Technical University of Denmark

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[Report]

Sustainable certifications as assessment method for renovation versus demolition

Creation of a decision supporting tool for evaluating renovation versus demolition of an office building, based on sustainable certification parameters.

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SUMMARY

Energy reduction, sustainability, environmental impacts and energy renovation are hot topics in the modern world of today. New materials and new construction methods have raised many possibilities for today's contractors, but are also leaving a mark on the world we live in. Global warming and large energy consumption are only some of the areas we are dealing with every day. Many strategies have therefore been developed in order to reduce these impacts. Amongst them are the sustainable certifications, which consider the environmental, economic and social sustainability of a building. The goal is to create more sustainable buildings, which reduces the impact on the world we live in. Many countries have their own certification, but some have grown large and are known and used all over the world. Some of these are BREEAM, LEED and DGNB, which are handled in this thesis.

A problem with the diversity and the large amount of systems and strategies for incorporating sustainability in buildings is the confusion it creates for the users. No common thread is achieved. This is also occurring during renovation projects. There are no specific guidelines that can be used by all contractors, which results in each project being "individual" and creates no standard measures which can be used by others or for multiple buildings. This is also the case when a building is to be assessed between renovation and demolition. The lack of tools or guidelines for this decision generates a possible tendency for a small amount of parameters to be the base for the decision. Economy is in most cases the turning point for what will be the outcome for the building.

By using a tool that would consider several sustainability parameters together, such as environmental and social sustainability, the assessment whether a building should be renovated or demolished, would be deeper analyzed and the base for the decision would be prepared more thoroughly. A tool like this could be used as a collective guideline, a united strategy for making the buildings more sustainable.

The objective of this thesis is to create a tool, based on and inspired by parameters from sustainable certifications, which can contribute to the assessment whether a building should be renovated or demolished and rebuild. It is found that a tool like this, could answer many questions for a contractor, and backup the decision that is made by relevant analyses.

The method is created through a development process, which is documented in this report. The process consists of a selection of parameter space from three sustainable certifications. This selection is made over several steps to limit the amount of parameters, by comparing with existing lists and recommendations. Based on the selected parameters, a tool is created which a contractor can use as a contribution to the assessment whether a building should be renovated or demolished and rebuild.

The decision supporting tool is divided in 5 steps, which guide the contractor through the analysis of the regarded building, for a renovation and a demolition scenario. In the first steps the specific case are sorted in order to see if further analysis should be made, or if the building only would benefit from regular maintenance. In the following step, the tool can be shaped to fit several cases, by having boundaries defined by the contractor. In the next two steps further analysis are made, which becomes more detailed as it prolongs. By this, the contractor can process the whole tool if wished, a simple- and a more detailed part, which adds severe cost and is more time consuming, or only one of them. The two steps which includes simple questions and more detailed calculations, results in a

scoring that can be related to the preference of renovating or demolishing. The final decision for the regarded building should although be made by the contractor.

Case studies are performed in this report on several buildings in order to test the decision supporting tool. By this, needed flaws and lacks in the tool can be discovered together with possible further development strategies.

The goal of this thesis is to create a simple tool that is easy and quick to use in the early stages, when a building is to be assessed between a renovation versus demolition. By using this tool, a united sustainability approach can be incorporated in the analysis, which ensures a well thought out solution for the respective building. The goal is not to create a tool that can give a final justification and decision making, if a building should be renovated or demolished and rebuild. The tool should be seen as a way to investigate the vision for the building, and can be used as background analysis for the decision making, which in the end should be made by the contractor.

RESUMÉ

Energi besparelse, bæredygtighed, miljømæssige påvirkninger og energi renovering er populære emner i dag. Nye materialer og nye konstruktions metoder har øget muligheden for dagens bygningsejere men har også påvirket verdenen som vi lever i. Global opvarmning og stort energi forbrug er bare nogle af de ting der kæmpes med til daglig. Der er derfor udviklet mange strategier til at reducere disse påvirkninger. Blandt disse er de bæredygtige certificeringer som tager hensyn til miljø, økonomi og social bæredygtighed i en bygning. Målet er at skabe bæredygtige bygninger der mindsker påvirkningen på jordkloden. Mange lande har deres eget certificerings system, mens andre certificeringer har vokset sig store og kendte og bliver anvendt i hele verden. Nogle af disse er BREEAM, LEED og DGNB, der også bliver benyttet i dette projekt.

Et problem med den store forskel på, og det store antal af systemer og strategier til at indføre bæredygtighed i bygninger, er den forvirring de skaber for brugerne. Der er ingen fælles strategi. Dette er også tilfældet ved renoverings projekter. Der forefindes ingen specifikke guidelines der kan bruges af alle bygherrer, hvilket resulterer i at hvert projekt behandles individuelt og der skabes ingen standard procedurer der kan benyttes af andre eller på andre bygninger. Det samme gælder for projekter hvor bygningen skal vurderes i forhold til om den skal renoveres eller rives ned. Manglen på værktøj og guidelines skaber et lille grundlang for beslutningen. Økonomi er ofte den vigtigste parameter, og det der bestemmer udfaldet.

Ved at anvende et værktøj der behandler flere bæredygtigheds parametre, så som miljø og social bæredygtighed, vil en vurdering af om en bygning skal renoveres eller rives ned, blive dybere analyseret og grundlaget for beslutningen ville være mere gennemarbejdet. Sådan et værktøj kunne benyttes som en fælles guideline, en samlet strategi for at gøre bygninger mere bæredygtige.

Målet med dette projekt er at skabe et værktøj, baseret på og inspireret af parametre fra bæredygtige certificeringer, der kan bidrage til vurderingen af, om en bygning skal renoveres eller rives ned og bygges op på ny. Det er vurderet, at sådan et værktøj kunne basvare mange spørgsmål fra en bygherre og supplere beslutningen gennem relevante analyser.

Metoden er skabt gennem er udviklings proces der er dokumenteret i denne rapport. Processen består af udvælgelse af parametre fra de tre bæredygtigheds certificeringer. Denne udvælgelse er udført over flere omgange for at begrænse antallet af parameter, ved at sammenligne med eksisterende lister of anbefalinger. Med udgangspunkt i de udvalgte parametre er et værktøj skabt, der kan benyttes af en bygherre til at vurdere om en bygning skal renoveres eller rives ned og bygges op på ny.

Værktøjet er opdelt i fem dele der vil guide bygherren gennem forskellige analyser af den bestemte bygning, både for en renoverings- samt en nedrivning situation. I den første del bliver bygningen vurderet i forhold til om flere analyser skal laves forover, eller om bygningen kun bør fortsætte med vedligeholdelse. I den efterfølgende del, formes værktøjet til at passe lige den bestemte bygnings situation, ved at bygherren definerer grænseværdier. I de næste to dele laves der flere analyser der bliver mere og mere detaljered. Ved dette kan bygherren, hvis ønsket, benytte hele værktøjet – en simpel og en mere detaljeret del der også vil koste mere og kræve mere tid, eller kun udføre én af analyserne. De to dele, der inkluderer simple spørgsmål og mere detaljerede beregninger, resulterer i

en bedømmelse der viser om bygningen bør overejes at blive renoveret eller revet ned og genopbygget. Den endelige beslutning skal dog træffes af bygherren.

Flere forsøg er lavet på forskellige bygninger, for at afprøve brugen af det skabte værktøj. Gennem dette kan fejl og mangler undersøges sammen med udviklingsmuligheder for fremtiden.

Målet med dette projekt er at skabe et enkelt værktøj der er nemt og hurtigt at bruge i de tidlige stadier af en bygningsproces, hvor en beslutning skal tages i forhold til om bygningen skal renoveres eller rives ned og bygges op på ny. Ved at bruge dette værktøj kan en fælles bæredygtigheds fremgang indarbejdes i analyserne, hvilket sikrer en velgennemtænkt beslutning for respektive bygning. Målet er ikke at skabe et værktøj der kan give en definitiv og endelig beslutning om en bygning bør renoveres ellers rives ned og genopbygges. Værktøjet skal ses som en metode til at undersøge visionen for bygningen og kan benyttes som baggrundsanalyser for beslutningen, der i den sidste ende skal træffes af bygherren.

CONTENT

LIST OF ABBREVIATIONS

BBB: Bæredygtig Boværdi Barometer

BDR: BREEAM Domestic Refurbishment

BEC: Byggeriets Evaluerings Center

BRE: Building Research Establishment Ldt.

BREEAM: BRE Environmental Assessment Method

CASBEE : Comprehensive Assessment System for Built Environment Efficiency

DF: Daylight Factor

DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Certificate)

DK-GBC: Green Building Council Denmark

HQE: Haute Qualité Environnmentale (High Quality Environmental standard)

LCA: Life Cycle Analysis

LEED: Leadership in Energy and Environmental Design

SBi: Statens Byggeforsknings institut

USGBC: U.S. Green Building Council

USED TERMS - EXPLANATION

“Method”
This thesis describes the development of a method where a tool is created to assess whether a building should be renovated or demolished and rebuild. The method is created through a longer process, which is documented in this report. The method should thereby be understood as the process and development of the resulting assessment tool.

”Certifications”
”Certifications” stated in the report, is to be understood as sustainable certifications such as BREEAM, LEED and DGNB, or a combination of the three. These are analyzed during the development of the above-described method.

“Parameters”
Parameters shall be understood as one single aspect of sustainability, e.g. annual energy demand that is used in this project. Some of the mentioned certifications above, have more parameters than others and during the process of the project, the parameters are explained more detailed and reduced to a smaller subset.

“Tool”
The tool in this thesis is the result of the method and includes the process described below. The tool is seen as the product of the analysis and development of this thesis. This tool is meant to be used for a quick and easy assessment of a building, whether it should be renovated or demolished and rebuild. The tool is not a final solution for the decision-making, but should be seen as a supplement and a guideline for the contractor and basic analysis. The final decision is made by the contractor.

“Process”
The process of this thesis is concerning the use of the tool that is developed. The process consists of 5 steps, which together creates the layout of the tool. By following the process of the tool, a basis analysis for the decision for the regarded building is created.

“Scenario”
In this thesis, “scenario” is used to explain the two analyses that are assessed during the development of the method and in the process of the tool. The scenarios are: *renovation of a building* & *demolition together with rebuilding of a building*.

“User guide”
The user guide is a supplement to this report, and treats only the tool that is created in this thesis. The user guide is a small handout, or a brochure where the tools is presented in a way that makes it possible to follow it step by step, and thereby guides the user through the process. The user guide is possible to bring, by an entrepreneur or contractor etc., when an assessment of a building shall be made. The tool itself is presented together with small explanations, which simplifies the use.

“Cases”

In the practical part of this thesis, the decision supporting tool is tested throughout a series of cases. These cases are used to analyze the user friendliness of the tool, and possible changes or further development that should be made to it. In one case, all 5 steps are analyzed, while only the first four is examined in the others.

1 INTRODUCTION

With the awareness today, of the increasing energy consumption and the eager of building low energy houses, there is now a need and necessity of being able to document the sustainability in a building. The term “sustainability”, how it should be defined and obtained, is although a very much discussed now days. In the Brundtland report [Brundtland, 1987], a definition of sustainability was created, which still is the most used, though how it is interpreted can vary from person to person. For some, sustainability equals lower energy consumption, for others it is the use of renewable energy, furthermore it can be interpreted as the impact on the environment or a combination of them all. Three fundamental sustainability parameters are although created, which can be found in almost all sustainability interpretations; economic, environmental and social sustainability.

Several sustainable certifications exist from where a new building can be assessed on its sustainability by analyzing a row of parameters. The sustainable certifications are used to define how well the buildings are performing in different categories, amongst them, environment, economy and materials etc. BREEAM, LEED and DGNB are just a few of the existing sustainable certifications, and new are developed with time, and old are updated and changed to fit the sustainability concept and standards of today. Although the certification exists, many contractors differ from using them. This is mainly because of the complexity of the analysis and the economic issues. A large documentation work is needed, in some cases over a longer period and also many of the sustainable certifications can only be performed by an educated assessor from the respective sustainability certification. Many contractors have although seen the benefits that follows a certified building. This can both be economical and energy saving benefits and not to forget the promotion of owning a “sustainable building.”

In Denmark, the Green Building Council has chosen the German DGNB certification as the national sustainability certification system. This decision is made based on a comparison of several certification methods. Other countries have chosen their own certification system, which reduces the unity in how buildings are made more sustainable.

Today, many buildings are in need of a larger renovation. Their building envelope is not “up to date”, according to the demands and requirements of today’s standards and also the energy consumption is too high, relative to the norm. By renovating a building, a lot of energy can be saved and a higher comfort for the users can be reached.

A sustainability certification would be a well-established method for assessing and prioritize energy renovation, as a lot of parameters would be considered and a good result would be achieved by focusing on a specific goal. Yet, there are almost no sustainability certifications for renovation projects. Some are under development, but not ready for daily use. Renovations of buildings today are often handled individually and thereby no united goal for how, and what to renovate exists. It confuses the contractors and in some cases, the needed renovations are not performed because of the lack of guidelines and missing information. In some cases the choice falls upon demolition of the building, because of the complexity of analyzing the possibility of renovation. A tool that can unite several parameters for this cause would be desirable, a decision supporting tool that can contribute to the assessment of a building, if it should be renovated or demolished and rebuild.

The objective of this thesis is to create a tool, based on inspiration from parameters from sustainable certification, which can contribute to the assessment whether a building should be renovated or demolished and rebuilt. It is found that a tool like this, could answer many questions for a contractor and back up the decision that is made by relevant analyses.

1.1 Why use sustainable certifications as a basis for an assessment method?

Many of today's houses were built 30-40 years ago, some are even older. The functions of the houses could have changed from offices to teaching, from residence to offices etc. The need of new functions in a building has most certainly changed though our way of life and the living standard of today have shifted. Furthermore, a building of a certain age is in need for attention, whether it has been maintained continuously or not. The standards and regulations regarding energy, indoor climate and building envelope have been optimized, not to forget the possibility of today's material and technical solutions.

Renovation is a hot topic that needs to be considered in many occasions. By renovating a building, there can be possible savings. Although there will be a cost for the intervention, the energy consumption will in most cases be lower and the savings will by time compensate for the investment.

It shall although not be forgotten that demolition of a building could be a better solution. A poor standard building could be rebuilt to a modern and top class building, which performs to the required standards of today. There is although a huge split between some people which see the benefit of demolish a building, to people which se the beauty and benefit of renovating a building and use the foundation that is set. Demolition is although more used on today's buildings and is more accepted as a good result, compared to a few years ago.

Sustainability is, as mentioned earlier, a modern and much used concept today. The way of living, the way we build buildings, the way we consume and handle materials are thought into a sustainable matter. We want to live the quality of life that we claim, but it should not be in a way that could jeopardize the world or future residence. The environment and the economical prospect is a large factor of the choices we make today, in order to live more sustainable. Standards and requirements are made to ensure that we live more sustainable and use the term in all that we do.

One of the initiatives is to make sustainable certifications. These are a method to incorporate sustainability when a new building is created, when renovating a building or planning a larger communal area. A certification ensures that certain procedures are followed, and enhances the standard of buildings, with one united goal – to become more sustainable. A sustainable certification makes the performance of a building transparent, and leaves no questions unanswered. By using a certification for judging the sustainability in a building, it ensures a certain level of quality in the building. There is achieved a transparency for the performance of the building that can't be hidden, and it heightens the bar for what the owner of the building aims for regarding the building.

The sustainable certifications have also shown that there becomes an aroused interest when a building can show a certificate on its sustainable scoring. It proves that it is a well performing building, with good qualities in many areas. "A healthy building". In some countries, such as England, a sustainable certification degree is required for public buildings [Birgisdottir et al., 2010].

The economy by having a sustainable certification is improved for a contractor, as it is shown that buildings are easier to sell, hire out or raise the rent upon, when a sustainable certification is achieved. In a report made by Byggeriets Evaluerings Center (BEC) [Birgisdottir et al., 2010] it is stated that a LEED certified building can achieve savings on energy use up to 30 %, reduced water use for 30-50 % and also large savings on waste. The same report also states that a LEED certified building can be rented out for 5 % higher rent and be sold for a 60 % higher price. This makes a certification of a building very attractive.

This can also be seen by the amount of buildings that are chosen to be certified. See Figure 1 and Figure 2.

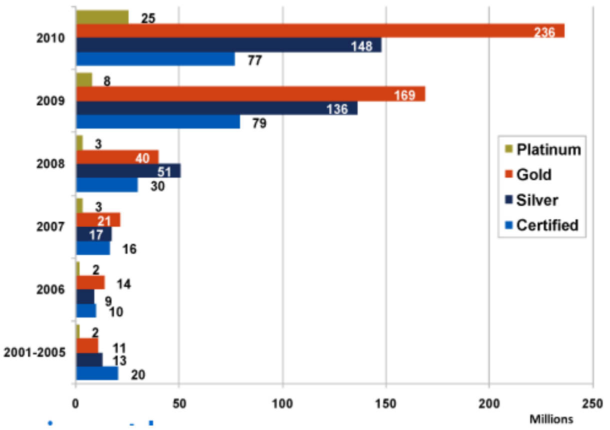


Figure 1: LEED certified buildings - 2001-2010 [USGBC, 2011]

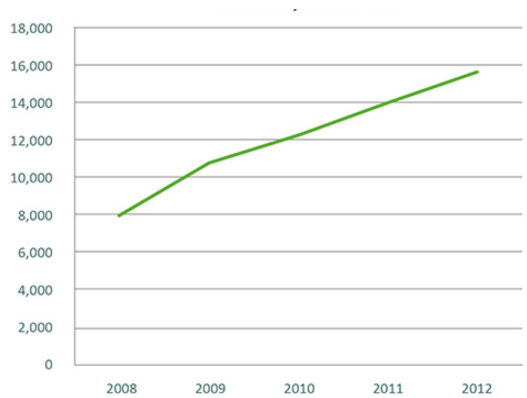


Figure 2: BREEAM projects certified - 2008-2012 [BREEAM, n.d.]

Figure 1 shows the rise of buildings and projects that have been certified with LEED and Figure 2 - the BREEAM certifications in the years 2001-2010 (LEED) and 2008 – 2012 (BREEAM).

There is a large increase of LEED certified building since 2006, as can been seen from the figure. This increase is similar for all certification methods and for all countries. In Figure 2, the amount of BREEAM certified projects since 2008 is presented. Also here there is an increase of certified buildings.

By creating a method, based on a sustainable certification, a qualified assessment can be made whether a building should be renovated or demolished and rebuilt. There are a lot of factors that can improve a building, but also a lot of problems that needs to be solved in order to be able to find the best solution. Sometimes, the easiest way isn't the best solution. The sustainable certifications are well-documented methods, and they consist of a large range of parameters that are seen important for the sustainability of a building.

1.2 Aim & Scope

By using sustainability certifications as inspiration for creating a tool that contributes to an assessment of renovation versus demolition and rebuilding, the work will be quality proved, though sustainable certifications considers many (if not all) important parameters in a building. This enhances the level of quality of the results that is given by the process and ensures a detailed analysis.

A certification method is a way of having a mutual agreement of goals and a guide for how to be able to make the final decision. The decision will not only be a guess, based on assumptions or experience from earlier project (although every case can be, or is different), but a qualified procedure from which you can receive the basic inputs on what could be the solution for the regarded building. It will be an assessment of whether the building should be renovated or demolished and rebuild.

In sustainable certifications an important parameter is the energy performance. It affects the economy of a building and the environment around, which makes it a large parameter to handle. By considering this in the early stages of a project, the energy consumption of the building could be rethought, by choosing better solutions, as a part of the decision making that can be performed by the presented method and thereby achieve better and more sustainable results.

It is shown that a certified building becomes more attractive for byers and tenants. This is also an important reason for creating this tool. A sustainable assessment can be made of the respective building and thereby a more attractive solution can be achieved for the chosen solution. Though the tool is inspired by the sustainable certifications, a possibility for having the building certified afterwards is also larger as many of the necessary parameters would be considered during the process of using the tool.

1.2.1 Thesis statements

- *What are the important parameters when assessing whether a building should be renovated or demolished and rebuild?*
- *Can sustainable certifications define the relevant parameters for an assessment between renovation versus demolition of a building?*
- *Are parameters from sustainable certifications enough for this type of assessment?*
- *Can a tool for assessing whether a building should be renovated or demolished and rebuild, be made quick and simple enough for a contractor to make an easy analysis of the regarded building without large costs and the need of specialists?*

1.2.2 Delimitation

During the development of the method, a limited admittance to literature occurred. This resulted in less information about certain parameters, which could have had an impact on the possibility of missing parameters from the certifications. This limitation revealed the difficulty of using the existing sustainable certifications as a normal person.

The area that is processed for this thesis is very large and the parameter space is wide. Large investigations could be performed for each parameter, which would demand a large amount of time and expertise. A smaller detailing is chosen for the parameter space of this thesis, in order to create an overview which is used to develop the tool.

In an early stage of the process, parameters regarding the site of a given building were deselected from the method. It was assumed that the site would not change whether the existing building was to be renovated or demolished and rebuild though the same site would be used for a new building. Thereby, this parameter would not influence the assessment between the two possible solutions and was not further used in the parameter space.

It is revealed that economy has a great impact on all results and is most often the one parameter that singly can decide if a building should be renovated or demolished and rebuild. Therefore, the economy is chosen to be a very small part of the tool and only as a factor in the first and last process steps of the tool. By this, it will still have a roll in the assessment, but not be the definitely parameter that will give a verdict to the outcome.

The lack of information for executing a Life Cycle Analysis, have contributed in making it necessary to reduce the importance of this parameter in this thesis. A Life Cycle Analysis (LCA) is a very large area to investigate, and can take a great deal of time. This is not in alignment with the idea of this tool to be a quick and easy way of being informed of what should be the preferred outcome for the regarded building. Furthermore, the achievable documentation of materials for use in an LCA is much sparse and outdated. Also, there are uncertainties of what the given result is showing, though the level of detailing will affect the outcome of the analyses. The LCA is therefore chosen to be a part of the more detailed calculations in the last step of the tool (Step 5). The detailed part is considered to be used for larger analyses and calculations, if this is seen necessary by the contractor.

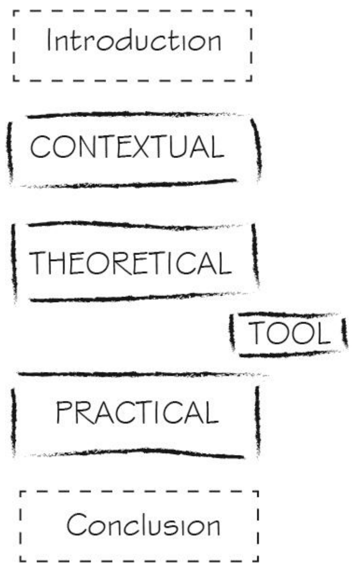
Because of the limited knowledge of economy and Life Cycle Analysis amongst other parameters, these aspects were not included in step 5 of the current case studies. This would have been preferred although considering the amount of time for this thesis, a larger expertise was not possible to achieve. Instead, fewer areas are chosen to be further investigated, such as the energy consumption, indoor climate and daylight factor in the building. This is executed in Case 2 – Building 224 DTU (see section 5.2.2) where the whole process of the tool is treated. The analysis in the detailed part – Step 5, is basically outside the current tool. It is included to show how these analyses could be performed and to how they demand a large area of expertise and time and generates a higher cost.

