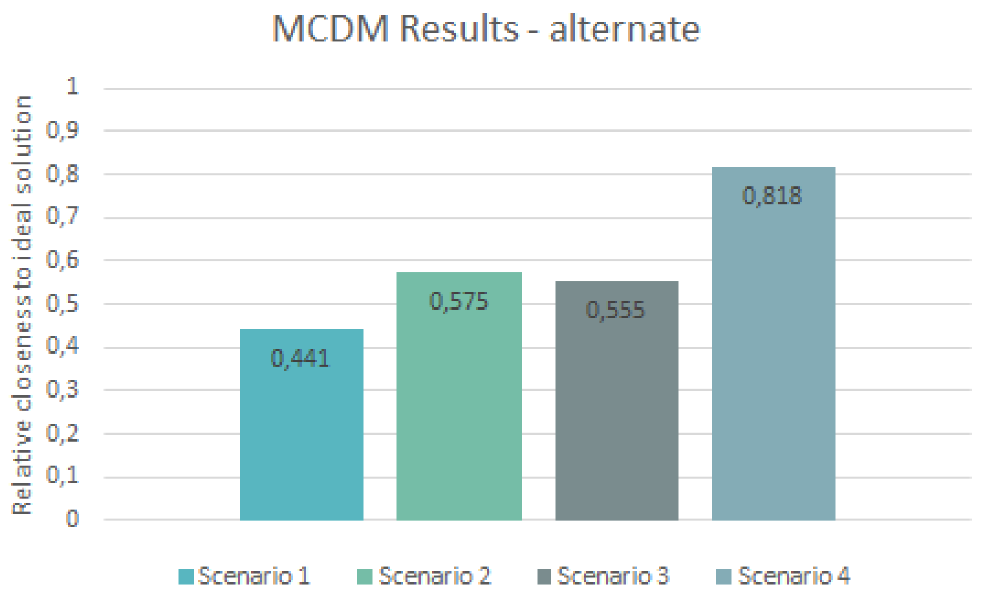


Figure 57: Diagram of alternate MCDM results

There are many things to consider when deciding a solution for any construction. In this case four scenarios for a building renovation or transformation has been presented. They vary in smaller or larger degree between many criteria. Scenario 4 got the highest score through the MCDM calculation. Is it then the best solution?

In the MCDM analysis is accounted for a number of criteria. In order for the method to be most reliable all important criteria should be included. In this case most important criteria are included with the exception of cost. Cost is an important factor and should be included if the decision was to be carried out in reality. Another criteria which could have been included is historic quality as the project deals with renovation issues.

Another important factor of the method is the weight of each criteria. The environmental impact was only given a low weight despite its otherwise great importance. If the criteria is given a weight of 5 the results would be looking slightly different. In Figure 57 these alternative results are shown.

In these new edited results scenario 4 is again the scenario with greatest closeness to the ideal solution. But in the original results scenario 1 followed and has now, in the edited results, the lowest score. Scenario 1 has great environmental impact compared to the other scenarios. If the criteria is then given higher weight this impact would have great consequences. Environmental impacts are however not given a high weight as the results have uncertainties. If other criteria are given a higher weight no change between the ranking of scenarios occurs and scenario 4 is hence the preferred scenario.

Calculations for environmental impacts are only concerning actions taken here and now and does not take maintenance necessities into account. This is an issue since maintenance can have a rather important impact on LCA analysis. It is however not included in the analysis as extrapolating is difficult and can be as wrong as it can be correct. To get a more precise and correct analysis more time should be spent on the analysis but has not been possible within the timeframe and priority of the project. The quality and validity of each criteria could have been cultivated further if more time had been available.

The uncertainties do not, however, imperfect the method but only highlights that the method should be used carefully and always critically and therefore results not trusted blindly. The results can give an indication of all the considerations made which cannot be evaluated singularly without a tool like this. The tool helps concretize each issue considered and can also be used as a communicative tool showing the thoughts, weights and partial results. The tool could also be used for e.g. architectural competitions. The tool can help decide which proposals have the highest quality and are preferable.

The MCDM tool has evaluated scenario 4 as the most preferable. Scenario 4 preserves architectural qualities as well as historic qualities. The building and its history through OUH has had a great impact on Odense city. This importance gives quality to the building and supports the state for preserving the building, despite the building transformation as the original structure as skeleton is preserved given a new expression complying with the original qualities. The energy consumption is reduced to 44% of the original and the daylight has been greatly improved. Overall the building qualities have been improved while having great functional compliance with the surrounding area and concept while also having improved attractional value.

The MCDM method has been carried out for both macro and micro scale, part 1 and part 2 of the entire project respectively. For the macro scale the tool was used for evaluation what building to preserve and which to demolish. In that case LCA analysis were preferred with high embodied impact such as to preserve what had already had a great impact. For the micro scale however, the MCDM tool has been used for evaluation scenarios for what actions to be taken for an existing building. In this case LCA impacts are preferred as low as possible to minimize the future impacts. This illustrates different ways of integrating LCA in a decision tool and how a tool like MCDM can handle all situations and criterias considered.

5 CONCLUSION

Through the MCDM analysis scenario 4 involving a major renovation with preservation of 71% of the original construction was preferred. The scenario is an update of the original construction with improved energy consumption and daylight. The scenario has qualities of the original building and preserves historic value, while getting a transformation which enhance functionality in connection with the overall area.

The MCDM analysis includes a number of criteria including energy, environmental impacts, functional and aesthetic values. The weight of these might vary depending on focus areas. Nevertheless, the criteria which can really change for this specific analysis is environmental impact. This criteria has a rather large range between the scenarios and hence has an important effect on the results. But due to uncertainties of the LCA analysis, which only concerns actions taken here and now and not future impacts, the criteria has been given less weight in the final MCDM analysis. If the criteria was however given high weight with the analysis made in this project, scenario 4 would still have the highest score.

The MCDM tool with implemented LCA analysis has proven very useful for evaluations including many criteria and variations on renovation subjects. Further the method has been applied for two different issues which differ in scale and also in phases. For the large scale, part 1 of the entire project, environmental impacts were preferred as high as possible to preserve impacts as they had already occurred. Opposite is it in this second part where actions are to be taken and environmental impacts hence are preferred as low as possible.

The multi-criteria decision making tool has proven useful and for more than one subject. For Odense University Hospital it has proven the ability to help decide what is to happen to the existing site as the hospital functions move out in 2022, including environmental concerns. The evaluation which is to be made is very complicated as the site consists of large variations within many criteria. The MCDM tool has in this case shown that we should preserve quality and resources when they have the ability to preserve or create value for future purposes.

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