The Cases are made to analyze the use of the decision supporting tool. Several assumptions and simplifications were needed due to lack of information about the regarded case or to the use of different programs. The result itself, of the performed cases, should not be seen as the important part, but document the user friendliness and process of the decision supporting tool.

It should be remembered that the created tool cannot be used as the final decision whether a building should be renovated or demolished and rebuild. The tool should be seen as a way to investigate the backgrounds for the regarded case and make decision supporting analyses. The final decision should be taken by the contractor.

1.3 Outline of the thesis

This thesis is a continuous process, where the method results in a tool that can be used for assessing whether a building should be renovated or demolished and rebuild. The thesis consists of three parts, a report, a separate user guide and an appendix. This section is a description of the outline of the report.



The report is divided into several sections, which also reflects the working process of the method.

The first section (Section 1) is the **introduction** and summary of the report. Here an understanding is made for the thesis and for what the goal is for developing a new assessment tool. This part is mainly meant for people interested in why this thesis is made, why sustainability is important and furthermore why sustainable certifications are used as background material for this project etc.

The second section (Section 2 - **Contextual**) is a collection of background knowledge that reflects the problems of today and the methods that exist. Also a presentation of the sustainable certifications that are used in this work is included. The presentation shall give an understanding of what the certification are focusing on, and the section is therefore for readers with little or no experience of sustainable certifications. Also, this section is for those with interest in the background material used for creating the assessment tool.

In the **theoretical** section (Section 3), the process of developing the method is presented. Here the parameter spaces from the used sustainable certifications are laid out and reduced to a more user-friendly subset, which is the base for creating the tool. Lists and other existing sustainability assessments are verified in this section to see if they can be used as an underlay for reducing the parameter space. This section is interesting for readers who want to know the development of the method and the background for the analysis.

The next section (Section 4 – the Tool) can be seen as an individual part of the report. This is the development and the presentation of **the tool**, which can be used for assessing whether a building should be renovated or demolished and rebuild. This section can be read individually, or as a part of this report. The tool section is for those interested in the decision supporting tool and the use of it. The tool is also presented in the separate “user guide”.

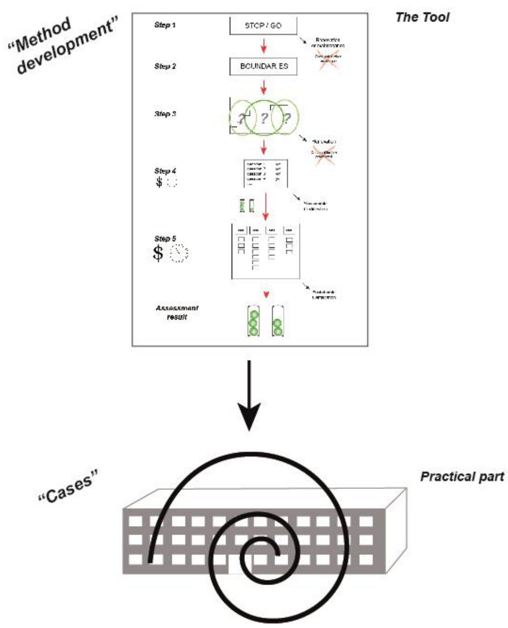


Figure 3: The developed tool will be used in case studies during the practical part of this report.

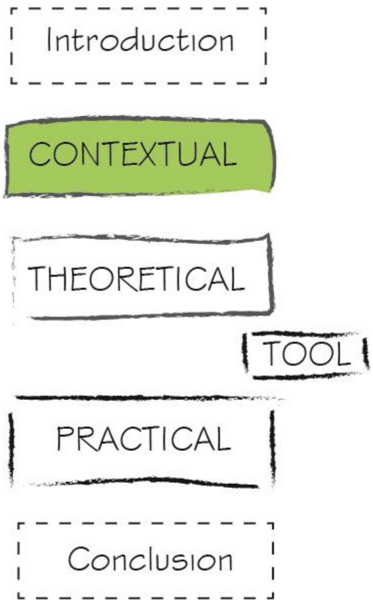
In the next section (Section 5), the **practical part** is presented. The practical part consists of several case studies such as buildings at DTU campus, a building in Oslo - Norway and an additional fictitious case. Here the tool is used on the regarded buildings and analyses based on the process are performed. Furthermore the results from the cases are analyzed together with the performance of using the method. Problems with the tool are noted and changes are suggested to improve the possibility of assessing between renovation and demolition. This section is for readers interested in the use and performance of the tool.

The last sections (Section 6 and 7) are the **discussion and conclusion** of this thesis. Here the results from the performed cases are further commented and the suggested adjustments to the tool will be discussed. A discussion of all the cases together will follow to give a collected opinion on the use of the method. Also, the development of the tool will be discussed further together with the used background knowledge and the selected sustainable certifications. The last section is meant for readers who have an interest in the results from the development of the tool and the comments on how well it is performing.

In the created user guide that is enclosed to the thesis, the tool is presented individually in a way that it can be used directly by the contractor in the field. The user guide shall be seen and read, as a handout for “how to use the tool” and by following the presented process, be able to achieve an assessment of whether the regarded building should be renovated or demolished and rebuild.

2 CONTEXTUAL

In this section, the background for this thesis is described. Many large areas are discussed and analyzed in this report, such as energy renovation, sustainability and sustainable certification etc. This section is meant to give a short introduction to these topics, and thereby give a basic understanding for the underlay of this thesis. It was written based on the literature study in the beginning of the process, to achieve a basic knowledge of the regarded issues. This section should therefore be read as a simple introduction, mostly for readers with little or no knowledge about sustainability, sustainable certifications and the reason for energy renovation amongst other.



2.1 Why energy renovation?

We all want to live, work and exist in well functional buildings. By this, it is meant – buildings with satisfying function, comfort, energy performance, indoor climate, daylight level and not to forget, architectural appearance. The building shall meet our requirements in order to carry out our daily life.

Our requirements are changing in time and our vision of “what is satisfying” are varying. This is partly because of the modern tools and knowledge that now exist. Energy supply and consumption are a large area that are investigated today and constantly optimized. In Denmark, the energy consumption from operation and usage of energy consuming objects in a building, reaches 43 % of the total amount[Havelund M, 2011]. Also environmental impacts are tried to be reduced in order to make the world “healthier” and bring more value into our lives.

Low energy buildings are becoming more requested in the whole world today. A lot of plans and strategies are made in order to optimize the buildings, both newly developed and older buildings.

In Copenhagen, the local authority have made a plan with visions for the city, which demands that all new building shall reach the lowest energy demand, energy class 2015. Besides the energy consumption, a request for the community is also to be CO_2 neutral in 2025. To reach this goal, changes are requested to be made to the energy supply, the building operation, transportation and not to forget the behavior of the citizens. A lot is to be done in order to reach a goal, which improves the environment for all [Københavns kommune, 2012]. In countries as the United Kingdom, Australia and the United states, the government puts a lot of effort into renovating areas of the city and financial assistance is one of the parameters they are using in order to make it more sustainable and green. [Ma Z et. al., 2012]

As written above, a lot of effort is brought into making new buildings as good performing and as comfortable as possible. Although, many buildings that already exist today, have reached the point where the comfort and function that was the intention form the beginning, is in deep need of attention. Some buildings have been maintained through time, some have not. Common for them all is; they do not reach the same performance level that is wanted for new buildings. Their building envelope is poor and delivers a bad indoor climate, compared to what is possible, their energy consumption is high and several other parameters could be found which need to be changed in order to meet the requirements of today. It is shown that a lot of energy can be saved by refurbishment [Ma Z et. al., 2012].

It is also shown by experience from several renovation projects and tests, that by renovating a building, with the goal of making it more green and sustainable, a healthier work environment is created [Ma Z et. al., 2012]. A 25-30 % more energy efficient building on average, can be achieved, better light quality and improved thermal comfort is also the results of green renovation, which in the end reduces illnesses and increases the productivity [Kats G. H., 2003].

By renovating a building, many of the above mentioned problematic can be improved and result in a building updated to the standards of today. In some cases, relative small actions are needed, in others, larger interventions are necessary.

2.2 Renovation – what influences the choice?

A lot of parameters can influence the choice of renovation vs. demolition. Zhenjun Ma mentions some key elements that influence the choice for refurbishment: Policies and regulations (such as energy standards), client resources, technologies, building specific information (building type, age, size, geographic location, energy source etc.), human factors and other uncertainty factors [Ma Z et. al., 2012]. The economy in refurbishment is a large factor and a problematic area to decide upon because of its complexity. Studies have shown that occupancy behavior has a large impact on the energy use of a building, and that a lot can be saved by rethinking the occupancy behavior and controlling [Ma Z et. al., 2012]. Furthermore, it should not be forgotten, that each building is unique, and that a renovation project in many ways will differ from one project to another.

In “Hvidbog om Renovering” [Havelund M, 2011], there are stated which problems that exist, in order to implement more energy efficient strategies in Denmark.

- Shortage of money
- Shortage of requirements
- Lack of knowledge, experience and coordination with the public government
- Shortage of offers for overall solutions
- Lack of prioritization of environmental beneficial building
- Lack of reference projects

If there were no need of dealing with these problems, an energy efficient approach when renovating a building would be easier to achieve and more often applied to more projects.

2.3 What is sustainability?

”Sustainability” is a common word today, and is used in many occasions. It can also be cited as “green”, “eco-friendly” “energy efficient” etc. and the definition can be just as divided. We use the term for many different situations, but the common parameter is, that it is meant as a way for us today to live a good life and develop, without jeopardizing the environment and the lives that follow us on the planet.

The concept of a sustainable development was founded in the beginning of the 1980’s by the World Commission on Environment and Development. In the report from 1987 “Our Common Future, From One Earth to One World” [Brundtland, 1987] the main description of a sustainable development is stated, which still is used as a basic description of the term sustainability:

> “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”
> [Brundtland, 1987]

The expression is for the cultural and technological wear on the world. By this it means how the world is handled today and what effect it has on the future. In the Brundtland report it is also stated that sustainable development should be seen as a process and that it should be considered all time. Changes should be made with the interest of our own wellbeing as well as the future.

But, as noted earlier, people have their own interpretation of the meaning of sustainability and a different interest in it, based on who they are and their position. As stated by Brundtland, it should be possible to change the interpretation with time, and by situation, though “there can be some advantages to leaving it somewhat open” [Robinson J, 2003]. The same focus is not beneficial for all and doesn’t mean improvements of quality of life the same way or at all in some cases. An energy efficient solution is in many cases very expensive and could therefore be deselected in the end. Also, a large focus can be given towards energy efficiency or a specific layout of a building, which results in a poor social sustainability. Furthermore, the lifetime of a component can also be a big discussion in which to choose – a component with longer lifetime, which is more expensive, or a component with shorter lifetime, which is cheaper but needs to be replaced once in a while. Decisions like this can only be taken by the building owner, and therefore a sustainable approach varies from project to project.

2.3.1 The three fundamental parts of sustainability

In the building industry, the concept of sustainable development has in many occasions been mistaken for “green development”, although a sustainable approach considers many other parameters than energy efficiency and environment.

Three fundamental sustainability categories are found to be the basic considerations that contribute to achieve sustainability. These parameters are well known and are the foundation of many sustainability approaches and incorporated in many sustainability tools. The three fundamental sustainability categories are:

The **ecologica**l sustainability; this parameter is concerning the footprint that is sat on the earth by us and how we use the resources that the world is giving us.

The **social sustainability;** which is meant to ensure that the values that we need to live a life with quality is communicated out to others.

The **economical sustainability;** this is to provide an adequate materialistic standard for all.

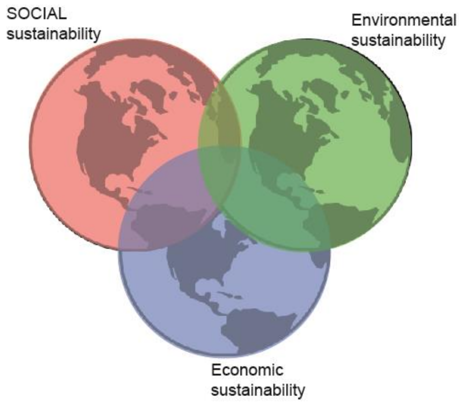


Figure 4: Diagram showing the three fundamental sustainability categories. The joint area is defined as the sustainable area.

All three categories should be considered and worked with in order to have a sustainable interest. Although, not necessary in the same amount or priority, but there should be an understanding of them all when dealing with sustainable development. [Bygherreforeningen et.al, 2013]

Each of the overall categories has several subcategories. These can be seen in the following lists:

Social sustainability

- Social and urban diversity
- Multiplicity
- Functional qualities
- Psychological qualities
- Well-being
- Welfare
- Cultural and spiritual qualities
- Architectural qualities

Environmental sustainability

- Climate
- Biodiversity
- Use of land
- Materials
- Energy
- Waste handling
- Indoor climate
- Health

Economical sustainability

- Management
- Organization
- Life cycle analysis
- Overall economy
- Environmental management

There are no correct answers to what sustainability is. It is a discussion, where some compromises can be necessary. For some people the environment is more important, for others the economy. To be sustainable, choices have to be made and by this, deselecting categories is also a part of it. It is not always possible to be sustainable without sacrificing something else. It can cost more money to “be green”, for instance can recycling cost extra money although it would be more sustainable for the environment. Sustainability can also be on a small scale, in the everyday household kitchen, in the office or in the streets etc. Sustainability exists in many things, but with a mutual cause.

Although we have a goal to reach, sustainability shouldn’t be seen as a possible solution, but as an ongoing process. The world should always work with making changes for a more sustainable solution and incorporate the though in all aspects.

2.4 What are sustainable certifications?

During a period of time, several indicators or certification systems are developed, which have defined a good guidance for a more sustainable development. The certifications give standards and methods on how to procedure in different cases and by this move towards more sustainable solutions.

Figure 5: Sustainable certifications around the world. [Birgisdottir et al., 2010]

Sustainable certification systems should be seen as guidance towards a sustainable solution. The sustainable certifications are although in the everyday life mostly known for household articles (Svanemærket) and not as much for building certificates. There are many different certifications, and many countries have one of their own, in order to fit their requirements and regulations (see Figure 5). But their common denominator is to maintain a standard for a longer period and to receive a higher value. A certification is a good branding for a building, it gives a signal of responsibility and it is shown that it can bring an increased economic benefit by performing a certification. Buildings are easier to rent out and the rent can be increased for residences [Birgisdottir et al., 2010].

BREEAM, LEED, HQE, and CASBEE are only a few of the existing building certifications. In Denmark, sustainable certification is still new and not used as commonly as in other countries. The Green Building Council Denmark is a committee, which is selected to decide how sustainability should be measured in Denmark and by this develop a certification system, based on the existing international certification systems. It is shown that DGNB, a German certification system, will be the base for the new system in Denmark. The Danish certification is based on the parameters, which are founded on European and German standards, which is very equivalent to the Danish.

A more detailed description of some certifications can be seen in section 2.4.1. As it can be understood, there are many differences between the certifications and also diversity in what is seen as more important parameters than others. For example, additional parameters such as innovation are included in BREEAM and LEED, while site is excluded from BREEAM Refurbishment (see section 2.4.3 for more details about this). Some parameters, such as energy, environment, water and transportation are although common for them all. Some of the certifications involve new developments, while a few of the certification systems also deal with maintenance or renovations of older buildings. There are also possible variations in the certifications, whether it is an office building, a school or a residence.

2.4.1 Three (Four) Sustainable certifications for this thesis

For this thesis, three sustainable certification systems were chosen to give inspiration and basis material to reach the goal of the method.

The decision of which sustainable certification that should be analyzed was based on the requirement of having an international system, which was well documented and tested throughout a longer period. Furthermore the certification system should be capable of being used in Denmark. The cases presented in section 5.2 is mostly Danish office buildings and therefore the tool was to be developed to fit into the Danish regulative and standards. It was therefore seen important that the certification were already used in Denmark and approved according to the Danish building codes.

Foundational information about the certification systems was achieved mainly by the report made by “Byggeriets evaluerings center” [Birgisdottir et al., 2010] where sustainable certification systems were analyzed in order to decide which system that should be used and transformed to a “Danish sustainable certification system”. It was therefore assumed that the used sustainable certifications in this report were approved to be used in Denmark and could thus also be incorporated in this thesis.

A final parameter for the choice of certifications was, that the sustainable certification should be applicable to a whole building and not only used for materials and inventory. This resulted in the decision of using BREEAM, LEED and DGNB as the sustainable certification systems for this thesis. The fourth system is BREEAM refurbishment – an outbreak from the original BREEAM certification. The four sustainable certifications are presented in the following sections.

2.4.2 BREEAM

BREEAM (BRE Environmental Assessment Method) is an English certification, which started to be developed in 1988. It is based on BRE (Building Research Establishment Ldt.) and was launched in the country in 1990. The main goal was to improve the environment and indoor climate [Birgisdottir et al., 2010]. In 2005 other countries started to use the certification method and in 2008 an international development of the certification was launched which made it possible for many other countries to benefit from the certification method.

Table 1: The parameters included in the BREEAM sustainable certification

BREEAM
• Management • Health and Well – being • Energy • Transportation • Water • Materials • Waste • Site and Ecology • Contamination • Innovation

Table 2: The achievable levels of the BREEAM certification

BREEAM - classification
Unclassified
Pass
Good
Very Good
Excellent

BREEAM can be used for new constructions with different functions, renovations or for larger areas in a local community. There are nine major categories in the method. Management, Energy, Transport and Materials are some of them [Fowler, Rauch; 2006]. Extra points can although be achieved by an additional parameter, "innovation" (see Table 1). When using the BREEAM certification system the project, or building, receives a score for the different criteria. There are certain minimum demands for BREEAM, in order to be certified. One level is needed to pass in order to be certified and two levels to reach the next step of certification and so on [Birgisdottir et al., 2010]. Based on the results a certification can be given as; unclassified, pass, Good, Very Good and Excellent (see Table 2). BREEAM is updated once a year, although the requirements can't be purchased personally, but is needs to be obtained through a licensed assessor [Fowler, Rauch; 2006].

2.4.3 BREEAM – Refurbishment

In 2000, BREEM launched "EcoHomes" as a method to assess the environmental performance of new buildings, although it was also used for refurbishment projects. In 2012, EcoHomes was replaced by BREEAM Domestic Refurbishment (BDR) which was specially designed for renovation and existing buildings [BREEAM, 2013]. The goal for BDR was to achieve better design in a building and heighten the standards. By using BREEAM's method for refurbishing, the environmental impact is reduced and the operation costs of the building will be lower [BREEAM Domestic Refurbishment, n.d].

"It also helps planners, regulators and asset managers (e.g. Registered Social Landlords) to set standards for refurbishment, and provides a market-focused label for more sustainable and higher quality refurbishments." [BREEAM Domestic Refurbishment, n.d]

Table 3: The parameters included in the BREEAM Refurbishment certification

BREEAM Refurbishment
• Management • Health and Well – being • Energy • Water • Materials • Pollution • Waste • Innovation

BDR has 8 categories for rating the refurbishment (see Table 3). The project can receive a rating from Pass to Excellent, the same as for the original BREEAM certification. During a pilot project it was learned that transportation and ecology credits was difficult to achieve or directly not relevant for a refurbishment project. They were therefore excluded from the assessment criteria's.

A second addition to the refurbishment method is soon to be created for non-domestic buildings. This will be launched in 2014.

2.4.4 LEED

LEED (Leadership in Energy and Environmental Design) is an American certification system and was based on information from the U.S. Green Building Council (USGBC) in order to create a system that was defined to measure "green buildings". This started in 1993 and in 1998 the first pilot program LEED version 1.0 was launched. The certification was made by a committee of architects, lawyers, building owners, people working with environmental and industrial issues etc. This gave a broad perspective to the parameters included in the certification.

Several modifications followed the certification system and new initiatives were taken. LEED 2009 also became devoted to existing buildings and the operation and maintaining of it. Furthermore, different types of buildings could now be certified, for example schools, healthcare buildings, homes and also neighborhood development projects. LEED became more specified and addressed several types of buildings.

For the certification of existing buildings, the evaluation is defined by the performance of the buildings whole life cycle and the rating system is created based on principles used now for energy performance and environmental impacts, together with expected future concepts.

Table 4: The parameters included in the LEED sustainable certification

LEED
• Sustainable sites • Water Efficiency • Energy and Atmosphere • Materials and Resources • Indoor Environmental Quality • Innovation in Operations • Regional Priority

Table 5: The achievable levels of the LEED certification

LEED - classification
Certified
Silver
Gold
Platinum

LEED has five base categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources and Indoor Environment. Furthermore there are additional categories, such as Innovation and Regional bonus, which can give extra points to the score (see Table 4) [USGBC, 2012]. LEED is much attached to the American standards and building routine, although adaptions in the requirements have been made, for some countries, in order to make it more international. A European version of the certification system is now applicable. Also for LEED there are certain minimum requirements which are needed to be fulfilled, and depending on the final score, a LEED certification can be defined as: certified, silver, gold, and platinum (see Table 5) [Birgisdottir et al., 2010].

2.4.5 DGNB

DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) (German Sustainable Building Certificate) is a German sustainable certification method, developed by the German council for sustainable buildings. It was developed in 2007 because of the increasing level of foreign certifications. It has its base in German and European standards, which is similar to the Danish in many ways. The DGNB certification for new buildings was finished in 2008 and today DGNB can be used both for new and existing buildings together with planning of local communities [Birgisdottir et al., 2010].

Table 6: The parameters included in the DGNB sustainable certification

DGNB
• Environmental • Economical • Social • Technical • Process • Site

Table 7: The achievable levels of the DGNB certification

DGNB - classification
Bronze Silver Gold

DGNB has six categories (see Table 6) and 49 criteria that are needed to be evaluated. Points are given for each parameter and based on the scoring a building can be certified with bronze, silver or gold (see Table 7). Different from the other certification methods, DGNB has no minimum requirements for the different criteria. Although a certain standard in the larger categories is necessary. Silver must be obtained in all categories, in order to receive the gold certification.

DGNB certification can be used on new buildings, existing buildings and for modernization of buildings. They claim to be "the only system worldwide that covers all of a property's lifecycle phases. Each building can be assessed and certified on the basis of different phases" [GBCD, 2012]. DGNB is the only certification system that considers LCA and economics over a 50-year life period. A pre-certification of a building can also be made. By this, a building is created with a sustainable goal, and can later be recertified to a higher level. It is documented, that an integrated process from the early stages can perform a better and more functional building to a lower cost, and with a more sustainable outcome.

2.4.6 GBC and Green Building Council Denmark (GBCD)

The World GBC was formal founded in 2002 and is a large network of different councils all over the world. Ninety countries are members of this organization [World GBC, n.d.]. It started as a national council of members, which met and discussed problems with each other and shared knowledge. In 1999 other members from several countries entered the council and the World GBC was at its beginning.

The Danish Green Building Council (GBCD) is a non-profit organization and counsels in questions regarding the environment and the sustainability in buildings. The organization is sponsored by members and other interested investors. Today they handle all the certification analyses of buildings in Denmark and teach new people how to handle a certification of a building through using the DGNB certification.

The Green Building Council has two main organizations – a World GBC and a Nordic GBC. So far, the Danish GBC isn't a member of these parts, but has a close cooperation with them, and attends to the Nordic meetings. The cause of this is, the Danish GBC want's to have the DGNB certification more established in the country, before becoming a full member.

The Danish GBC has a code of conduct:

- "Fremme, tilskynde og udbrede bæredygtigt byggeri *
    - (To promote, encourage and spread sustainable construction)

- Fremme forskning i bæredygtigt byggeri *
    - (To promote research in sustainable construction)

- Dele og udbrede viden om bæredygtigt byggeri *
    - (To share and spread knowledge of sustainable construction)

- Være bevidst om de sociale, økonomiske og miljømæssige konsekvenser af medlemmernes aktiviteter
    - (Be aware of the social, economic and environmental consequences of the member's activities)

- Fremme fælles internationale og europæiske løsninger
    - (To promote joined international and European solutions)

* Construction is to be understood as buildings, real estate and houses.
[GBCD code, n.d.]

2.4.7 Sustainable certifications in Denmark

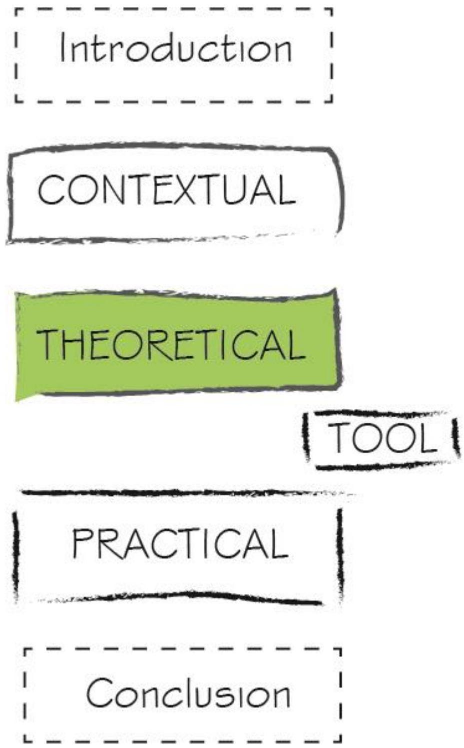
In Denmark there was no certification method, which was created from Danish regulation or standards, until very recent. Sustainable development is a relative new term in Denmark and the problem with interpretation of it and how to incorporate it in the planning of buildings have made it difficult to use. Therefore there have been calls for a system, which can be used as guidance for all development in the building industry, in order to make the work sustainable.

Attempts have been made in order to use international certification systems such as BREEAM, but these are not adapted to the Danish building regulation or standards, which makes it problematic to follow [Hansen T, 2009].

Green Building Council Denmark has although decided to use DGNB which then is adjusted to fit the Danish standards. The reason for choosing DGNB is that they are focusing on environmental, social and economic parameters in the certification, which also are the main parameters in the sustainable discussion in Denmark. Also the European standard CEN/TC 350, which explains about sustainability aspects in buildings, can be compared to the German certification. A larger investigation of the best suitable certification system for use in Denmark was made by RealDania in cooperation with Statens Byggeforsknings institut (SBi) in 2010, and resulted in the report "Afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri" [Birgisdottir et al., 2010] which explains the procedure and more details about the project. In this project four certification methods were investigated, LEED, DGNB, HQE and BREEAM. Consultants, which are specialized in respected certification system, are a part of the project team. Two buildings were used for testing of the certification systems, and besides the scoring, also time consumed on the certification and price for creating the certification of the buildings, were considered in the project. Based on this, DGNB was found the most suitable certification system for use in Denmark and in 2012 the DGNB system Denmark became launched. [GBCD, n.d.]

3 THEORETICAL SECTION

In this section the theoretical material of the current work is presented, also described as the selection of parameter space. Based on an analysis of the many aspects involved in evaluating a renovation versus demolition of a building, a range of parameters from the sustainable certifications are chosen, defining a smaller parameter set, that still ensures a proper decision process but gives better overview for developing the tool presented in next section.



3.1 Development of an evaluation and decision supporting method

In the process of creating a tool that can be used for determining whether a building should be renovated or demolished and rebuild, many factual quantities are needed for the selection of which parameters are important.

The method is, based on the existing sustainable certifications – LEED, BREEAM and DGNB. These certifications should only be seen as a first inspiration and a starting point for what parameters that are important and to ensure that the method becomes as sustainable as possible. Additional parameters are included, based on further knowledge received and absence in the certifications among others due to the fact that most certifications are designed for new buildings and missing aspects regarding renovation.

It is discovered that a lot of information concerning the details of the certifications are limited to customers and assessors. Thereby the founders of the sustainable certifications are hiding the necessary information for many people, including this project. The explanation is that their customers pay for the certification and therefore wish to have an advantage to others. To achieve admittance to the detailed information, an authorization is needed, an assessor, in order to complete the certification of a building. This has reduced the information that is found for this thesis regarding the parameters and which requirements there are for achieving points for the different certification. To overcome this, it is assumed that an overall judgment of the parameters, based on the existing knowledge and information received about the certifications, can be made and thereby over a sequence of reductions, find the most appropriate parameters for assessment tool.

The three basic parameters for a sustainable approach are used, as a first selection of the parameter space. The three areas, social-, economic- and environmental sustainability together, covers a lot of important issues, both for renovation and new buildings. See more in section 2.3.1. These three parts are seen important as the “ground pillars” of sustainability and they will therefore have a great impact on the first sorting of parameters.

Furthermore the renovation parameters “20 punkts listen” – the 20-point list (see Figure 7), is used as an introduction to which parameters that are considered in a renovation project. The 20 point list is a Danish guide which is used as a directory and a checklist when renovation a building. [BVB, 2007]. The list is analyzed to ensure that all relevant parameters are covered by the decision supporting tool and method.

3.1.1 Evaluation of background for selection of parameter space

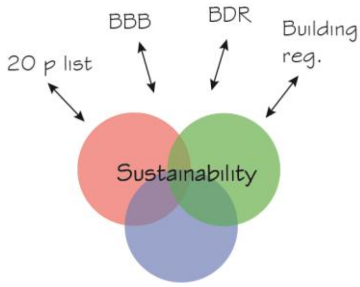


Figure 6: Diagram showing how sustainability is analyzed in the used background material

Sustainability and renovation is the main concepts this current thesis focuses on. Therefore lists, parameters and developed tools, which consider these facts, are found to be used as qualification of the choices that are made during the selection process of the parameter space. The sustainable certifications are in most cases only considering new buildings. In order to define the method from a renovation point of view also applications for these are analyzed and incorporated in the selection process. In the following part, these background materials are pointed out and analyzed in order to see the sustainability approach in them and the importance and usability of these in a decision process between renovation and demolition.

The fundamental sustainability parameters are, as explained in an earlier section, in many cases seen as the basis input and analyses that can make a project sustainable. They are seen as three very important parameters to consider, although it is undefined how they are to be used and in which amount. Many of the sustainable certifications are also built according to these fundamental categories. The three overall parameters should therefore be seen as a collective guideline to ensure sustainability in a project. This will also be considered in this thesis. The three fundamental sustainability parameters will form a basic interpretation of the parameters and will therefore be considered when deselecting parameters.

The 20 point list

As mentioned in section 3.1, the 20 point list is a guide in categories which is to be considered during a renovation project in Denmark. The list can be seen in Figure 7.


20 PUNKT LISTEN

De 20 hovedpunkter i listen er en fast standard. Underinddelingen af listen kan derimod variere efter lokal praksis.

* Friarealer er udgået som støtteberettiget udgift p.g.a. lovændringer.

01 TAGVÆRK
Brandkamme
Tagkonstruktioner
Kviste, eks. vinduer
Ovenlys
Tagvinduer
Taglemme
Skotrende, grater, rygninger, sterne
Varmeisolering
Tagdækninger
Tagrender
Nedløb
Aftræks- og faldrørshætter
Skorstene
Øvrigt tag

02 KÆLDER / FUNDERING
Fundamentsforstærkning
Istandsættelse af lyskasser
Istandsættelse af udvendige trapper
Fugtisolering under terræn
Omfangsdræn
Øvrigt kælder / fundering

03 FACADER / SOKKEL
Altaner og karnapper, gade
Altaner og karnapper, gård
Gavle og bagvante
Overfacade gade
Underfacade gade
Ornamenter / gesimser gade
Overfacade gård
Underfacade gård
Øvrigt facader / sokkel

04 VINDUER
Vinduer i facade
Trappevinduer
Kældervinduer
Altandøre
Vinduer i tagkviste
Øvrigt vinduer

05 UDVENDIGE DØRE
Hoveddøre
Kælder- og bagtrappedøre
Øvrigt udvendige døre

06 TRAPPER
Hovedtrapper
Bitrapper
Overflader hovedtrapperum
Overflader bitrapperum
Elevatorer
Øvrigt trapper

07 PORTE / GENNEMGANGE
Ramper for renovation
Porte
Døre i portrum
Varmeisolering mod beboelse
Overflader i portrum
Øvrigt port / gennemgange

08 ETAGEADSKILLELSER
Etagedæk
Bjælkelag
Isolering af etagedæk
Øvrigt etageadskillelser

09 WC / BAD
Installationsskakte
Vægge, inklusiv overflader
Gulve, inklusiv overflader
Lofter, inklusiv overflader
VVS, eksklusiv faldstammer
Sanitetsudstyr
El-armaturer
Øvrigt WC / bad

10 KØKKENER
Installationsskakte
Vægge, inklusiv overflader
Gulve, inklusiv overflader
Lofter, inklusiv overflader
VVS, eksklusiv faldstammer og ventilation
VVS-armaturer
El-armaturer
Køkkeninventar
Øvrigt køkkener

11 VARMEANLÆG
Rum for varmecentral (overflader)
Automatik
Demontering af eksisterende anlæg
Varmecentral (installationer)
Radiatorer og rørinstallationer
Teknisk isolering
Målere
Øvrigt varmeanlæg

12 AFLØB
Demontering af eksisterende anlæg
Faldstammer og grenrør
Teknisk isolering
Øvrigt afløb

13 KLOAK
Reparation eksisterende ledninger
Udskiftning, stikledninger
Brønde
Øvrigt kloak

14 VANDINSTALLATION
Demontering af eksisterende anlæg
Koldtvandsinstallation
Varmtvandsinstallation
Målere
Teknisk isolering
Automatik
Øvrigt vandinstallation

15 GASINSTALLATION
Demontering af eksisterende anlæg
Gasinstallation, inklusiv trykprøvning
Målere
Teknisk isolering
Automatik
Øvrigt gasinstallation

16 VENTILATION
Demontering af eksisterende anlæg
Kanaler og armaturer
Ventilatorer og automatik
Teknisk isolering
Emhætter i køkkener
Øvrigt ventilation

17 EL / SVAGSTRØM
Lysarmaturer for udvendig belysning
Antenneanlæg
Tavleanlæg
Rør og ledninger
Lysarmaturer for rumbelysning
Demontering af eksisterende anlæg
Svagstrømsinstallationer iøvrigt
Stærkstrømsinstallationer iøvrigt

18 ØVRIGE OMBYGNINGSARBEJDER
Istandsættelse af boligrum
Istandsættelse af pulterrum
Istandsættelse af fællesrum
Indvendig isolering af ydervægge
Asbestsanering

19 PRIVATE FRIAREALER*

20 BYGGEPLADS
Byggepladsetablering og -afrigning
Byggepladsdrift
Stillads, etablering og afrigning
Stillads, drift
Byggepladsarealer, retablering
Renholdelse, bortskaffelse af affald
Slutrengøring af bygninger
Vinterforanstaltninger
Øvrigt byggeplads

18

Figure 7: The 20-point list (a larger figure can be seen in Appendix A) [BVB, 2007]

From the list (Figure 7), it can be seen that the list is very detailed in the areas concerning building parts and constructional parameters. All parts of a building are noted, together with parameters regarding electricity, installations and construction site. It is noticed that many, or all in some circumstance of the included parameters are also used in the different sustainable certifications. For example; water consumption and water installations are parameters in both the 20-point list and in the sustainable certifications, so is the ventilation systems and thereby thermal comfort. Furthermore, management on the construction site – such as waste management is also included in both systems. The largest difference is therefore seen to be the level of detail in the 20-point list and the process oriented viewpoint in the sustainable certifications. The certifications can be seen as an analysis guide where the 20-point list is a “list” with parameters to consider. There are thereby no description of how or what to do with the 20-point list – it is only noted for own definition.

If the 20-point list is compared with the three fundamental categories for sustainability, some basic principles can be seen. Many, or all, of the parameters in the 20-point list can be mapped into the three categories of the fundamental sustainability (see Table 9). For example, installations and other technical parameters are part of the environmental and social sustainable group, though an improvement of these would improve the indoor climate and also give a better social quality in the building (better ventilation or water installations improves the indoor climate in the building and thereby provides a better working space for the users). Asbestos, which also is included as a parameter in the 20-point list, could be placed in the environmental sustainability group, though it would have an impact on the environment when renovating the building. This sorting is presented further in the next section (See also Table 9).

The sustainability in the 20 point list – analyzed with the fundamental sustainability parameters

Table 8: The three fundamental sustainability parameters:

Social sustainability
Environmental sustainability
Economical sustainability

The 20-point list is compared to the fundamental sustainability categories (see

Table 8), in order to see what parameters of the list that could have an impact on sustainability and how they could influence it. If some of the parameters show no directly influence on the sustainability, they could be sorted out in this stage. Furthermore, this process can be used for analyzing how sustainable it is to use the 20-point list in a renovation process and thereby evaluate if it should be used for the development of this method. The impact of the 20-point list on sustainability can be seen in the following table.

Table 9: Table showing the sorting of the 20-point list after the three fundamental sustainability parameters (The comments and decision background can be seen in Appendix B)

20 point list	**Fundamental sustainability categories for buildings**		
	Social	**Environmental**	**Economic**
1 Roof			
2 Basement / foundation			
3 Facade / footing			
4 Windows			
5 Outer doors			
6 Stairs			
7 Gates / Passages			
8 Horizontal division			
9 Bathroom			
10 Kitchen			
11 Central heating			
12 Drain			
13 Sewer			
14 Plumbing			
15 Gass installation			
16 Ventilation			
17 Electricity			
18 Other renovation areas			
19 Private spaces			
20 Construction site			

The analysis of the parameters:
Almost all parts of the 20-point list are considering the environmental parameters, which is a category that deals with a large part of the factors included in the 20-point list such as materials, energy and indoor climate. Also, all parameters have an impact on the economical sustainability in some way, for example due to cost of materials or savings, which could be the result of a renovation case.

To discuss the fundamental sustainable categories, it is noticed that well-being and welfare is a part of the social sustainability and indoor climate meanwhile energy is a part of the environmental sustainability. The "difference" between these could be discussed, though one affects the other and thereby contributes to each other's parameter outlet.

As it can be understood, the 20-point list is in many aspects included in both the fundamental sustainable parameters and in the sustainable certifications, though they overlap, in some circumstances in several categories at the same time. It is therefore assumed that the 20-point list isn't necessary to be used directly as a selection for the parameter space, although the parameters are in some extent included in the certification methods. The 20-point list can although be used as an inspiration for creating a "check list" to follow and will therefore still be used in some extent in this thesis.

BREEAM Domestic Refurbishment (BDR)

As written earlier in the report (section 2.4.3), BREEAM created a method for certifying refurbishment projects. The method of the certification for sustainable homes (new buildings) was not capable of being used for renovation projects and therefore some changes were made in order to enable this. Some of these changes were removal of the transport and ecology category [BDR Faq's, n.d.]. The cause of removing transportation was due to that an existing building is fixed to the site and therefore distance to public transport or possible transportation routes is not changeable. The site was also the reason for removing the ecology credits. It was argued that since the site was already selected and build upon, credits weren't possible to receive due to limited possibilities in change of site and/or protection of site [Summerson, 2011]. Alterations were thereby made in order to fit the certification to a renovation project.

By this sorting, done by BREEAM for the new certification method, it can be seen how some arguments can be made for what parameters are important or not in a renovation scenario. Although, parameters from the BREEAM certification for new buildings will still be analyzed, it is found that the removed parameters are a good solution, though they handle the problems with the site of the building amongst other. This project is to create a tool, which shall analyze a renovation project versus a demolition project and the site will still be the same for both scenarios and therefore it is assumed that the site won't influence the judgment and can't contribute to any of these parameters. This argument will be a part of the selecting and deselecting process further on.

As only a few parameters is changed from BREEAM to BDR, it is also assumed that the necessary parameters already are implemented in the certification methods and only smaller changes are necessary in a renovation scenario. If this can be said definitely for the other certification methods (LEED and DGNB) as well, is not sure. Although is assumed that a great part of the needed parameters for a renovation is included and that some parameters only needs a redefinition or replacement in order to fit a renovation project, though there are many similarities between the certifications.

Danish building regulation

In BR10 regulations for Danish buildings can be found and the demand for new buildings built today which shall achieve the 2015 and 2020 requirements. When renovating a building, there are some requirements to the standard of renovation, especially when making a larger renovation [DBR, 2013]. The more a building is renovated, the larger is the request of calculations and documentation of the work.

In this project it is although assumed that the renovation of the building, and off course the new build building, is striving to achieve the 2015 requirements as a minimum, though the contractor will always be interested in having a fully updated building, which achieves the demands of the building regulations. Thereby it is assumed that the requirements of the building regulations and the included parameters, isn't in need of a dominating part of the method.

Bæredygtig Boværdig Barometer (BBB)

The "BBBarometer" is a tool, which gives an assessment of **the value of living** in the respected building. It is based on a sustainable approach and has its underlying basis in the sustainable certifications, which is also used for this project, LEED, BREEAM and DGNB, together with the Danish building regulations and other sustainable approaches. The barometer uses simple questions, which handles the state of the building and which installations are used. In the end a scoring is given between 0-10 [MacIntyre, n.d.]. A higher score equals a better value of living in the building. There are nine categories for this method (see Table 10).

Table 10: The parameters used in the BBBarometer [MBBL, 2012]

BBBarometer
• Energy • Environment • Indoor climate and air quality • Welfare and hygiene • Architecture and lay-out • Social qualities • Comfort and convenience • Elder- and handicap friendly • Urban environment

"The focus is parameters that can be changed by renovation"
Translated from [MBBL, 2012]

The BBBarometer is thereby also including parameters that can be used for analyzing the sustainability approach in a renovation project. It is assumed that it would be beneficial to incorporate this in the selection of the parameter space as an inspiration, also because of the simplicity of the layout of the tool.

Conclusion for the selection of parameter space

As this thesis is concerning renovation, but also demolition and new buildings, it is understood that many of the focus parameters are the same as for the BBBarometer and 20 point list. Parameters such as energy, indoor climate and welfare, as well as functionality of the building and environment, have been analyzed as important parameters when dealing with sustainability and with renovation projects. This has been confirmed both by the 20-point list and by the fundamental categories of sustainability, and not to forget, by the sustainable certifications, which are concerning these very parameters amongst others. It can therefore be assumed, that the achieved background knowledge are important and sustainable correct, though it is used for larger standards and methods, together with newly created systems.

A resulting list is generated, with a large parameter space collected from the three sustainable certification methods, BREEAM, LEED and DGNB (see Figure 10). This is the foundation for the sorting process described in the next sections and the development of the tool.

3.2 Sorting of the parameter space

In this section, the selection of the parameter space is developed. As explained earlier, the three sustainable certifications (or four if BDR is included) include a large range of parameters, which creates an overwhelming span of parameters that is analyzed in this method.

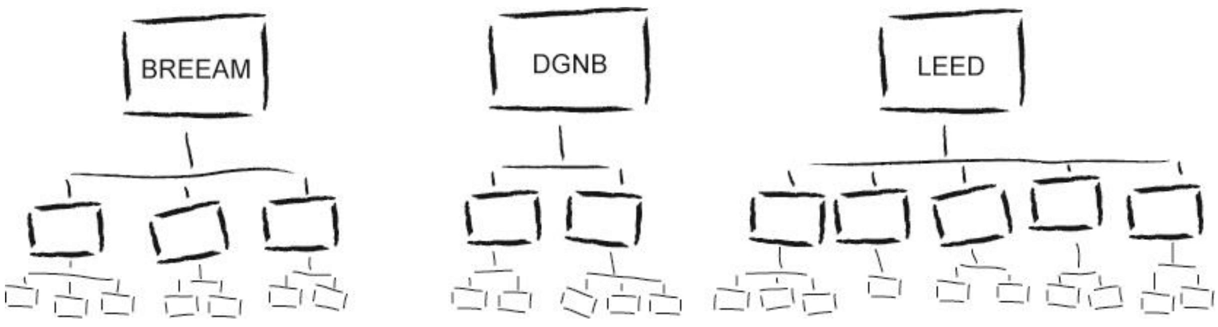


Figure 8: The certifications has many categories and subcategories which gives a lot of parameters to handle

To reduce the parameter space, in order to achieve only a few parameters, which shall be incorporated in the tool, and to analyze the relation between the different certifications, a sorting of the parameter space is made. This development will be presented through an analysis and reduction process documented in the current section. The selection process is based on the before described lists and sustainable approaches (see section 3.1.1).

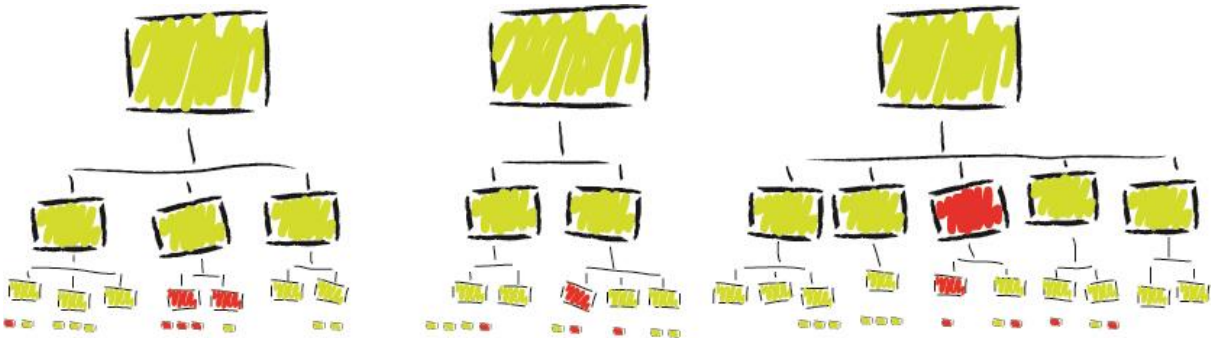


Figure 9: The selection and deselecting of categories. Some are deselected immediately (red square), some are unsure, while other parameters are selected to be used for the method at once (green squares).

The selection of the parameter space are made over three phases, a **primary sorting** (see section 3.2.1), a more **detailed sorting** (see section 3.2.2) by using a developed “limitation graph” (see page 47) and in the end a **final sorting** (see section 3.2.3) of the remaining parameters together with a generalizations of them in order to create the tool.

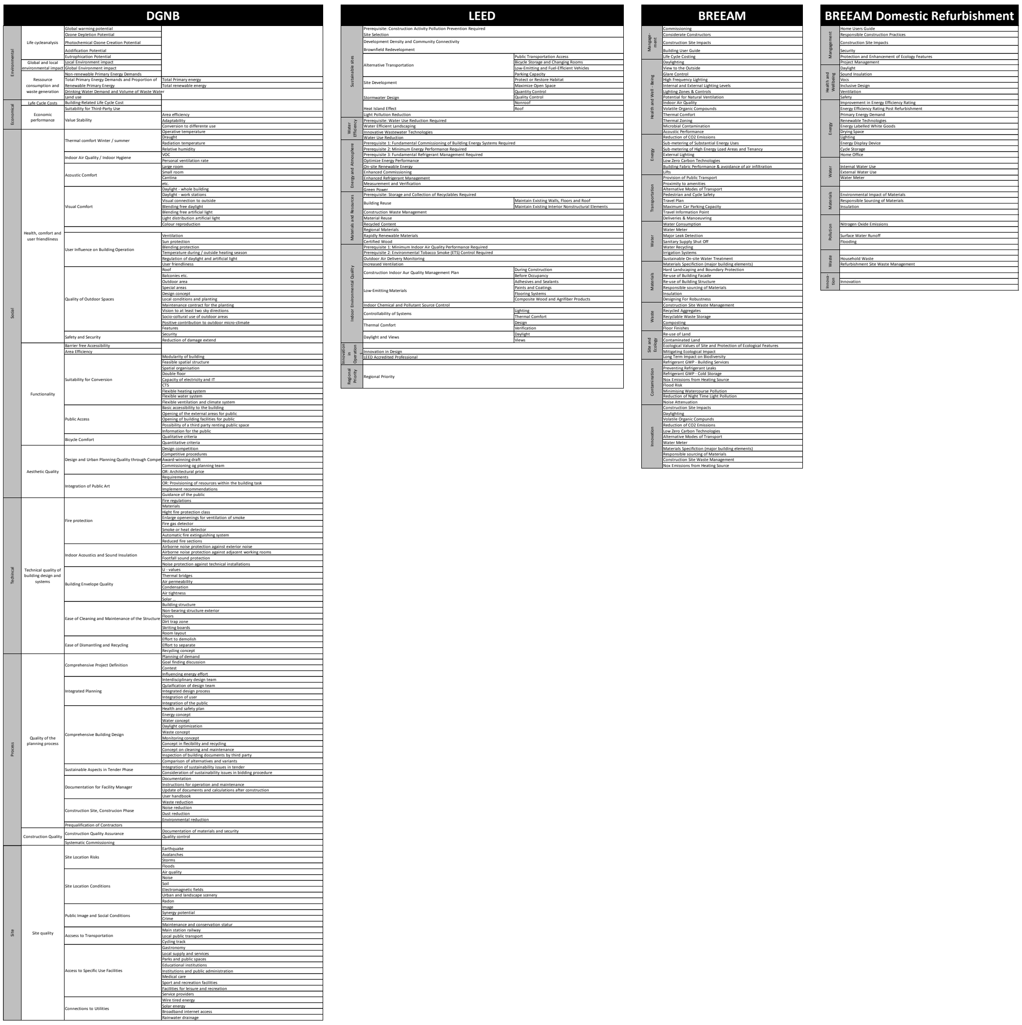


Figure 10: All the parameters from the four sustainable certifications before any sorting or reduction is made – a very large parameter space. A readable size can also be seen in Appendix C.

3.2.1 First selection of parameter space – relevancy for decision

In the first phase, only the main and sub categories are looked upon from each sustainable certification. This is executed in two stages though these categories are seen as very large categories and they should be handled separate also to keep an overview. Thereafter more detailed parameters are analyzed. The parameters are compared to the 20-point rule, the three fundamental sustainability criteria and the knowledge received from the BBBarometer. With regard to these and the fact that an assessment between renovation and demolition should be possible, the main categories are reduced. Each of the categories are analyzed and commented. (All comments can be seen in Appendix D - H). The sustainable certifications are kept separated, though some variations exist between the parameters and the definitions of the respective parameters.

Stage 1: Main categories

The main categories are selected and the parameter space is reduced to a smaller amount. The comments from the analyses and decision process of this stage can be seen in Appendix D. From the first stage of the primary sorting process, the main categories left are:

Table 11: Table of the main categories remaining from the first selection of parameter space.

DGNB	LEED	BREEAM	BDR
• Environment • Economical • Social	• Water Efficiency • Energy and Atmosphere • Materials and Resources • Indoor Environmental Quality • Innovation	• Health and Well-Being • Water • Materials	• Health and Well-Being • Energy • Water • Materials • Pollution • Waste • Innovation

The main reason for choosing the parameters shown in Table 11 above is the possibility of using these as an assessment whether a building should be renovated or demolished and rebuild. Furthermore, these parameters are found important in several of the lists and requirements, analyzed earlier in this thesis. A few of the comments can be seen below in Figure 11 and Figure 12.

Environmental	It handles the LCA and other environmental issues such as ressource and waste generation. It is although not nown at which level these parameters are investigated, or how they are credited.

Figure 11: A comment for one of the selected categories

Deselected "Site"	The parameter - site, is deselected though the site is supposed to allready be chosen in this project. The existing building is on the specific ground area, which also will be the area used when building the new building after demolishion (if this is the chosen solution). Therefore parameters sutch as social conditions, location condutions, acess to public transport and facilities is not parameters that can be changed. Although, the sub categori of location risks sutch as flodding could be a part to investigate though an existing building has its limitations toward what can be done in order to minimize the risk of destruction of the building, while a new building could be planned to handle risks of these proportions. Also the possibility of connecting utilities could be important. - is the building capable of adding solar panels or other utilities for example energi resources etc.

Figure 12: A comment for one of the deselected categories

Stage 2: Sub categories

In the next stage of the primary sorting face, the sub categories from the selected main categories (Table 11) are considered for each certification. Here, the parameters are more detailed and handles the more precise consideration for sustainability. Energy performance, material and waste handling are some of the parameters that are included in the sub categories. The sub categories are selected and deselected in the same way as before, by comparing with the 20-point list, considerations in the BBBarometer and the fundamental sustainability criteria. In some of the categories, a third sub category exists. These are considered as one part and analyzed together. The whole parameter selection and the comments for each selection can be seen in Appendix E.

By this stage the rough sorting of the parameter space are made. The result (the parameters left) will only be listed in appendix, due to the large ammount of parameters (see Figure 13 for a segment of the remaining parameter space).

DGNB			
Environmental	Life cycleanalysis	Global warming potential	
		Ozone Depletion Potential	
		Photochemical Ozone Creation Potential	
		Acidification Potential	
		Eutrophication Potential	
	Global and local environmental impact	Local Environment impact	
		Global Environment impact	
	Ressource consumption and waste generation	Non-renewable Primary Energy Demands	
		Total Primary Energy Demands and Proportion of Renewable Primary Energy	Total Primary energy
			Total renewable energy
		Drinking Water Demand and Volume of Waste Water	
		Land use	
Economical	Lyfe Cycle Costs	Building-Related Life Cycle Cost	
	Economic performance	Suitability for Third-Party Use	
		Value Stability	Area efficiency
			Adaptability
			Conversion to differente use
	Health, comfort and user friendliness	Thermal comfort Winter / summer	Operative temperature
			Draught
			Radiation temperature
			Relative humidity
		Indoor Air Quality / Indoor Hygiene	VOC
			Personal ventilation rate
		Acoustic Comfort	Large room
			Small room
			Cantina
			etc.
		Visual Comfort	Daylight - whole building
			Daylight - work stations
			Visual connection to outside
			Blending free daylight
			Blending free artificial light
			Light distribution artificial light
			Colour reproduction
		User Influence on Building Operation	Ventilation
			Sun protection
			Blending protection
			Temperature during / outside heating season

Figure 13: Small segment of the large parameter space left. The red parameters are the selected ones. A readable size can be seen in Appedix E.

After this stage, all the selected parameters are sorted into categories based on the fundamental sustainable parameters (Environmental, Economic and Social), in order to compare the ammount and analyse the similarities between the certifications. (See Appendix F for a detailed view of this sorting). By this it can be notices how many parameters are included in the three fundamental sustainability categories and furthermore, where parameters are possibly missing.

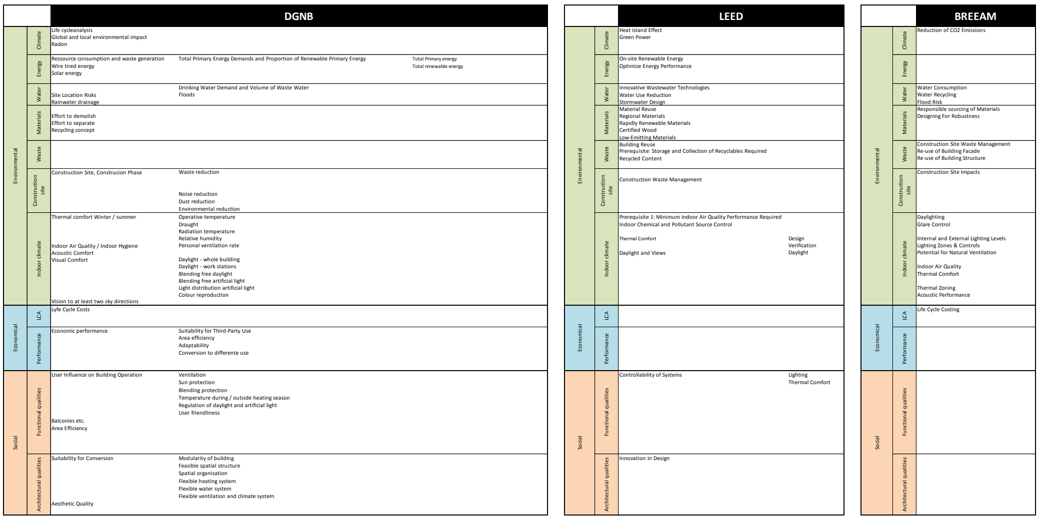


Figure 14: Parameter space sorted in categories; Environmental, Economical and Social. A readable size can be seen in Appendix F.

It is seen from the above selection process of the parameter space, there are some differences in the ammount of parameters between the categories of the certifications. Especially in the economical category. Here, certifications such as LEED and BDR have no parameters in the respective category, although indoor climate is a large post for all certifications. Furthermore it can be seen that the description of the parameters are varios for the different certifications, although the definition and intention is similar. For example, the impacts from the construction site varies from a clear definition such as “waste, noise and dust reduction” to “construction site management” – which handles the same parameter, without specifying the exact output.

3.2.2 Detailed sorting of parameter space – obvious choices are excluded

In this stage, the parameters from the above described selecting process are to be reduced further, in order to achieve a smaller amount of parameters that can form the foundation for the development of the tool. By analyses and discussion during the first part of the method development, it occurred that some arguments directly could show if a building should be renovated or demolished and rebuild. A graph (the “Limitation graph”) was created which could be used as a communication of the method and to validate the choice of parameters, as some of the obvious choices could be excluded. This development and the “Limitation graph” are explained in the following sections.

Limitation graph

Although, the use of parameters from the 20-point list can vary from project to project and the importance of the regarded parameter is based on the contractor’s insight of what’s important in the specific project, there are some foundational interventions when renovating, which can be sorted in larger categories. Maintenance, installations and renovation of facades are some of these larger categories.

In the verification between whether a building should be renovated or demolished and rebuild, there are noticed a connection between some of the parameters for renovation and a final outcome. Some renovation procedures are small enough that it is assumed that a renovation of the building will be the natural preferred choice.

For example, it is assumed that a regular maintenance is the minimum degree of renovation that will occur in a building and if this is the only necessary act for the building, the choice of demolishing the building, will probably not be an alternative. Also, a necessity for renovation of the installations in a smaller degree won't assess any necessity for demolishing the building either, although a renovation is preferred and achievable. In another hand, if more severe measures are needed for the building, such as renovation of the façade, renovation of the construction of the building etc., an assessment could point towards the necessity of demolishing the building and rebuild it. It could thereby be understood, that there are some outer categories, which will give a clear verdict to either renovate or demolish and rebuild, immediately (see Figure 15).

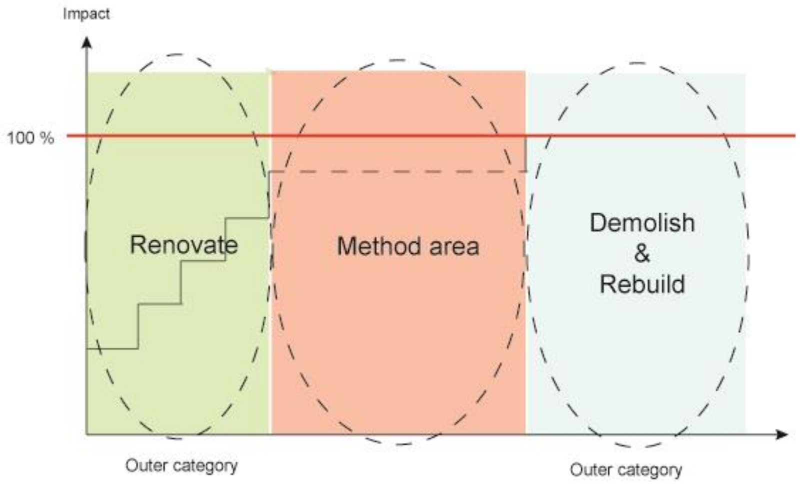


Figure 15: The impact of renovation parameters can be sorted in outer categories, though they immediately indicate towards a specific result – renovation or demolition. The space between is defined as the method area in this thesis which can result in either scenario.

As Figure 15 shows, a category with smaller renovation projects, which doesn't demand too large an intervention, and a category with larger renovation interventions, which will have a large impact on the building and be expensive and time consuming etc., is defined as the outer categories. The two categories will be of a specific dimension, which will make the project inclined towards a decision of renovation (the green area) or demolition of the building (blue area). The parameters between these are an undefined space (the red area), which can result in either one of the scenarios. In some cases, the parameters of this space will lead to the benefit of a renovation of the building, or in other cases towards demolition. It depends on the type of building, the intervention and/or the contractor of the building, what the outcome will be.

In order to create a tool, that can contribute to the analysis between whether a building should be renovated or demolished and rebuild, the considered parameters from the sustainable certifications could be reduced to the once that only regard the middle space of the above shown graph. It should thereby be understood as parameters that could result in both solutions. These parameters will have a necessity of being analyzed, though they could give an outcome to one or the other side of the possible two scenarios. This categorization will reduce the parameters from the sustainable certifications remarkably and thereby constrain the area for the method. It will become more precise and goal-oriented towards a few areas. The process could therefore possibly be made more detailed and a more precise outcome of the tool could be produced.

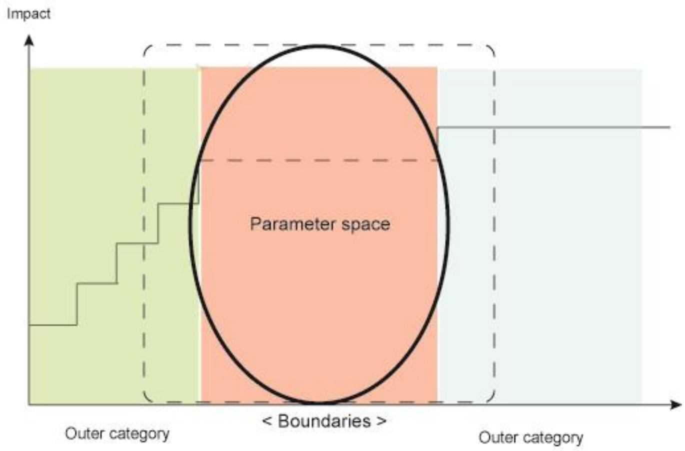


Figure 16: The area of importance, which is the parameter space the method is handling, should be adjustable in order to fit the specific project. The figure shows how this space can change with defined boundaries (the dashed line).

Building projects are not identical and thereby it is important to have a span that can be adjusted to the specific case, though an important parameter in one project is not necessary the same category in another. A regulation of this parameter space (the red area in the graph) should therefore be made possible by using boundaries (see Figure 16).

Important categories in renovation

It is assumed that a renovation project can be divided into three parts, as explained before. As can be seen in Figure 15, only the center part is of relevance for the decision process at hand, whereas for "small" and "large renovations" we find below that a decision is controlled by other means.

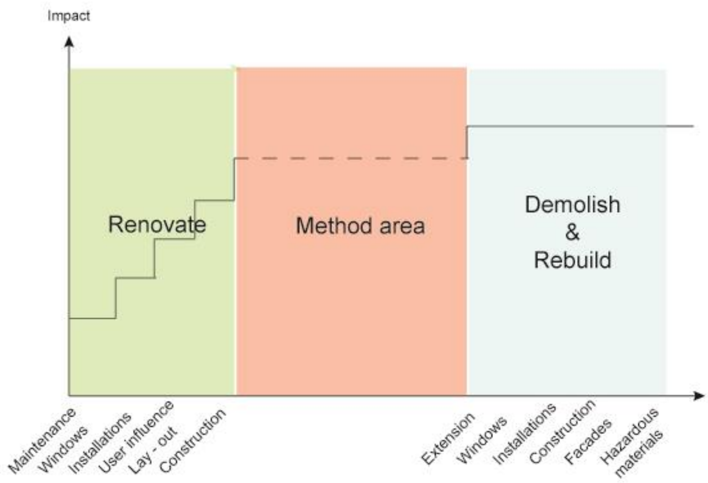


Figure 17: The renovation categories that leads directly towards renovation or demolition and rebuilding. Smaller task to the left and larger renovation tasks to the right.

As visualized in Figure 17, the smaller renovation categories leads instantly to a renovation, while the larger categories leads towards the solution of demolition and rebuilding. The area between is defined as the "method area" which will be handled in section 4, though this will be the area for the decision tool. The possible adaptions to the specific case will also be defined in the tool development later in this thesis (see section 4.2).
Below the two outer categories are presented, based on own knowledge, analyses and assumptions.

Smaller renovation tasks:
The smaller renovation is supposed not to be as large an intervention as it won't be economically justifiably or achievable without any large effort. It is procedures that relative easily can be performed on a building, and therefore is assumed that it always will be chosen as a renovation project. **Maintenance** is assumed always to be performed in some extent on a building. Painting jobs, maintenance of doors and windows and a cleaning procedure that will sustain the quality of a building and prolong the lifetime. Also an exchange, if needed, of older **windows** is assumed to be a smaller renovation task. Windows are optimized and in older buildings the windows can consist of 2 (or less) layers of glass without any thermo layer. Also the fitting of the windows is to be maintained in order to prevent draft and thermal leakage and thereby obtain a satisfying indoor climate. **Installations** in a building are assumed to be a smaller renovation project (if the installations do exist in some extent from the beginning. A whole new pack of installations is considered to be in the larger category). Existing ventilation systems can be used and be optimized, cleaned or shifted in order to perform satisfying and by the requirements. **User friendliness** is the possibility of regulating the temperature, ventilation or daylight entering the room, which is assumed to be a relative small area to incorporate in a building. Furthermore, the **lay-out** of the building is in many cases very adjustable. Removal or adding of walls in order to change the layout is seen as a smaller renovation project (if the construction allows it). A non-load carrying wall is often relative simple to remove and can easily be rebuild in another area. By this, a building can be made from smaller rooms/offices to larger open rooms and opposite. It is therefore also assumed that changing of the function in the building is a similar smaller renovation project, as long as the type of function is similar (office work / residential / Kitchen or Chemistry etc.). As the last "smaller renovation category", renovation of the building **construction** is placed. In many cases a renovation of the construction is a relative simple procedure, if not everything is to be renovation or shifted. Many simple procedures can be made to renovate the construction in order to optimize it and prolong the lifetime. Materials can be shifted to new and better materials, an extra system can be added and other measures can be taken to renovate the construction. In some cases a renovation of the primary construction can although be a larger intervention, though it is the foundational or bearing structure, which is of great importance for the building life time and stability.

Key words – smaller renovation projects

- **Maintenance**: Painting, cleaning and other minimum required maintenance jobs to sustain the building in good condition.
- **Windows**: Change of windows to required level (optimization of existing windows)
- **Installations**: Renovation of installations to required level (Ventilation, heating / cooling, Glare handling etc.)
- **User influence**: User friendliness and possibility of regulating functions of the building (ventilation, heating etc.)
- **Lay-out of building**: Removal / addition of walls, change of interior building lay-out, change of building function
- **Construction**: Change or larger renovation of primary construction components (Roof, bearing construction, foundation

Larger renovation tasks:

The larger renovation task, are areas so large, that it will change most of the building construction, façade etc. and thereby be very costly, time consuming and affect wide areas around and not to forget the users of the building. In the cases where these larger renovation task is the solution – it will most often be preferable to demolish the building and rebuild it (with the needed changes), though it will be more beneficial in many ways.

A **major building extension**, is meant as to be as large that the whole design and function of the building will be changed. Also the construction is in need of being renewed and thereby it is almost a new building that is made. By adding more **windows**, or redesign the size or layout etc. of the existing building, the façade is changed a lot and a large work is produced to incorporate the new windows. This is structural demanding and though the façade is changed as much, it is assumed that it will be less demanding to demolish the building and rebuild it. If there is no room for implementing **installations** in the building, the possibilities are limited. Installations are in need of a certain height and space and the comfort of the users shouldn't be compromised for implementation of new installations and more space for installations is very difficult to achieve in existing buildings. The major renovation of the **construction** is defined, as when all the construction is in need of exchange, the foundation is too poor though the building is in stability risk. In these cases the building is unsecure for the users and it will be better to demolish the building. The second last category is when more than 25 % of the **façade** is to be changed. This requires a large and consuming renovation project and also requirements of recalculation of the building [DBR, 2013). When a building is in demand for such a large intervention it is assumed that most cases will select to demolish the building and rebuild it. Finally, **hazardous materials** such as asbestos and PCB are creating a large health risk for the users of the building. In cases where a large amount of the hazardous materials exist in the building, also a renovation of the building can create large risks for the users and a large capital is needed to remove the materials safely. Also radon is incorporated in this category. Buildings in the risk zone, without a well performed securing towards radon, will be in a demand of a large intervention to ensure no leakage into the building. This is costly and requires a lot of work to ensure that the protection is implemented correctly.

Key words – larger renovation projects

- **Major building extension:** A large extension of the building (Upward or outward, which will demand a large impact on the existing construction)
- **Windows**: Adding of extra windows in the façade or roof, or changing window type and sizes.
- **Installations**: Larger renovation of installations or problems with the space for implementation of the service routes etc.
- **Major construction renovation**: Most of the load carrying construction, foundation or /and roof is in need of renovation and replacement.
- **Facades**: Major intervention on the façade, which will affect more than 25 % of the existing façade.
- **Hazardous materials**: If the building consists of hazardous materials, such as asbestos, and a safe removal of this isn't possible; the intervention can become excessive and time consuming. Furthermore if radon exists and the foundation is not secured towards leakage, also this will have a large impact towards demolition of the building though it will be difficult to renovate in a safe way, and to ensure the health of the future users.

By using the above explained limitation graph, the two outer categories define parameters that can be deselected from the parameter space from the sustainable certifications and guides the regarded case towards the best solution. Some of the parameters that can be deselected are the social sustainability parameters though they handle parameters such as user influence and user friendliness. The limitation graph also confirms the assumptions made for some of the earlier parameter selections such as maintenance and management, which were assumed not important for this method. Indoor climate is a parameter of both the outer categories. It is seen there are some circumstances that can cause problems with for example renovating a ventilation systems, such as lack of enough ceiling height to apply the new system. If this is the case a demolition and rebuilding is most certain the best solution, to be able to have a fully functional ventilation system etc. in the building. A renovation can be sufficient, why it is important to analyze for the assessment between the two scenarios.

		DGNB		
Environmental	Climate	Life cycleanalysis Global and local environmental impact Radon		
	Energy	Ressource consumption and waste generation Wire tired energy Solar energy	Total Primary Energy Demands and Proportion of Renewable Primary Energy	Total Primary energy Total renewable energy
	Water	Site Location Risks Rainwater drainage	Drinking Water Demand and Volume of Waste Water Floods	
	Materials	Effort to demolish Effort to separate Recycling concept		
	Waste			
	Construction site	Construction Site, Construcion Phase	Waste reduction Noise reduction Dust reduction Environmental reduction	
	Indoor climate	Thermal comfort Winter / summer Indoor Air Quality / Indoor Hygiene Acoustic Comfort Visual Comfort Vision to at least two sky directions	Operative temperature Draught Radiation temperature Relative humidity Personal ventilation rate Daylight - whole building Daylight - work stations Blending free daylight Blending free artificial light Light distribution artificial light Colour reproduction	
Economical	LCA	Lyfe Cycle Costs		
	Performance	Economic performance	Suitability for Third-Party Use Area efficiency Adaptability Conversion to differente use	
Social	Functional qualities	User Influence on Building Operation Balconies etc. Area Efficiency	Ventilation Sun protection Blending protection Temperature during / outside heating season Regulation of daylight and artificial light User friendliness	
	Architectural qualities	Suitability for Conversion Aesthetic Quality	Modularity of building Feasible spatial structure Spatial organisation Flexible heating system Flexible water system Flexible ventilation and climate system	

		LEED	
Environmental	Climate	Heat Island Effect Green Power	
	Energy	On-site Renewable Energy Optimize Energy Performance	
	Water	Innovative Wastewater Technologies Water Use Reduction Stormwater Design	
	Materials	Material Reuse Regional Materials Rapidly Renewable Materials Certified Wood Low-Emitting Materials	
	Waste	Building Reuse Prerequisite: Storage and Collection of Recyclables Required Recycled Content	
	Construction site	Construction Waste Management	
	Indoor climate	Prerequisite 1: Minimum Indoor Air Quality Performance Required Indoor Chemical and Pollutant Source Control Thermal Comfort Daylight and Views	Design Verification Daylight
Economical	LCA		
	Performance		
Social	Functional qualities	Controllability of Systems	Lighting Thermal Comfort
	Architectural qualities	Innovation in Design	

Figure 18: The parameters left (the red colored) after use of the limitation graph. A readable size can be seen in Appendix G.

The parameter space is now reduced further after the incorporation of the limitation graph and the analyses related to it. The full parameter space of this stage can be seen in Appendix G. Above (Figure 18) a small section of the parameter space is shown.

3.2.3 Final sorting of parameter space

Based on the above described limitations, the parameters from the sustainable certification could be sorted further into a single table, though the parameter space was reduced to a much more tangible amount.

Environmental	Climate DGNB	Life cycleanalysis Global and local environmental impact Radon		
	Climate LEED	Heat Island Effect Green Power		
	Climate BREEAM	Reduction of CO2 Emissions		
	Climate BDR	Renewable Technologies Environmental Impact of Materials		
	Energy DGNB	Ressource consumption and waste generation Wire tired energy Solar energy	Total Primary Energy Demands and Proportion of Renewable Primary Energy	Total Primary energy Total renewable energy
	Energy LEED	On-site Renewable Energy Optimize Energy Performance		
	Energy BDR	Primary Energy Demand		
	Water DGNB	Site Location Risks Rainwater drainage	Drinking Water Demand and Volume of Waste Water Floods	
	Water LEED	Innovative Wastewater Technologies Water Use Reduction Stormwater Design		
	Water BREEAM	Water Consumption Water Recycling Flood Risk		
	Water BDR	Internal Water Use Surface Water Runoff Flooding		
	Materials DGNB	Effort to demolish Effort to separate Recycling concept		
	Materials LEED	Material Reuse Regional Materials Rapidly Renewable Materials Certified Wood Low-Emitting Materials		
	Materials BREEAM	Responsible sourcing of Materials Designing For Robustness		
	Materials BDR	Responsible Sourcing of Materials		
	Waste LEED	Building Reuse Prerequisite: Storage and Collection of Recyclables Required Recycled Content		
	Waste BREEAM	Construction Site Waste Management Re-use of Building Facade Re-use of Building Structure		
	Construction site DGNB	Construction Site, Construcion Phase	Waste reduction Noise reduction Dust reduction Environmental reduction	
	Construction site LEED	Construction Waste Management		
	Construction site BREEAM	Construction Site Impacts		
	Construction site BDR	Refurbishment Site Waste Management Construction Site Impacts		
	Indoor Climate LEED	Thermal Comfort Daylight and Views		
	Indoor Climate BREEAM	Daylighting Thermal Comfort		
	Indoor Climate BDR	Daylight Ventilation		
	Indoor Climate DGNB	Thermal comfort Winter / summer	Daylight - whole building Daylight - work stations	

Economical	LCA DGNB	Lyfe Cycle Costs
	LCA BREEAM	Life Cycle Costing
	Performance DGNB	Area efficiency

Figure 19: Section of the parameter space in a single table. A readable size can be seen in Appedix H.

In this stage it was noted in the tables which parameter belonged to which certification (see Appendix H for details). From this created table it could be seen, that many of the parameters were related, or equal. Thereby a generalization was made and the different parameters that were equal were defined as one parameter. In some cases, an interpretation of the parameter name was made, where it was simplified and tried to be made clearer, although the content and understanding of the background was the same. The final parameters can be seen in Figure 20. By this generalization, the parameter space became much more tangible and could be the final stage before developing the assessment tool.

Climate	LCA CO2 reduction Renewable technologies
Energy	Energy concumption Renewable energy
Water	Risk of site Water use consumption Water recycling
Materials	Use of materials Choice of materials
Waste	Recycling Waste handeling
Construction Site	Construction site impacts Construction site waste handeling
Indoor Climate	Daylight factor Thermal comfort

LCA	Life cycle costs
Performa nce	Efficiency

Figure 20: The parameters selected for the final parameter space. (A readable size can be seen in Appendix I)

It can be seen that the parameters handle the climate in different ways, waste, LCA – cost and analysis together with use of materials etc. Compared to the fundamental sustainable parameters, these are the environmental and economic sustainability parameters. The social sustainability parameters have been deselected though they handle the site and other well fare analyses, which throughout the development in the precious sections is assumed not relevant for this method.

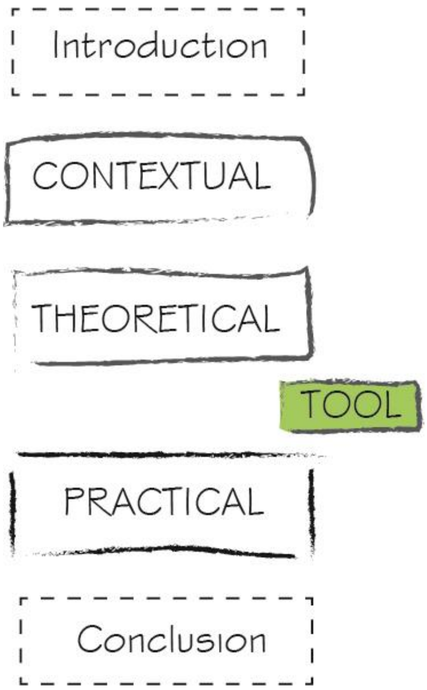
The parameters left (see Figure 20) are to be used for the further method process and will therefore be the base of the analysis whether a building should be renovated or demolished and rebuild. The parameters can also be seen in Appendix I. In the following section, these parameters will be included in the decision tool and transformed into questions, in order for the contractor to assess what the best solution for the regarded building would be.

4 THE TOOL

In this section the tool that is developed based on the parameter space, is presented. The aim of the current section is to document the development of a decision supporting method that can be applied to the assessment whether a building ought to be renovated or demolished and replaced by a new building. The decision is based on sustainability criteria that are defined and discussed in detail in section 3.2. The result of this method is a map that supports the decision making process for the relevant decision makers. By this, it is assumed that the best, most sustainable and most beneficial result, for both owner and user, will be the outcome.

Some knowledge and requirements exist in the beginning of a project, while more detailed analyses can be made after elimination of parameters. By this, a sequence of steps, in a specific order followed in order to achieve a decision map between a renovation and demolition of a building.

The presentation of the tool is divided into three parts. The first part is an **overall presentation** of the tool, which describes the process of the method. In the second part, the steps of **the tool is explained** in order to understand the background for each of them and which analysis that shall be performed. In the last part, the **steps are more defined** and detailed described. The questions and needed analysis are stated and explanations are included for a larger understanding of the work. The needed documentation material for the tool is also presented in this part as well as in the user guide.



4.1 The method proces

The process of the tool is in five steps. Some of the steps (Step 1 and 2 combined with step 3) are used to define towards which direction the building should take, if there are clear definitions for the building in the very beginning, or if there are limitations from the contractor which equals a certain result for the building (see section 4.2). The next part of the analysis is made over two steps. The first of these (step 4) is a simple analysis, which all contractor would be able to answer, by simple questions, mostly Yes/No questions. Through this a better foundation for the assessment whether the building should be renovated or demolished and rebuild is founded. For each of the questions, a point is given to the best performing scenario (the renovation project or the new demolished and rebuilt building). The case with highest scoring is assumed to be the preferred action, according to this tool, although the final decision is made by the contractor. If further detailing is needed, or wanted, the final step (Step 5) can be executed. Here large analyses are made which demands more expertise, time and economical capacity. It would also be possible to perform a sustainable certification in this step instead, with a certification method of own choice. The whole process can be seen in the following figure (See Figure 21) and further explanation and detailing for each step are given in the following sections.

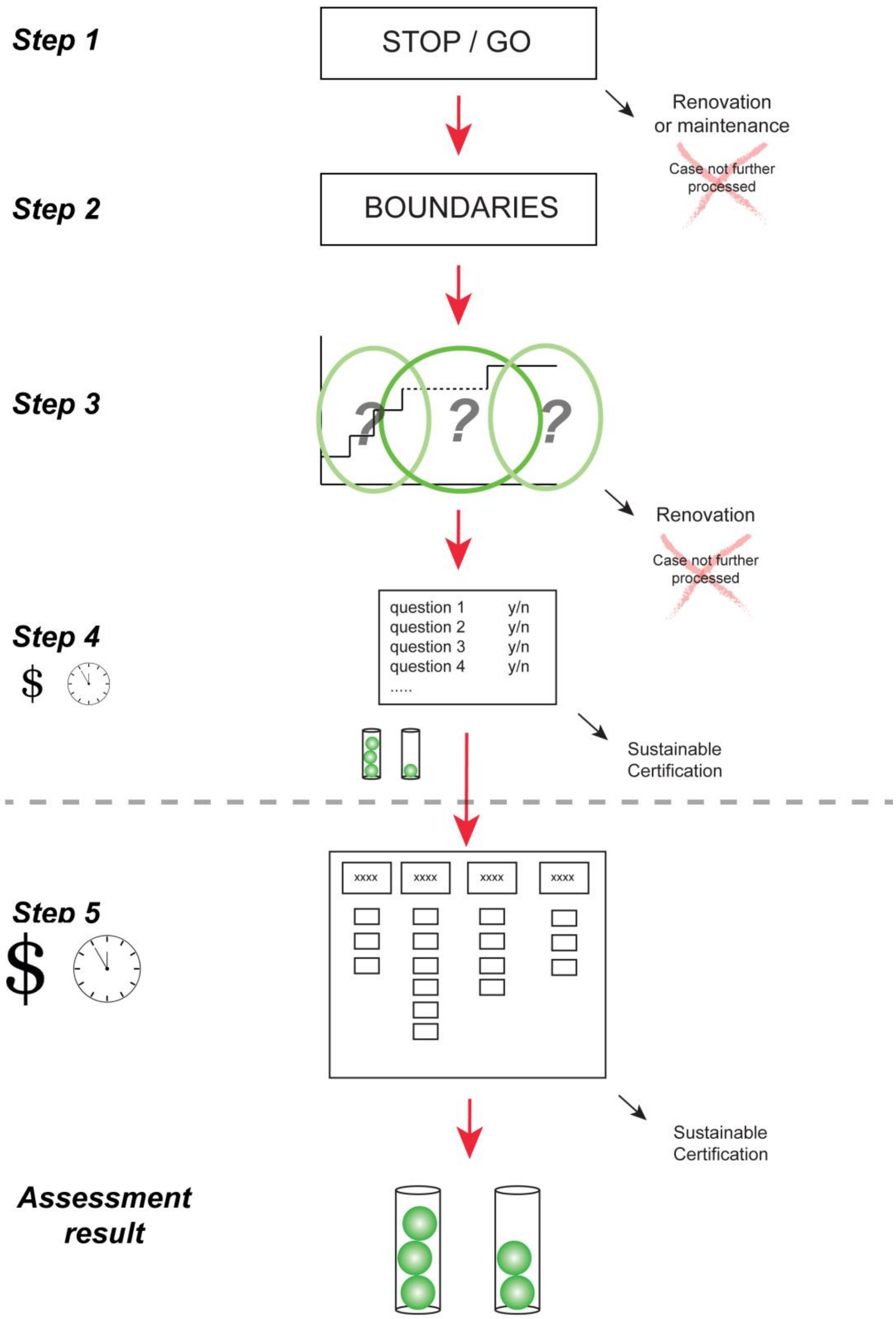


Figure 21: Diagram showing the method process. The dollar sign symbolizes the cost that these steps demand. Step 5 is seen as a much more costly procedure than step 4, though expert knowledge and larger analyses are needed. The clock presents time consumption, as it is assumed that step 5 will be more time consuming than step 4.

4.2 Explanation of the steps

Step 1: Stop/Go parameters

It is expected that some fundamental categories have severe impact on the decision whether a building should be renovated or demolished and rebuild, categories that can be evaluated from the very beginning. Therefore the situation of the regarded building should be defined in an early stage, if further analyses of the decision supporting tool shall be made or if it should stop the process and continue in form of daily maintenance.

The created Stop/Go parameters are seen as an opportunity to analyze the possibility for the regarded project and point it in the right direction from the beginning, without making unnecessary investigations and calculations. As an example, a listed building is not allowed to be demolished, and renovation or maintenance is the only possible solution. If the Stop/Go parameters result in a “Go”, the project can move further to the next step of the method, if not – the regarded case have no further use of the decision supporting tool.

Parameters in this part could be economical issues, as if the owner has the capital to renovate the building or demolish and rebuild. If the economy isn’t adequate for enabling the project further steps can’t be taken. Also, there can be restrictions for the building, the architecture or for the urban area around the building, which prevents a renovation or demolition the building etc.. At DTU, the two presented cases in section 5.2, are placed in an area with similar construction and materials, which gives a specific design for the whole campus. A “restriction” is made for DTU in which new buildings are necessary to fit the architecture. In cases like these a new building could be difficult to implement.

Step 2: Boundaries

It is assumed that there are some minimum requirements the developer wish to fulfill but also thresholds for what is the maximum that can be tolerated for the regarded project. This can be economical boundaries, amount of time the project is allowed to take, or magnitude of the project. These sorts of parameters can incline the project towards one scenario or the other (renovation or demolition).

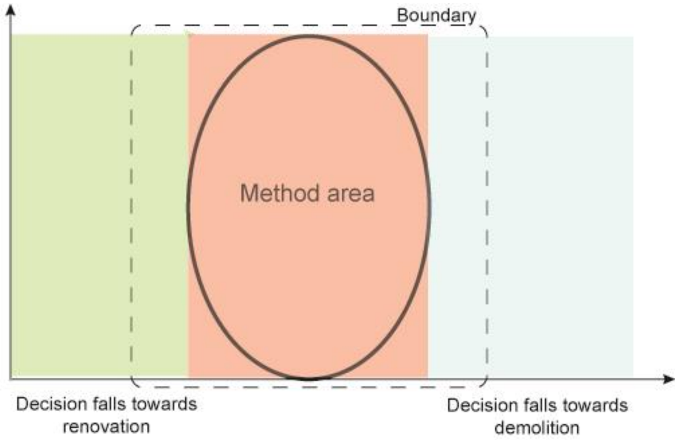


Figure 22: The boundaries from the limitation graph. These define in which category the case is positioned and thereby if the tool should be further used or not. The two outer categories presents parameters which only will lead towards renovation (green) or demolition and rebuilding (blue) as a possible solution. The red area is the method area – if the boundaries results in this as the "target area", the next step of the tool can be evaluated, as both renovation and demolition is a possibility for the regarded building.

If the Stop/Go parameters are fulfilled and the project can continue with the process– some statements are made, according to the limitations of the contractor and minimum requirements from for example the Danish building regulations. This will define the boundaries for the parameter space (see Figure 22), and therefore the boundaries for the method. Parameters values, which are outside the boundaries, can result in simple decisions that don't demand any further analysis – this can be the case if the demand for renovation ends in simple maintenance tasks as the only possible option (the green area). Other parameter values that lay outside the boundaries could also end in the other extreme (the blue area), where the requirement to the building makes it necessary to replace the building in any case.

By defining the boundaries, it can be evaluated if the current case lies in the method area (the red area of the limitation graph, which is the area where the method applies), hence one can move further into the assessment process and a step further in the method.

The boundaries will vary from project to project and will be defined by the contractor, though it is he who knows where the limits for this project are. By this, the method is very flexible and can be transformed to the specific cases.

Step 3: Parameter space

The parameter space is defined by the boundaries and by this means the subsequent to it. The limitation graph illustrates if the project is in one of the outer categories or if the method area can be handled.

If the results of the boundaries inclines only towards renovation, as mentioned before, no further measures will be taken to the project as it is the owners own interest for what renovations that shall be done and in which amount. The same is regarding the other outer category. If the boundaries results in demolition as the only solution, no further analyses from the tool needs to be performed. If the result inclines towards the middle part of the limitation graph, the method area, the next step of the method will be used to define if the building should be renovated or demolished and rebuild, though both scenarios can be assessed as the best solution for the regarded case.

Step 4: The simple questions

Within the method area, a set of simple questions will be used in the next step for a quick introduction to the possible assessment whether the building should be renovated or demolished and rebuild. The questions are based on the parameters from the sustainable certifications, sorted in section 3.2. A point is given for each answer, which is summed to illustrate the assessment of the building. Points can also be given to both scenarios, if they are equally performing. Further detailing is possible if preferred in order to evaluate the decision. This is defined in the next step.

Step 5: Detailed analysis

In the detailing process, further calculations and analyses are made, in order to verify the assessment of the regarded building. This part is more time consuming and requires more knowledge from the contractor. It can be chosen not to perform further levels of detail of the regarded case, to avoid unwanted additional cost for this assessment step, and thereby trust in the results from the earlier questionnaire (step 4). The detailed analyses consist of LCA analysis, economical calculation of the cost-effectiveness and the environmental impact etc. Furthermore, energy calculations for comparing the building in a renovation scenario and as a new building should also be produced, in order to see what benefits the one or the other has. This step is, as mentioned before, more detailed and time consuming, but will give a great insight in what should be done to the respective building.

Scoring and assessment result

As a result from the previous steps, an assessment is created where it can be seen what could be the preferred solution of the project. If the method is used correctly, it would shape a good basic analysis of the project and several arguments are achieved for what measures that should be taken to the building.

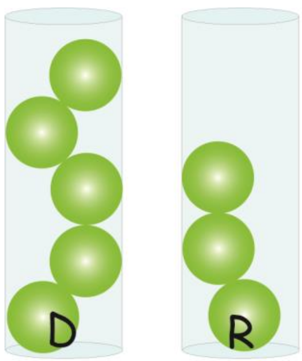


Figure 23: The figure explains the scoring results for the renovation versus the demolition and rebuilding scenario. A point is given for each question, which in the end sums up and reveals the assessment result.

Each question, in the simple and detailed steps of the tool, gives a point to the best performing scenario (the renovation or the demolition and rebuild). The scoring is in the end gathered and the assessment for the regarded building can be seen by the scenario with the highest score. The final assessment and decision for the regarded building should although be taken by the contractor.

4.3 Tool definitions and elaboration

While the previous section gave an overview of the decision supporting tool, this section will explain the tool into operational detailing, introducing the individual tools of the toolbox. The created schemes for the toolbox are to be used when performing the assessment of the regarded case. The schemes, which are the outcome of the decision supporting tool, are explained in this section, in order to create an understanding of the use of the tool. These schemes are also included in the user guide.

Step 1: Definition of STOP/GO – parameters

The ”Stop/Go” parameters are based on existing knowledge and statements that occurred during the process of this thesis. It was seen important to included parameters that immediately could tell if the given case should go forth with the analyses or if there was incidents that would reveal whether the project should stop now or move directly towards one solution or the other (renovation or demolition and rebuild). The questions for this step are as following:

The Stop/Go parameters:

- Is the economy good enough to be capable of a large renovation or to demolish and rebuild the building?
- Is the building listed?
- Is there any restriction in the area towards actions that may be taken to the building?
    - Does the area demand a specific design?
    - Is there a limitation according to safety measurements?
    - Is there a communal restriction for renovation or new buildings?
    - Can these restrictions be worked around?
- Is there an architectural restriction that limits the possibilities for the building?
- Is the architecture of the building special, well performed and worth preserving?
- Is the building attacked with fungus or mold?
    - Is it a severe problem?
- Is there Asbestos in the building?
    - Will this affect the process?
- Are there other hazardous materials in the building? (PCB)
    - Will this affect the process?
- Is the existing building in risk of flooding?
    - Will the building always be in risk on this site?
    - Can measures be taken to reduce the impact on the future building?
- Does the building meet the requirements from the Danish Building regulation?
    - If not: is it possible to achieve in this building?
- Is there enough height to improve/implement installations in the building and thereby reach the energy requirement?
- Is the daylight factor high enough for office work?
    - If not: is it possible to adjust the facade to achieve a higher DF?
- Will a renovation or rebuilding affect other buildings attached to - or around the building?
    - If yes: is it acceptable?

The questions are made very simple and quick to answer. They should give an immediate impression if the tool should be further processed or if there are circumstances, which forces the case to stop the analyses.

STOP / GO

Questions		Answer	Consequence	
			Stop	Go
Is the economy good enough to be capable of a large renovation or to demolish and rebuild the building?				
Is the building listed?				
Is there any restriction in the area, towards actions that may be taken to the building?				
	Does the area demang a specific design?			
	Is there a limitation according to safety measurements?			
	Is there a communal restriction for renovation or new buildings?			
	Can these restrictions be worked around?			
Is there an architectural restriction that limits the possibilities for the building?				
Is the architecture of the building special, well performed and worth preserving?				
Is the building attacked with fungus or mold?				
	Is it a severe problem?			
Is there Asbestos in the building?				
	Will this affect the process?			
Is there other hazardous materials in the building? (PCB)				
	Will this affect the process?			
Is the existing building in risk of flooding?				
	Will the building always be in risk on this site?			
	Can measures be taken to reduce the impact on the future building?			
Does the building meet the requirements from the Danish Building regulation?				
	If not: is it possible to achieve in this building?			
Is there enough height to improve / implement installations in the building and thereby reach the energy requierement?				
Is the daylight factor high enough for office work?				
	If not: is it possible to adjust the facade to achieve a higher DF?			
Will a renovation or rebuilding affect other buildings attached to - or around the building?				
	If yes: is it acceptable?			
		Result		

Figure 24: The scheme to be used when performing the assessment of a building. (A readable version is also included in the user guide and in Appendix J)

The Stop/Go scheme is the first part of the tool and is formed like shown in Figure 24. The scheme consists of a set of questions, some with sub questions. After answering all questions, an evaluations of the answers are made and a "consequence" are given for each questions to define if it results in stop or go. The questions are answered by the contractor and if there are a large amount of "stop criteria's", it is assumed that no further steps needs to be followed, though a smaller renovation, or regular maintenance, is the preferred solutions for this building. If most of the questions equal "go" – the next step in the process of the tool can be taken. It shall although be noticed, that the definition of each question and if the answer equals a Stop or a Go – should be defined by the contractor, although he knows what the possibilities are for the regarded building and the vision for it.

Step 2: Definition of boundaries

In this step the contractor is asked to define the max- and minimum limits for the project in numerical terms, such as time and cost etc. If the project exceeds the maximum limits, the method should not be further used, although this will demand more than is accepted. The boundaries can also result in the possibility of a demolition to be the best solution for the building. Thereby, the limit is set if the building shall keep on being renovated, be demolished or go further and analyze what the best solution could be.

Parameters for the Boundaries:

Σ Price
Σ Time
Σ Building envelope changes
Σ Amount of hazardous materials
Impact on the building users
Functions of the building

Boundaries

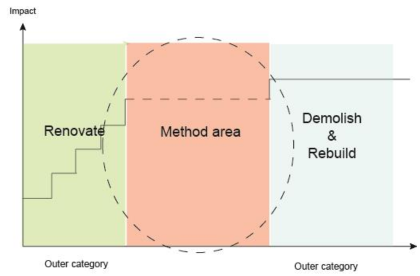
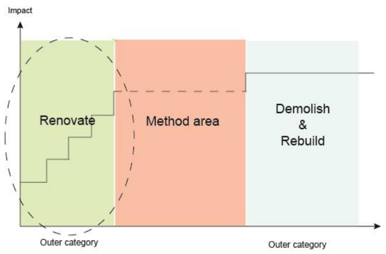
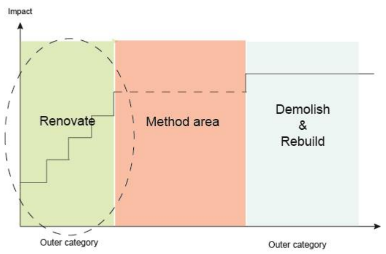
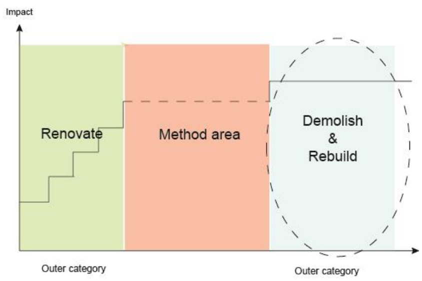
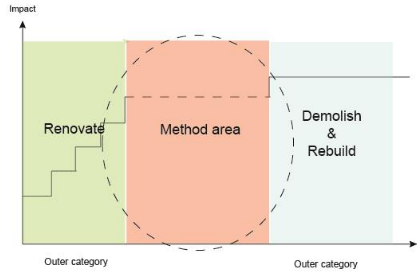
Lower limit		Parameter		Upper limit
<		[XX]		>
		Price		
		Time		
		Building envelope changes		
		Hazardous materials (ammount)		
		Impact on users		
		Necessary functionality		

Figure 25: The scheme to be used when performing the assessment of a building. (Also included in the user guide and Appendix K)

The scheme in Figure 25 is to be used for defining the boundaries. Here an upper limit can be placed, or a lower limit. Questions that can't be answered, or is seen irrelevant for the regarded building, can be neglected. The boundaries are thereafter analyzed and the further procedure is defined in the limitation graph in the next step.

Step 3: How is the building going to proceed? – Layout of parameter space

The boundary in step 2 defines the relevant parameter space. By this, it can be seen if the building only should be renovated or if demolition is a possibility and thereby the contractor can move forward with the next step. Below, some examples are given to explain how the boundaries can be used together with the limitation graph. These examples are fictive and some are very extreme. It is meant to be used as a display of how the boundaries is used together with the limitation graph and which analysis that should be made between the two. By this it should be noticed, that although some upper limitations are stated, it can always be discussed the meaning of it and the respective contractor should always look into the interest of himself, the users of the building and the vision for the future. Thereby, a judgment of each boundary can be made in order to fit the regarded case.

<table>
<tr><th colspan="2">Price > unlimited</th></tr>
<tr><td>
</td><td>By having an unlimited or very large budget, both renovation and demolition and rebuilding is possible for the regarded case. The limitation graph shows that the method area is considered, both scenarios can be the solution, and thereby the tools should be used for further assessment</td></tr>
<tr><th colspan="2">Time > ½ year</th></tr>
<tr><td>
</td><td>A demolition and rebuilding is assessed to take more than ½ a year, and if the time is limited to under this, a renovation would be the only choice. As the limitation graph shows, larger categories of renovation will demand more time, and the lower outer category is therefore the only considered are in this case.</td></tr>
<tr><th colspan="2">Building envelope > no changes allowed</th></tr>
<tr><td>
</td><td>If no changes can be made for the façade, a demolition and rebuilding would not be a possible solution. Also, larger renovations would neither be achievable to the façade. Thereby, only smaller renovation jobs can be made in this case, and the tool shall not be further used.</td></tr>
<tr><th colspan="2">Hazardous materials > 50 % of building material</th></tr>
<tr><td>
</td><td>If the limit for an amount of hazardous materials exceeds this limit, a demolition would be the preferred solution, although it is assessed not to be safe to renovate the building – for the constructions, the users of the building and the risk of not have removed all hazardous materials.</td></tr>
<tr><th colspan="2">Impact on users > building can’t be used during renovation</th></tr>
<tr><td>
</td><td>In this case, a demolition could be the solution, although the building can in any way not be used during a renovation.</td></tr>
</table>

Step 4: Definition of the simple questions

The parameters that lay inside the "method area" are estimated through simple and fast answered questions, to make a first assessment whether a renovation or a demolition and rebuilding is the best solution. Most of the questions can be answered with yes or no and thereby it gives an insight if the building would be better off to be renovated or demolished. These questions in some extend relates to the "Stop/Go" parameters, though they give a quick insight in the possible verdict. The stated questions are also simple in a way that most contractors would be able to answer them immediately. Thereby, no large analysis, calculations or expensive entrepreneurs are needed.

This step could be used as the decision supporting assessment and the achieved scoring can allude to the best solution for the regarded building. If further detailing is needed, the next step can be executed.

The simple question scheme is inspired by the BBBarometer [MacIntyre, n.d.] [MBBL, 2012] and the certifications used in this thesis. The questions are listed below:

Simple question:
Energy

- How is the energy rating performance?
    - If the building is renovated:
    - If the building is demolished and rebuild
- Is renewable energy used for the building?
    - If the building is renovated:
    - If the building is demolished and rebuild
    - Can renewable energy technology be implemented in the building?
- How large is the production of energy by renewable energy?
    - For the renovated building
    - For the newly constructed building
- Will different energy sources be used for the two types of building?
    - If yes: which energy source is chosen for renovation of the building?
    - If yes: which energy source is chosen for the new building?
    - Which of the two energy sources contributes with the least emissions?

Materials

- Is environmental proved materials used?
    - For the renovated building
    - For the newly constructed building
- How much of the material?
    - For the renovated building
    - For the newly constructed building
- Is the building materials reused?
    - For the renovated building
    - For the newly constructed building

Water

- Is green roofing used to absorb rainwater?
    - For the renovated building
    - For the newly constructed building
    - Is green roofing a possibility to implement on the building?
- Is collected rainwater used for toilets etc.?
    - For the renovated building
    - For the newly constructed building
- Is water recycling used?
    - For the renovated building
    - For the newly constructed building
- Is hot water reused for heating?
    - For the renovated building
    - For the newly constructed building
- Can possible moist and fungus problems (if existing) be solved by
    - Renovation of the building
    - By demolition and rebuilding of the building

Hazardous materials

- Is there sealed PCB in the building materials:
    - In the renovated building?
    - In the newly constructed building?
- Will there be asbestos
    - In the renovated building?
    - In the newly constructed building?
- Is the building sealed for Radon?
    - In the renovated building
    - In the newly constructed building

Construction site

- Will the renovation affect the users?
    - Can the building be used during renovation?
    - Are other locations nearby usable without great inconvenience?
    - How much inconvenience will this cause for the users [1 (non) - 5 (a lot)]
- Will a demolition and rebuilding affect the users?
    - Are other locations nearby usable without great inconvenience?
    - How much inconvenience will this cause for the users [1 (non) - 5 (a lot)]
- Are other buildings nearby affected?
    - By the renovation
    - To what extent? [1(very little) - 5 (very much)]
    - By demolition and rebuilding
    - To what extent? [1(very little) - 5 (very much)]

Building plan & flexibility

- How efficient is the building plan (work places/m^2)
    - In the renovated building
    - In the newly constructed building
- Is the building flexible?
    - In the renovated building
    - In the newly constructed building

Indoor climate

- Is the thermal comfort sufficient:
    - In the renovated building?
    - In the newly constructed building?
- Is the DF sufficient:
    - In the renovated building?
    - In the newly constructed building?
- Can the facade/glass proportion be changed:
    - In the renovated building?
    - In the newly constructed building?
- Is there a risk of glaring:
    - In the renovated building?
    - In the newly constructed building?
    - Is the used solar shading the best solution for the renovated building?
    - Is the used solar shading the best solution for the new building?

	Question		Answer	Best case [x]	
				Renovation	Demolition & rebuilding
Energy	How is the energy rating performance?				
		If the building is renovated:			
		If the building is demolished and rebuild			
	Is renewable energy used for the building?				
		If the building is renovated:			
		If the building is demolished and rebuild			
		Can renewable energy technology be implemented in the building?			
	How large is the production of energy by renewable energy?				
		For the renovated building			
		For the newly constructed building			
	Will different energy sources be used for the two types of building?				
		If yes: which energy source is chosen for renovation of the building?			
		If yes: which energy source is chosen for the new building?			
		Which of the two energy sources contributes with the least emissions?			
Materials	Is environmental proved materials used?				
		For the renovated building			
		For the newly constructed building			
	How much of the material?				
		For the renovated building			
		For the newly constructed building			
	Is the building materials reused?				
		For the renovated building			
		For the newly constructed building			
Water	Is green roofing used to absorb rainwater?				
		For the renovated building			
		For the newly constructed building			
		Is green roofing a possibility to implement on the building?			
	Is collected rainwater used for toilets etc.?				
		For the renovated building			
		For the newly constructed building			
	Is water recycling used?				
		For the renovated building			
		For the newly constructed building			
	Is hot water reused for heating?				
		For the renovated building			
		For the newly constructed building			
	Can possible moist and fungus problems (if existing) be solved by				
		Renovation of the building			
		By demolition and rebuilding of the building			
Hazardous materials	Is there sealed PCB in the building materials:				
		In the renovated building?			
		In the newly constructed building?			
	Will there beasbestos				
		In the renovated building?			
		In the newly constructed building?			
	Is the building sealed for Radon?				
		In the renovated building			
		In the newly constructed building			
Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?			
		Are other locations nearby usable without great inconvenience?			
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?			
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Are other buildings nearby affected?				
		By the renovation			
		To what extent? [1(very litte) - 5 (very much)]			
		By demolition and rebuilding			
		To what extent? [1(very litte) - 5 (very much)]			
Building plan & flexibility	How efficient is the building plan (work places / m2)				
		In the renovated building			
		In the newly constructed building			
	Is the building flexible?				
		In the renovated building			
		In the newly constructed building			
Indoor climate	Is the thermal comfort sufficient:				
		In the renovated building?			
		In the newly constructed building?			
	Is the DF sufficient:				
		In the renovated building?			
		In the newly constructed building?			
	Kan the facade / glass proportion be changed:				
		In the renovated building?			
		In the newly constructed building?			
	Is there a risk of glaring:				
		In the renovated building?			
		In the newly constructed building?			
		Is the used solar shading the best solution for the **renovated** building?			
		Is the used solar shading the best solution for the **new** building?			

Figure 26: The scheme to be used when performing the assessment of a building. (Also included in the user guide and Appendix M)

As for the ”Stop/Go ” scheme, the simple questions is a row of questions that shall be answered. The questions are divided into larger categories such as water, materials and energy etc., which can be related to the sustainable certification methods. Some have follow up questions in order to lead the assessment of the project in the right direction. Each question is defined for the renovation scenario as well as for the demolition and rebuilding. By this, both visions are analyzed. For each question, the best-performing scenario is given one point. What the best-performing scenario is shall be defined by the contractor.

Step 5: Definition of detailed analysis

The detailed questions are divided into similar categories as for the simple questions. Here, larger analysis wil be performed and a larger expertise in the different area are needed. Some of the categories are environment, materials and economy. It was stated earlier that economy only would be a part of the detailed questions. This is because of the needed level of detailing, the need of expertise and the cost to make these analyses. Some of the needed analyses are Life cycle analysis and life cycle costs. Other analyses are regarding the indoor climate, the energy consumption and the daylight in the building. Calculations for these can be made by using Be10, BSim or Daysim.

The included questions for analysis can be seen below.

Environment

- What are the environmental impacts of the two cases?

Materials

- How much of the materials can cause environmental risk
    - For the renovated building?
    - For the newly constructed building
- What materials are used?
    - For the renovated building?
    - For the newly constructed building
- Can they be excluded or can other materials be used instead?
    - For the renovated building?
    - For the newly constructed building?
- Are certified materials used:
    - For the renovated building?
    - For the newly constructed building?
  - If Yes, in which amount are certified materials used?
    - For the renovated building?
    - For the newly constructed building?
- How is the embodied environmental impact in the materials, relative to the thermal property?
    - For the renovated building?
    - For the newly constructed building?
- Are others, and more environmental friendly materials, considered?
    - For the renovated building?
    - For the newly constructed building?
- Is the materials sourced responsibly?
    - For the renovated building?
    - For the newly constructed building?
- Is local products used? (Or materials from nearby?)
    - For the renovated building?
    - For the newly constructed building?

Waste and construction site

- How much waste is assumed to be the outcome?
    - For the renovated building?
    - For the newly constructed building?
- What kind of waste?
    - For the renovated building?
    - For the newly constructed building?
- Is there a plan for management of reduction of waste and waste handling?
    - For the renovated building?
    - For the newly constructed building?
- Can the deconstruction materials be used for future construction materials?
    - For the renovated building?
    - For the newly constructed building?
  - In which amount?

  - For the renovated building?
  - For the newly constructed building?
- Is the materials reused on site, or other sites?
  - For the renovated building?
  - For the newly constructed building?
- Are materials from other sites used for the two cases?
  - For the renovated building?
  - For the newly constructed building?
- Is unused materials returned to the supplier?
  - For the renovated building?
  - For the newly constructed building?
- Are options considered for reusing and recycling waste?
  - For the renovated building?
  - For the newly constructed building?

Energy

- How high is the primary energy demand?
  - For the renovated building?
  - For the newly constructed building?
- How good is the energy rating?
  - For the renovated building?
  - For the newly constructed building?
- Is renewable energy used for the cases?
  - For the renovated building?
  - For the newly constructed building?
  - If not, can renewable energy be incorporated in the building?
- How much of the energy use is covered by renewable energy?
  - For the renovated building?
  - For the newly constructed building?

Water

- What is the water consumption?
  - For the renovated building?
  - For the newly constructed building?
- Is the use of potable water limited by refurbishment or by demolishing and rebuilding?
  - How much is it reduced?
  - For the renovated building?
  - For the newly constructed building?
- Is low water fittings used?
  - For the renovated building?
  - For the newly constructed building?
- Is use of gray water and/or rainwater incorporated in the building?
  - For the renovated building?
  - For the newly constructed building?
  - Can it be incorporated in the building?
- Is green roofing used as an alternative way to reduce flooding and collect rainwater?
  - For the renovated building?
  - For the newly constructed building?

Economy

- What is the life cycle cost – for the whole lifetime?
    - For the renovated building?
    - For the newly constructed building?
- What is the area efficiency of the two cases?
    - For the renovated building?
    - For the newly constructed building

Flexibility

- Are the interior walls movable?
    - For the renovated building?
    - For the newly constructed building?

- Can it easily be change to another purpose? (Open office, single offices, coffee area, etc.) ?
    - For the renovated building?
    - For the newly constructed building?

- Is the installations and electricity also flexible? (Easy to move, and dimensioned to several purposes)?
    - For the renovated building?
    - For the newly constructed building?

Indoor climate

- How is the thermal comfort?
    - In the renovated building?
    - In the newly constructed building?
- How high is the DF?
    - In the renovated building?
    - In the newly constructed building?
- Which building has the largest risk of glaring?
    - The renovated building?
    - The newly constructed building ?

	Question			Answer	Best case [x]	
					Renovation	Demolition & rebuilding
Environment	What are the environmental impacts of the two cases?		*			
Materials	How much of the materials, can cause environmental risk					
		For the renovated building?				
		For the newly constructed building				
	What material is this?					
		For the renovated building?				
		For the newly constructed building				
	Can they be excluded or can other materials be used instead?					
		For the renovated building?				
		For the newly constructed building				
	Are certified materials used:					
		For the renovated building?				
		For the newly constructed building				
	In which amount are certified materials used:					
		For the renovated building?				
		For the newly constructed building				
	How is the embodied environmental impact in the materials, relative to the thermal property?					
		For the renovated building?				
		For the newly constructed building				
	Are others, and more environmental friendly materials, considered?					
		For the renovated building?				
		For the newly constructed building				
	Is the materials sourced responsibly?		*			
		For the renovated building?				
		For the newly constructed building				
	Is local products used? (Or materials from nearby?)					
		For the renovated building?				
		For the newly constructed building				
Waste and construction site	How much waste is assumed to be the outcome:					
		For the renovated building?				
		For the newly constructed building				
	What kind of waste:					
		For the renovated building?				
		For the newly constructed building				
	Is there a plan for management of reduction of waste and waste handling:					
		For the renovated building?				
		For the newly constructed building				
	Can the deconstruction materials be used for future construction materials:		*			
		For the renovated building?				
		For the newly constructed building				
	In which amount:					
		For the renovated building?				
		For the newly constructed building				
	Is the materials reused on site, or other sites?					
		For the renovated building?				
		For the newly constructed building				
	Are materials from other sites used for the two cases?					
		For the renovated building?				
		For the newly constructed building				
	Is unused materials returned to the supplier?					
		For the renovated building?				
		For the newly constructed building				
	Are options considered for reusing and recycling waste?					
		For the renovated building?				
		For the newly constructed building				
Energy	How high is the primary energy demand:					
		For the renovated building?				
		For the newly constructed building				
	How good is the energy rating:					
		For the renovated building?				
		For the newly constructed building				
	Is renewable energy used for the cases?					
		For the renovated building?				
		For the newly constructed building				
		If not, can renewable energy be incorporated in the building?				
	How much of the energy use is covered by renewable energy?					
		For the renovated building?				
		For the newly constructed building				
Water	What is the water consumption:					
		For the renovated building?				
		For the newly constructed building				
	Is the use of potable water limited by refurbishment or by demolishing and rebuilding?					
	How much is it reduced?					
		For the renovated building?				
		For the newly constructed building				
	Is low water fittings used?					
		For the renovated building?				
		For the newly constructed building				
	Is use of gray water and/or rainwater incorporated in the building?					
		For the renovated building?				
		For the newly constructed building				
		Can it be incorporated in the building?				
	Is green roofing used as an alternative way to reduce flooding and collect rainwater?					
		For the renovated building?				
		For the newly constructed building				
Economy	What is the life cycle cost – for the whole lifetime:					
		For the renovated building?				
		For the newly constructed building				
	What is the area efficiency of the two cases?		*			
		For the renovated building?				
		For the newly constructed building				
Flexibility	Is the interior walls movable?		*			
		the renovated building?				
		the newly constructed building				
	Can it easily be change to another purpose?		*			
	(open office, single offices, coffe area, lounge etc.)	the renovated building?				
		the newly constructed building				
	Is the installations and electricity also flexible? (Easy to move, and dimensioned to several purposes?)		*			
		the renovated building?				
		the newly constructed building				
Indoor climate	How is the thermal comfort					
		In the renovated building				
		In the newly constructed building				
	How high is the DF					
		In the renovated building				
		In the newly constructed building				
	Which building has the largest risk of glaring?					
		The renovated building				
		The newly constructed building				

Figure 27: The scheme to be used when performing assessment of a building. (A readable example is also included in the user guide and Appendix N)

The scheme for the detailed questions as seen in Figure 27 is also divided into larger categories with subcategories. The detailed questions are as explained before, more demanding and a larger expertise is needed. This step is more time consuming due to calculations and analyses etc. By this, the cost of this step will be larger, relative to the previous step. Although, the detailed questions gives a good background knowledge about the building and is close to the existing sustainable certifications. Thereby it can be evaluated if a sustainable certification should be performed instead of step 5 – or as a following procedure.

Some of the questions are marked with " * ", which symbolizes a greater need of discussion and assessment of the regarded question. For example: the flexibility and when a building is defined flexible can vary from contactor to contractor. This should thereby be discussed before this is assessed in order to find the level that fits the regarded case.

4.3.1 Scoring results and the final assessment

Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?	No		X
		Are other locations nearby usable without great inconvenience?	Yes	X	
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?	Yes		X
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Are other buildings nearby affected?				
		By the renovation	Yes		X
		To what extent? [1(very litte) - 5 (very much)]			
		By demolition and rebuilding	Yes	X	
		To what extent? [1(very litte) - 5 (very much)]			

Figure 28: Small section of the simple question scheme – example with fictitious results. The green are scorings for a renovation scenario and the blue for demolition and rebuilding.

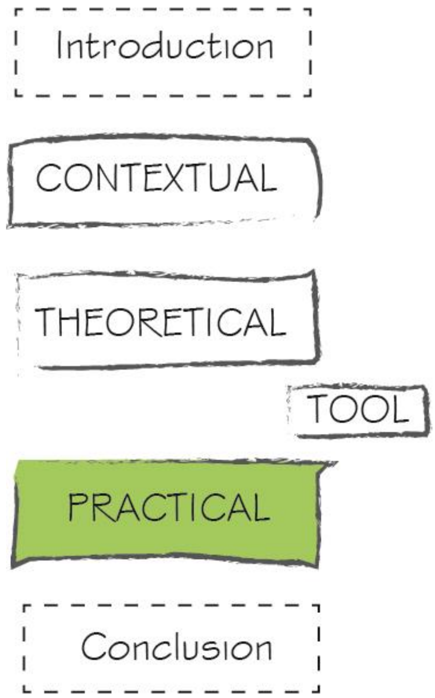
For each question there are given a scoring for the benefit of renovation or demolition and rebuilding. In the example above, Figure 28, a small section of the simple questions are presented although the same procedure is given for the detailed calculations. Each question is assessed and an answer is given. Thereafter, the answers are reflected in order to evaluate if the answer should give points to the renovation or the demolition and rebuilding scenario. The answer does although not equal a specific scoring – for example: if the users of the buildings are affected by a demolition and rebuilding, doesn't mean that a renovation is better. This should be assessed by the contractor, though it could be beneficial for the users to move into another building which is better for the regarded purpose and work environment, this should therefore give a higher score to demolition.

As seen from Figure 28 most points are given to the demolition scenario. By this, it is assed in this example that a demolition and rebuilding could be the best solution for this building.

5 PRACTICAL PART

In the practical part of this thesis, several cases are performed in order to analyze the decision supporting tool and the use of it on different buildings and in different areas. Three different buildings are chosen for the cases. Two buildings are from DTU campus while another is from Norway. In some of the cases, the building was already chosen to be renovated or demolished, which resulted in using the tool "backwards", by analyzing on the decisions made for the regarded building and to see if the same result would be achieved. A fictitious case was also created to test a specific output of the tool.

Due to a limited knowledge and time, the whole tool is only processed for one of the cases, while step 1-4 is evaluated for the others. This is to show how the detailed analysis could be performed and to demonstrate the whole process of the tool.



5.1 Implementation of the practical part

Four cases are used to analyze the decision supporting tool. The buildings for the regarded cases are two DTU buildings, an office in Norway and a fictitious case. These buildings are all office buildings, which are chosen to be the buildings for analysis of this tool.

Offices are very similar in layout and function and are not filled with heavy machinery in need of severe ventilation systems, or other parameters that can contribute to a large variation between the cases. Also, most buildings at DTU are offices (or teaching rooms, which are assumed to be very similar to an open office), which was the first draft to the cases. Furthermore, the sustainable certifications, which are the basis for the decision supporting tool, are in most cases developed to fit office buildings, which contributes to the necessary of analyzing these.

In the practical part, step 4 is fully analyzed and executed for all cases. Due to limitation of time and knowledge, only a few parameters of step 5 are analyzed for one of the cases. This is made to show how some of the analysis is performed and to illustrate the depth in the last step. It is assumed that the last step both will be heavy in detailing, regarding analysis and calculations as well as costs and time. The chosen categories for the performed calculations are energy, indoor climate, and daylight factor. In the executed calculations, assumptions are made when seen necessary in order to receive an output from the used programs. These are further explained in the regarded case.

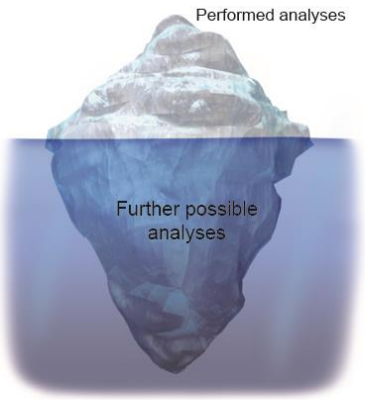


Figure 29: Figure explaining only a small amount of the possible detailed analysis is performed in Case 2, to illustrate the extent of knowledge that is needed. ("The tip of the iceberg")

5.2 The performed cases

In the following sections the cases are presented together with the analysis from the tool and the results. In the discussion, the overall results and the use of the tool will be analyzed and discussed.

Case 1 – Building 201 at DTU, is the first of the performed cases. Here, all questions couldn't be answered, which limits the outcome of the tool. An assessment was although made, based on the achieved information, which was shown to be different from the plans already made by DTU for the regarded building.

In Case 2 – Building 224 at DTU, is the case which have a fully processed tool analysis. The whole progression of the tool is fully described in order to illustrate how the tool is used and what visions are needed for the different steps. The case can be seen in section 5.2.2.

Case 3 is performed as a fictitious case. This is due to the interest in seeing how much is needed in order to achieve the assessment of renovation as the best solution, though it was mostly demolition and rebuilding which was the assessed result in the other cases. This case is based on Case 2 because of the amount of information that was received for this building.

A Norwegian building was used for case 4. Here the only achieved material was the competition materials for the renovation of the building, which again limits the output from the tool. Assumptions were made which is presented further in section 5.2.4.

5.2.1 Case 1 – Building 201 DTU

Figure 30: Placement of building 201 - DTU campus

Building 201 is placed in the North West part of DTU campus. It neighbors upon the through-going road “Anker Engelundsvej” and a larger green area. Building 204 is placed opposite this green area and is included in the vision that is made for the zone. Today, laboratories and chemistry facilities are the main functions of the building and the whole is considered for research and teaching for chemistry related subjects. The area consisting of building 201, 204 and the green area between are thought into a larger process where a building will be added and larger changes will be made for the existing buildings. It is thereby decided that building 201 will be renovated and formed for office work, while laboratory facilities will be moved to the adjoining new building.

Building 201 is a typical “DTU building”. Its layout is rectangular – a “100 m building”, with yellow brick façade. This type of building is found on most areas of DTU and it is seen as the design that creates the “DTU spirit and identity”.

Execution of the tool

The execution of the tool is made together with Lisbet Michaelsen CAS, which participates in the process and project around building 201. During a meeting, the steps and various questions were discussed and answered by Lisbet. The meeting was performed in a way where Lisbet was seen as the contractor of the building and with her expertise the tool was used as an assessment for building 201.

Some of the questions couldn´t be answered by Lisbet and further knowledge could not be achieved. Some of the answers are thereby missing for this case, but an assessment is made for the building, based on the information that is received and by the use of the tool.

In some situations, one question could lead to a better scoring for the demolition scenario than first assumed. Through the comments given by Lisbet, the answers would indicate to be beneficial for the renovation scenario, though Lisbet would explain that the focus at DTU, in this regarded question would lie different than for the Danish building requirements or for the sustainability solutions. It shall thereby be understood, that although an answer from one or the other question is received, it is still the contractor that decides what the focus are in the regarded situation and thereby, what scenario that should receive a point.

Comments from the meeting can be seen in Appendix O.

Results: Stop/Go, Boundaries and Simple questions

The first step of the tool, the “Stop/Go” scheme, was filled out based on the conversation with Lisbet Michaelsen. Most of the questions could be answered, except a few regarding restrictions of the area and daylight in the building.

Questions		Answer	Consequence	
			Stop	Go
Is the economy good enough to be capable of a large renovation or to demolish and rebuild the building?		Yes		X
Is the building listed?		No		X
Is there any restriction in the area, towards actions that may be taken to the building?				
	Does the area demang a specific design?			
	Is there a limitation according to safety measurements?			
	Is there a communal restriction for renovation or new buildings?			
	Can these restrictions be worked around?			
Is there an architectural restriction that limits the possibilities for the building?		No		X
Is the architecture of the building special, well performed and worth preserving?		No		X
Is the building attacked with fungus or mold?		No		X
	Will this affect the process?			
Is there Asbestos in the building?		Yes	X	
	Will this affect the process?	No		X
Is there other hazardous materials in the building? (PCB)		Yes	X	
	Will this affect the process?	No		X
Is the existing building in risk of flooding?		No		X
	Will the building always be in risk on this site?			
	Can measures be taken to reduce the impact on the future building?			
Does the building meet the requirements from the Danish Building regulation?		No	X	
	If not: is it possible to achieve in this building?	Yes		X
Is there enough height to improve / implement installations in the building and thereby reach the energy requierement?		Yes		X
Is the daylight factor high enough for office work?				
	If not: is it possible to adjust the facade to achieve a higher DF?			
Will a renovation or rebuilding affect other buildings attached to - or around the building?		Yes	X	
	If yes: is it acceptable?			
		Result	**4**	**10**

Figure 31: The results from step 1 - Case 1. A readable size can be seen in Appendix P.

From the scheme it was first noticed, that the Stop/Go analysis resulted in the possibility to continue with the regarded case. The answers that gave "Stop" as a result, were parameters regarding hazardous materials, the performance of the building and disturbance of neighboring buildings. From the meeting with Lisbet Michaelsen, it was although understood that the amount of hazardous materials wouldn't be a problem for the renovation of the building although there was a certain amount of money put aside for this purpose. The other parameters was also not seen as definite for the project not to go on with the process, though it was assumed that the future building would achieve the requirements from the building regulations and it was expected that some disturbance would come to the neighboring buildings, which was acceptable according to Lisbet. Thereby there was no hindrance for the regarded case to move on to the next step of the tool.

The boundaries are not included in this case, though these were parameters Lisbet Michaelsen knew nothing about. Although through the meeting is was understood that the boundaries would result in the method area of this tool, as for instance the amount of money, the time limit and aspect of hazardous materials wouldn't cause any problems either for a renovation or for a demolition and rebuilding. It was thereby not limiting the project to one of the outer categories, and the case could move forward in the process.

In the next step, there were many missing answers, mostly for the vision for a renovation of the building. Many of the missing answers where handling the performance of the building, materials that would be used, economy and time perspective. The main reason for the lack of information was due to the limited vision that was achievable for the renovated case. The ideas for the new building that was being developed were much more clear and definite, which resulted in a larger amount of answers for this scenario.

	Question		Answer	Best case [x]	
				Renovation	Demolition & rebuilding
Energy	How is the energy rating performance?				
		If the building is renovated:	2010	X	
		If the building is demolished and rebuild	2015		
	Is renewable energy used for the building?				
		If the building is renovated:	No		
		If the building is demolished and rebuild	No		
		Can renewable energy technology be implemented in the building?			
	How large is the production of energy by renewable energy?				
		For the renovated building			
		For the newly constructed building			
	Will different energy sources be used for the two types of building?				
		If yes: which energy source is chosen for renovation of the building?			
		If yes: which energy source is chosen for the new building?			
		Which of the two energy sources contributes with the least emissions?			
Materials	Is environmental proved materials used?				
		For the renovated building	?		X
		For the newly constructed building	Yes		
	How much of the material?				
		For the renovated building			
		For the newly constructed building			
	Is the building materials reused?				
		For the renovated building	No		X
		For the newly constructed building	Yes		
Water	Is green roofing used to absorb rainwater?				
		For the renovated building			X
		For the newly constructed building	Yes		
		Is green roofing a possibility to implement on the building?			
	Is collected rainwater used for toilets etc.?				
		For the renovated building			X
		For the newly constructed building	Yes		
	Is water recycling used?				
		For the renovated building	No		
		For the newly constructed building	No		
	Is hot water reused for heating?				
		For the renovated building			
		For the newly constructed building			
	Can possible moist and fungus problems (if existing) be solved by				
		Renovation of the building			X
		By demolition and rebuilding of the building	Yes		
Hazardous materials	Is there sealed PCB in the building materials:				
		In the renovated building?	(no) ?		X
		In the newly constructed building?	No		
	Will there be asbestos				
		In the renovated building?	(no) ?		X
		In the newly constructed building?	No		
	Is the building sealed for Radon?				
		In the renovated building			
		In the newly constructed building			
Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?	Yes	X	
		Are other locations nearby usable without great inconvenience?	Yes	X	
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?	Yes		X
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Are other buildings nearby affected?				
		By the renovation	Yes		X
		To what extent? [1(very litte) - 5 (very much)]			
		By demolition and rebuilding	Yes	X	
		To what extent? [1(very litte) - 5 (very much)]			
Building plan & flexibility	How efficient is the building plan (work places / m2)				
		In the renovated building			X
		In the newly constructed building	Efficient		
	Is the building flexible?				
		In the renovated building	Yes	X	
		In the newly constructed building			
Indoor climate	Is the thermal comfort sufficient:				
		In the renovated building?			
		In the newly constructed building?			
	Is the DF sufficient:				
		In the renovated building?			
		In the newly constructed building?			
	Kan the facade / glass proportion be changed:				
		In the renovated building?			
		In the newly constructed building?			
	Is there a risk of glaring:				
		In the renovated building?			
		In the newly constructed building?			
		Is the used solar shading the best solution for the **renovated** building?			
		Is the used solar shading the best solution for the **new** building?			
			Result	**5**	**10**

Figure 32: The results from step 4 - Case 1. A readable size can be seen in Appendix P.

From the given answers in the simple question scheme (step 4) it can be seen that the majority of the answers inclines towards demolition and rebuilding. The parameters that weigh for a renovation were regarding disturbance of the users and neighboring buildings and the flexibility of the building. Another parameter that adds to the scoring of the renovation scenario is the energy performance of the building. This is a case, where the answered would indicate a specific output, although, based on the comments from Lisbet, the point is given to the other scenario.

Question		Answer	Best case [x]	
			Renovation	Demolition & rebuilding
How is the energy rating performance?				
	If the building is renovated:	2010	X	
	If the building is demolished and rebuild	2015		

Figure 33: Section of the "simple question scheme" where the given answer doesn't equal the assumed result.

As seen in Figure 33, the visions of the energy performance for the two scenarios are different. It would thereby be assumed that the best energy rating would be the best performing scenario. Although, as Lisbet explained, a better energy performance in this case doesn't equal lower energy consumption and thereby the point is given to the renovation scenario.

Table 12: Results from Case 1

Result	Renovation	Demolition and rebuilding
	5 p	10 p

As can be seen in Table 12, the scenario of demolish and rebuilding achieved the most points, and could, based on this tool, be assessed as the best solution for this case. It is not known, if a fully answered diagram would bring another solution. Near 10 questions was not given an assessment between renovation and demolitions, which is a large amount compared to the possible amount. Furthermore, the detailed analysis is not performed for this case which could contribute to another result.

All the schemes can be seen in Appendix P.

Conclusion: Case 1

Due to the lack of information for this case, not all questions could be answered for the schemes. Much of the missing information was because of the limited vision for a renovation of the building. It is thereby seen how important it is for this tool that some knowledge about the renovation or the new building exists in order to make a full assessment.

The best performing scenario with the most points was the demolition and rebuilding of the case. This result is interesting though the executed solution for this building is decided to be a renovation together with addition of a new building.

5.2.2 Case 2 – Building 224 DTU

Figure 34: Placement of building 224 - DTU campus

Case 2 is very similar to the first case. Building 224 is also placed in the North West end of DTU campus and is, as well as building 201, a typical DTU building long, rectangular and has a façade with yellow bricks. Building 224 is the last building in this quadrant and only neighbors up to one building. On the other side, the DTU soccer field is resident together with larger green areas.

The building is today an office building with some laboratory facilities. It is assumed that the building can be used for the case, despite the laboratory facilities, although most of the building is offices. The laboratory will thereby be disregarded in this case.

Based on the received information for this case, it was informed that it was preferred if the building could be demolished. This was although not approved. Thereby a total renovation was the intention, but also there the limitations only allow possible renovation of the façade. This also contributed with further limitations, though the DTU design and “identity” should not be removed. At the stage of the performance of the case, the future renovation was consisting of smaller updating of the interior and renovation of the façade. The renovation of the façade was although not clear how large the inception could be.

Execution of the tool

During a dialog with Lisbet Sand CAS, most of the questions for the decision supporting tool were answered. Many of the answers were although limited to where the development of the project was at the moment and to what decision that was being allowed. The whole tool was processed in this case and therefore calculations of the energy performance, daylight and indoor climate were performed in a certain extent. These are described further in the following section.

Results and discussion: Stop / Go, Boundaries and Simple questions

The answers to the schemes were filled out during the conversation with Lisbet Sand. The steps were processed in the intended way of the decision supporting tool.

Questions		Answer	Consequence: Stop	Consequence: Go
Is the economy good enough to be capable of a large renovation or to demolish and rebuild the building?		Not for demolition	X	
Is the building listed?		No		X
Is there any restriction in the area, towards actions that may be taken to the building?		No		X
	Does the area demang a specific design?			
	Is there a limitation according to safety measurements?			
	Is there a communal restriction for renovation or new buildings?			
	Can these restrictions be worked around?			
Is there an architectural restriction that limits the possibilities for the building?		Yes - partly*	(X)	X
Is the architecture of the building special, well performed and worth preserving?		Yes - partly*	(X)	X
Is the building attacked with fungus or mold?		No		X
	Will this affect the process?			
Is there Asbestos in the building?		Yes	X	
	Will this affect the process?	Unsure - but no *	(X)	X
Is there other hazardous materials in the building? (PCB)		Yes	X	
	Will this affect the process?	Unsure - but no	(X)	X
Is the existing building in risk of flooding?		No		X
	Will the building always be in risk on this site?			
	Can measures be taken to reduce the impact on the future building?			
Does the building meet the requirements from the Danish Building regulation?		Not todays req.*	X	
	If not: is it possible to achieve in this building?	Yes		X
Is there enough height to improve / implement installations in the building and thereby reach the energy requierement?		Yes*		X
Is the daylight factor high enough for office work?		Yes		X
	If not: is it possible to adjust the facade to achieve a higher DF?			
Will a renovation or rebuilding affect other buildings attached to - or around the building?		Yes - some*	(X)	X
	If yes: is it acceptable?			
		Result	**9**	**12**

Figure 35: The results from step 1 - Case 2. A readable size can be seen in Appendix S.

The first step was fully answered and the result enabled the case of moving forward with the process. The most uncertain parameters were regarding hazardous materials and if the existence of these would affect the process. Lisbet was assuming that it wouldn’t be a problem.

Lower limit		Parameter		Upper limit
<		[XX]		>
		Price		33 million
		Time		No deadline
		Building envelope changes		Only facade*
		Hazardous materials (ammount)		No ammount
		Impact on users		No limit
		Necessary functionality		

Figure 36: The results from step 2 - Case 2. Can also be seen in Appendix S.

Through the conversation with Lisbet, the boundaries scheme was filled out. Here the only limitation was the change of the façade, which was limited because of the DTU design. As there were no other limitations for this case, it was clear that the boundaries opened up for both possible scenarios of renovation or demolition and rebuilding the building.

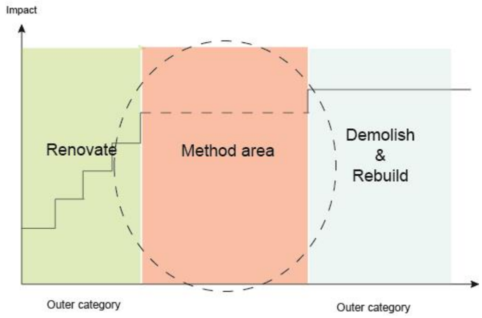


Figure 37: The method area is the defined area by the boundaries of this case. Both scenarios can be the solution and therefore the next step can be taken.

The whole method area in the limitation graph was defined (See Figure 37) in this case and thereby the next step of the tool could be processed in order to make an assessment of which scenario would be the best solution for this building.

	Question		Answer	Best case [x] Renovation	Best case [x] Demolition & rebuilding
Energy	How is the energy rating performance?				
		If the building is renovated:	<2015	(X)	X
		If the building is demolished and rebuild	2015		
	Is renewable energy used for the building?				
		If the building is renovated:	Yes*	X	X
		If the building is demolished and rebuild	Yes		
		Can renewable energy technology be implemented in the building?	Yes	X	
	How large is the production of energy by renewable energy?				
		For the renovated building			X
		For the newly constructed building	Largest		
	Will different energy sources be used for the two types of building?				
		If yes: which energy source is chosen for renovation of the building?	District h.	X	X
		If yes: which energy source is chosen for the new building?	District h.		
		Which of the two energy sources contributes with the least emissions?			
Materials	Is environmental proved materials used?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
	How much of the material?				
		For the renovated building	Equally	X	X
		For the newly constructed building			
	Is the building materials reused?				
		For the renovated building			
		For the newly constructed building			
Water	Is green roofing used to absorb rainwater?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
		Is green roofing a possibility to implement on the building?	Yes	X	
	Is collected rainwater used for toilets etc.?				
		For the renovated building	No		X
		For the newly constructed building	Yes		
	Is water recycling used?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
	Is hot water reused for heating?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
	Can possible moist and fungus problems (if existing) be solved by				
		Renovation of the building			
		By demolition and rebuilding of the building			
Hazardous materials	Is there sealed PCB in the building materials:				
		In the renovated building?	No - small ammount*	(X)	X
		In the newly constructed building?	No		
	Will there be asbestos				
		In the renovated building?	No	X	X
		In the newly constructed building?	No		
	Is the building sealed for Radon?				
		In the renovated building	?*		X
		In the newly constructed building	Yes		
Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?	No		X
		Are other locations nearby usable without great inconvenience?	Yes	X	
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?	Yes		X
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Are other buildings nearby affected?				
		By the renovation	Yes		X
		To what extent? [1(very litte) - 5 (very much)]			
		By demolition and rebuilding	Yes	X	
		To what extent? [1(very litte) - 5 (very much)]			
Building plan & flexibility	How efficient is the building plan (work places / m2)				
		In the renovated building	Lower		X
		In the newly constructed building	Higher		
	Is the building flexible?				
		In the renovated building	Yes	X	X
		In the newly constructed building	Yes		
Indoor climate	Is the thermal comfort sufficient:				
		In the renovated building?	Yes	X	X
		In the newly constructed building?	Yes		
	Is the DF sufficient:				
		In the renovated building?	Yes	X	X
		In the newly constructed building?	Yes		
	Can the facade / glass proportion be changed:				
		In the renovated building?	Maybe*	(X)	X
		In the newly constructed building?	Yes		
	Is there a risk of glaring:				
		In the renovated building?	No*	X	
		In the newly constructed building?	No*		
		Is the used solar shading the best solution for the **renovated** building?			
		Is the used solar shading the best solution for the **new** building?			
			Result	**16 (19)**	**21**

Figure 38: The results from step 4 - Case 2. A readable size can be found in Appendix S.

The simple question scheme was then executed and the answers were analyzed. Points were given to the parameters and a final scoring was achieved for this step. There were uncertainties in some of the questions, which are shown in the results by “(X)”.

Table 13: Results from Case 2 – Simple questions

Result	Renovation	Demolition and rebuilding
	16 (19) P	21 P

The results can be seen in Table 13. Here there are two scores for the renovation scenario. One with the uncertainties excluded – 16 p, and one with all points included (19 p). As can be seen, the assessment of this case is demolition and rebuilding, although with a very small margin. If the uncertainties were removed, the results of the assessment still leans towards the possibility of demolish and rebuild as for the previous case. If the uncertain questions are valid and included in the scoring, the two scenarios, renovation or demolition and rebuilding, almost receives equally many points. It can thereby be assumed, based on the scoring from this step of the tool, that both solutions are a possibility and that the contractor can make a decision towards the one or the other.

For this case, the next step was also performed. Here some of the more detailed analyzes was performed, which could contribute to the assessment of the building. See the following section.

Detailed calculations – **Renovated building**

The detailed calculations for this case are performed for the renovated scenario – though most information is achieved for the vision of the renovated building. All programs are therefore modeled according to this, which for most parameters equals to the state of existing building as it is today.

It is assumed that the demolished and new developed building will achieve and be built according to the newest requirements, the building regulations 2015 or 2020 and indoor environment class 1. These will therefore not be simulated in the used programs, as there are no achieved layouts of the possible new building. This will be commented in a following section.

The calculated results for the renovated scenario are compared to the requirements from the Danish building regulation and standards. These are assessed as the minimum requirements for both scenarios.

Requirements to achieve:

- Energy consumption 2015: 41 kWh/m^2 per Year / 2020: 25 kWh/m^2 per Year [DBR, 2013]
- Indoor environment: CO_2 max 900 ppm (2015) or 700 ppm (2020) [DBR, 2013]
- Maximum 5 % of the user time with a temperature over 26 degrees [DS, 2007]
- Daylight factor: 3 % in the middle of the room [DBR, 2013]
- Illuminance: 500 lux - single offices, 100 lux – corridors [DS, 2007]

The detailed calculations are performed by using IdBuild, BSim, Be10, DaySim and Velux visualizer. These are chosen in order to simulate the performance of the indoor environment (IdBuild and BSim), the energy consumption (Be10) and the daylight level in the building (DaySim and Velux Visualizer).

In order to perform the needed calculations, some simplifications and assumptions are made:

- The building is calculated as an office building, though there will exist some laboratory areas.
- Simplification of the model – less details
- Simulation of single offices only (IdBuild and BSim)
- U – values equal to the present building (see Table 14 below) based on information from building 118 – DTU.

Table 14: U –values for building 118 [Bossow, Jensen; 2005]

Building element	U-value [W/m^{2}K]
Floor element	2,008
Façade	1,222
Roof	0,452
Foundation	0,45

IdBuild

IdBuild is used in order to analyze the indoor climate of the building. The simulated model is a single person office as this is defined as the most frequent room in building 224. As a traditional DTU building, the room has one window divided into multiple sections with a part that opens. In this model the window is created as one large, due to limitations of the program. The ventilation of the room is through natural ventilation, though according to the questions answered by Lisbet, the renovation will not include installation of mechanical ventilation. The office is turned towards south as most of the single offices in building 224 have this orientation. By information from Lisbet, the existing solar shading is very functional and it is assumed that these will be used for the renovated building also. The model has therefore defined blinds, which are adjusted according to the amount of sun and the time of day. The heating is district heating.

Results - IdBuild

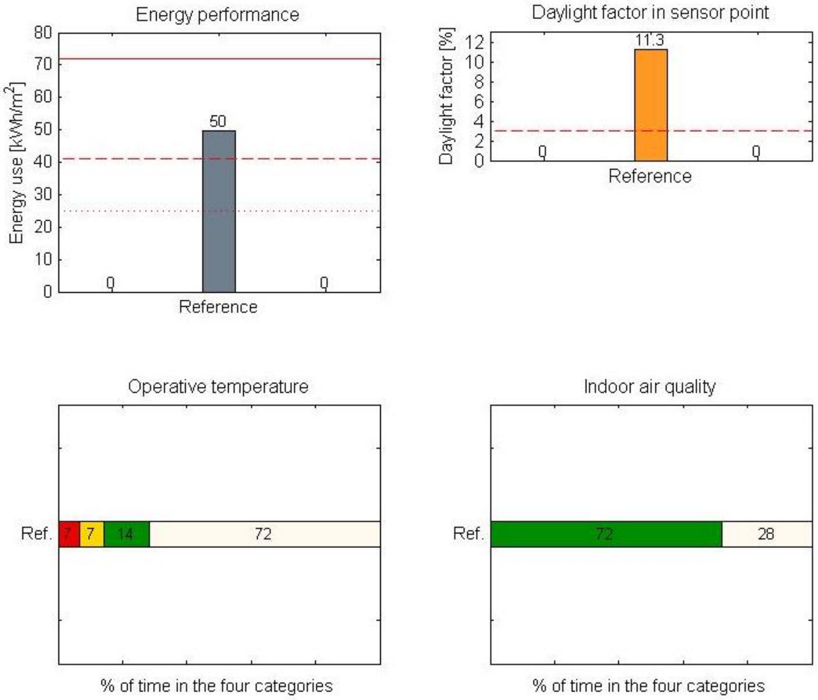


Figure 39: Results from IdBuild

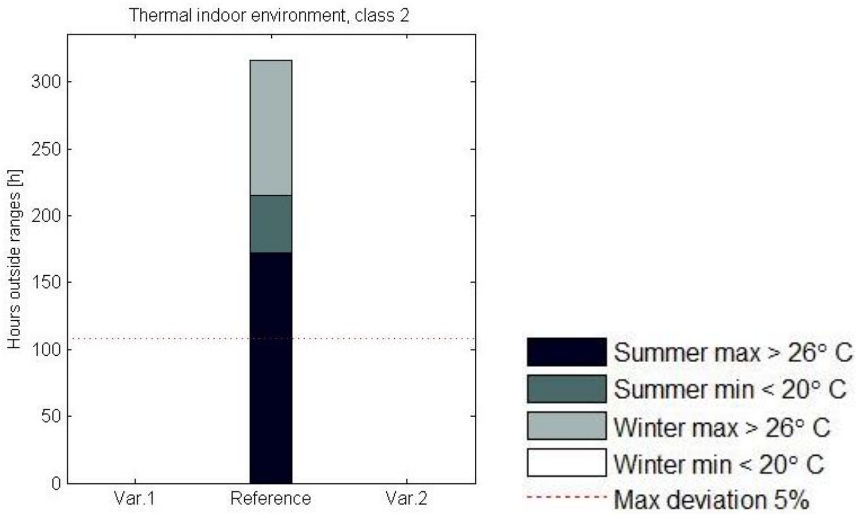


Figure 40: The thermal indoor results for time of use for building 224

As can be seen from Figure 39 the office doesn’t achieve the requirements listed earlier. The energy use is higher than the 2015 building regulation demand and the operative temperature doesn’t achieve class 2 of the indoor climate classifications [DS, 2007]. As can be seen in Figure 40, the summer period has a lot of hours above 26 degrees and thereby overheating is a problem in the room. The daylight factor is although much higher than the needed 3 %. This could implement to a possible problem with glaring in the room. The indoor air quality of the office is satisfying according to the indoor class 2, which shows that the natural ventilation works. It can although not be seen if draft is a problem in the room.

BSim

In BSim analyzes of the indoor climate for a single person office is simulated too. This room is chosen based on the same assumptions as for the IdBuild simulation, though it is the most frequent room in the building. This simulation should be used as an addition to the IdBuild simulation.

The model is created equally to the IdBuild model with the same parameters (where possible). In some situations other values were necessary to be used for this model. This was mostly regarding the U-values though the program was limited to a specific material list. It is assumed that this room and the performed simulations are representative for the building and that other rooms would perform equally to the chosen single office.

Results- BSim

Hours > 21	93,7 %	93,7 %
Hours > 26	39,6 %	39,6 %
Hours > 27	34,0 %	34,0 %
Hours < 20	0,0 %	0,0 %

Figure 41: BSim results – percentage above, when the building is in use

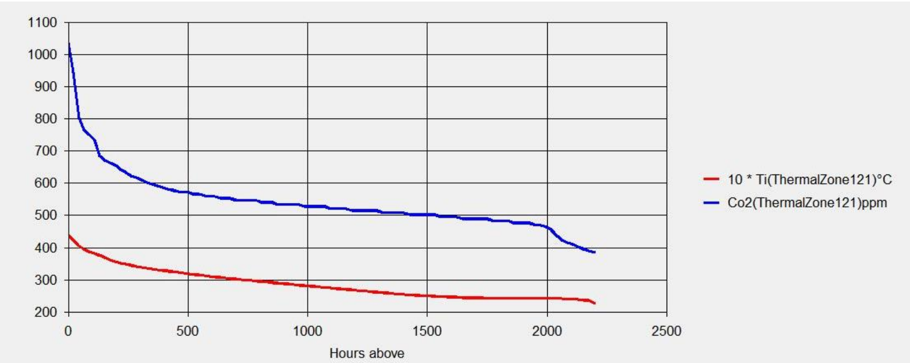


Figure 42: BSim results – CO_2 level and Temperature – hours above

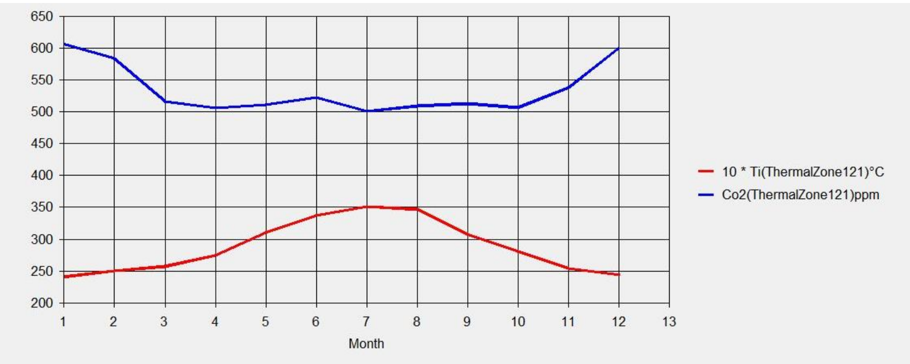


Figure 43: BSim results – Distribution of temperature and CO2 level during a year.

As can be seen from the figures above, the temperatures in the room exceeds 26 degrees almost 40 % of the occupation time and 27 degrees for 34 % of the time (see Figure 41). This is a lot of hours and overheating is assumed to be a large problem in the building. By this it can be seen that the maximum deviation of 5 % according to the Danish standard 15251 is not achieved.

From Figure 42 it can be seen that only a short period of time has a CO_2 level above 900 ppm. In Figure 43 it can be seen that the CO_2 level is highest in the winter season. This is assumed caused by the natural ventilation and that windows aren't opened as much during the winter-time. Also, the temperature is naturally higher during the summer, although it exceeds to 35 degrees, which is too much for an office and again it is visualized that overheating is a large problem for this scenario. The reports from the simulation can be seen in Appendix Q.

Be10

The Be10 calculation is made for the whole building in order to analyze the energy performance of the renovated building. The building is divided into sections in order to make adjustments and controls fit to the specific purpose of the room. The sections are:

- Offices
- Kitchen, auditorium etc.
- Meeting rooms
- Hallway
- Residual

By the obtained drawings of the entire building, areas and dimensions are defined. See Table 15, Table 16 and Table 17.

Table 15: Area of the facades

Orientation etc.	Dimensions	Area façade
	[m]	[m^2]
North	58.11 x 10.55	613.35
South	58.11 x 10.55	613.35
East	15.83 x 10.55	167.1
West	15.83 x 10.55	167.1
Roof		919.0
Foundation	148	

Table 16: Area of windows in the facade

Orientation	Amount of windows	Area – one window	Total area windows
	-	[m^2]	[m^2]
North	124	2.1 m x 2.1 m = 4.41	546.84
South	112	4.41	493.92
East	0	4.41	0
West	0	4.41	0

Table 17: Area of facades - window area excluded

Orientation	Area façade - total	Area windows	Area façade
	$[m^2]$	$[m^2]$	$[m^2]$
North	613.35	546.84	67
South	613.35	493.92	120
East	167.1	0	167.1
West	167.1	0	176.1

The areas are inserted in the program together with the needed information for U-values, ventilations system and energy performance of the building. These parameters are taken from the IdBuild and BSim simulations. For more information about the inputs and the simulation reports see Appendix R.

Results – Be10

Figure 44: Results from Be10 – the key numbers

From Figure 44 it can be seen, as from the IdBuild and BSim calculation, that none of the requirements from the building regulation 2015 or 2020 is achieved. The building has a high energy consumption, which results in not achieving the 2010 regulation either.

Nøgletal, kWh/m² år

Energiramme BR 2010

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
71,9	0,0	71,9
Samlet energibehov		127,3

Energiramme Lavenergibyggeri 2015

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
41,4	0,0	41,4
Samlet energibehov		97,1

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
25,0	0,0	25,0
Samlet energibehov		76,8

Bidrag til energibehovet	
Varme	150,9
El til bygningsdrift	7,2
Overtemp. i rum	11,6

Netto behov	
Rumopvarmning	142,1
Varmt brugsvand	8,7
Køling	0,0

Udvalgte elbehov	
Belysning	6,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,5
Varmepumpe	0,0
Ventilatorer	0,0
Pumper	1,2
Køling	0,0
Totalt elforbrug	21,3

Varmetab fra installationer	
Rumopvarmning	0,0
Varmt brugsvand	3,5

Ydelse fra særlige kilder	
Solvarme	0,0
Varmepumpe	0,0
Solceller	21,3
Vindmøller	0,0

Figure 45: Results from Be10 with solar panels– the key numbers

Neither by adding solar panels to the building, the requirements can be achieved. The key numbers from Be10 also shows the problem with overheating in the building (see Figure 44 and Figure 45).

Velux Visualizer

Velux Visualizer is used in order to simulate the daylight performance of the building and to assess if glaring is a possible problem. The whole building is simulated in this program.

The model is created in SketchUp, based on the obtained drawings of the regarded building. These drawings have been simplified in order to import the model to Velux Visualizer. For the renovated building it is stated by Lisbet Sand, that no real change would be made to the interior, although new doors with glass middle would be implemented to the corridor. To simulate these, the doors between corridor and offices have been removed. By this, it can be evaluated how far the daylight can enter the building. Standard materials are defined for the building parts in Velux Visualizer in order to implement reflectances that are suited for the building elements. Solar shading has not been implemented in this model, though the possible length of the penetration of the sunlight is wanted to be analyzed.

Results – Velux Visualizer

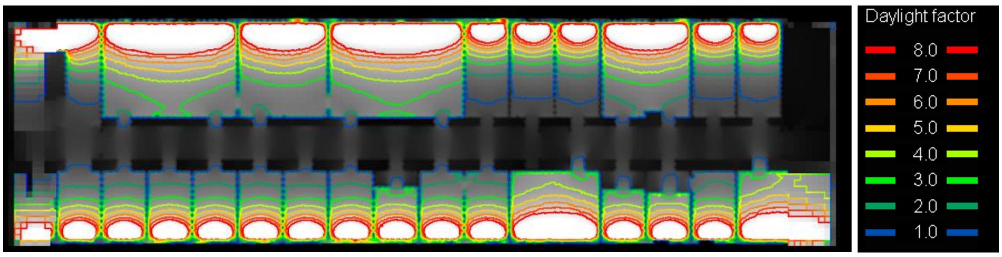


Figure 46: Velux visualizer – DF [%]

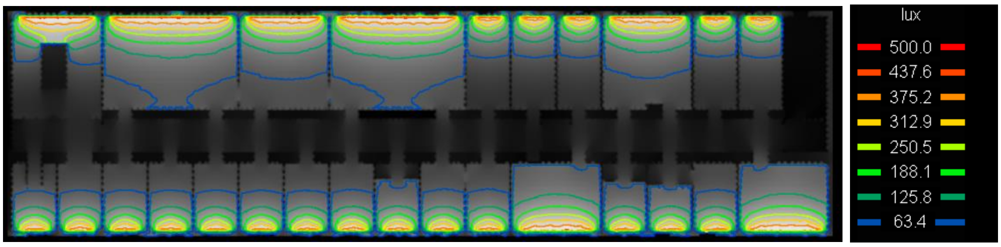


Figure 47: Illuminance [Lux]: January - 12.00

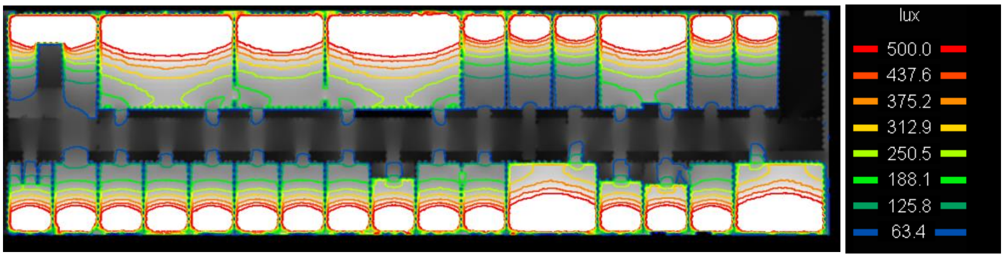


Figure 48: Illuminance [Lux]: June - 12.00

As can be seen in Figure 46, the daylight factor is satisfying in the offices. The daylight factor reaches 3 % in the middle of the office and in some cases (the larger rooms with more windows) a little deeper. The best area for office work is although by the windows as the daylight factor is almost non-existing in the back of the room, in some offices. It can also be seen that despite a glass door to the corridor, the daylight doesn't´ enter this deep and doesn't give the required daylight in this area. It can be seen that some daylight does enter the corridor around the door openings, although artificial lighting is necessary as an addition to achieve the required level of light.

By looking at the illuminance levels from the simulations (Figure 47 and Figure 48) it can be seen that there is a risk of glaring at the window area. This is partly because of the missing solar shading, which would reduce the risk a lot. It can although be analyzed where the largest risk for glaring is and that solar shading is a necessity for this building. The biggest risk for glaring is in the larger rooms near the window area. The largest risk for glaring is also in the summer period where the illuminance is a lot lower during the winter season.

DaySim

DaySim simulations are made in order to achieve a more precise and detailed daylight analysis of the building. Here many different categories can be analyzed and artificial lighting and shadings are included in the model.

The model, imported in DaySim, is simplified to a much narrower area of the building in order to perform the needed simulations. Only a few offices are included in the model, though the same results will be achieved for the other rooms because of the simplicity and repeated design of the building. The model is therefore a larger and some smaller rooms, which are placed towards the south and north with a corridor in between (aka a smaller section of one of the levels). The model is created based on the achieved AutoCAD drawings for the building. No shadings are included in the model, though it can be stated as a parameter for the windows in DaySim. A mesh is created for the model also. This is chosen to be created only in the offices, though this is the interesting area to analyze. From the Velux Visulizer simulation it was seen that very little daylight could penetrate to the corridors. Therefore it is assumed that artificial light is needed here and that the correct lighting will be used in order to achieve the minimum illuminance of 100 lux for a corridor.

Results - DaySim

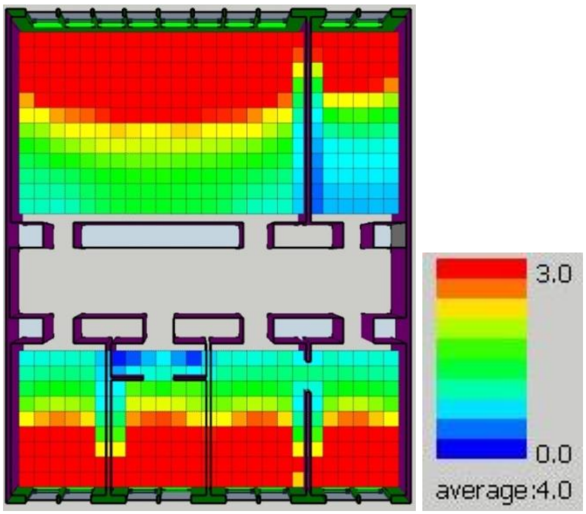


Figure 49: Daylight factor [%] – DaySim

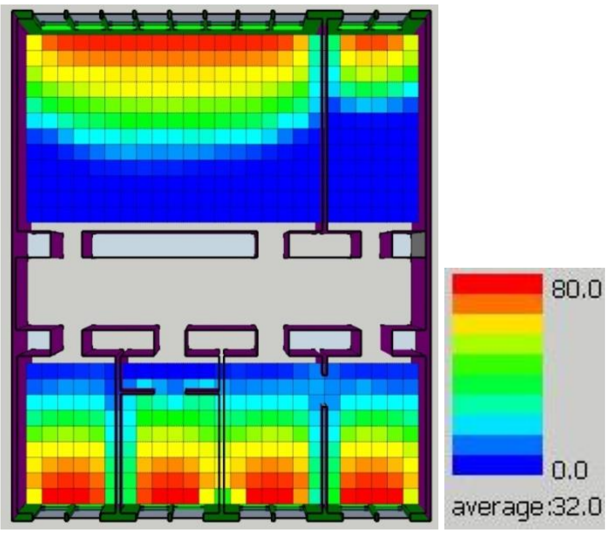


Figure 50: Damax [%]– DaySim

As can be seen in Figure 49, the daylight factor is minimum 3 % from the windows and to the middle of the offices. In the back of the room, the daylight level will although not be sufficient for office work and it is therefore assumed that a desk or working area will be placed near the windows, as stated in the Velux Visualizer simulations. From this simulation, the difficulty of achivieng daylight into the corridor can be seen. Almost no daylight are achieved in the back of the room and if the corridor was inlcuded in the simulation, it is assumed that it will only be lit by artiifical lighting.

By evaluating Figure 50 (Damax) the risk of glaring can be seen. Here the percentage of time when the minimum illuminance is achieved during a day is shown. As seen in the figure, 80 % of the time the minimum illuminance of 500 is achieved nearest the windows but in the back of the room, this is not achieved at all during the day. It can thereby be assumed that artificial lighting will be needed, at least in the back of the room and that there will be a risk of glaring in the area nearest the room. It can also be seen, that the risk of glaring is larger in the rooms oriented to the south. Here the need of solar shading would be larger. Though the shading solution is reducing the risk og glaring remarkably, the working area should be chosen carefully.

Step 5: Detailed calculations – **Demolished and rebuild building**

If similar knowledge was available for the new building after demolition, the simulations and calculations could be performed in the same way as for the previous renovation scenario. Though geometry of the room, window definition, building elements etc., has a large impact on the simulations and their results, the vision for the new building should be of a certain extent in order to make the simulations. Preliminary visions and ideas are although enough, as shown above for the renovation, to perform the needed analysis.

As stated before, it is assumed when demolishing and rebuilding a building, it will be designed to achieve the minimum requirements or more. By this, indoor class 2 or more and requirements according to the Danish building regulation 2015 (or 2020) will be reached and the building will be constructed to fit the users and their comfort. The final results and comparing of the two scenarios will therefore be based on these assumptions.

Results and discussion: Case 2 – detailed calculations

Energy	How high is the primary energy demand:				
		For the renovated building?	150,4 kWh /m2 year		X
		For the newly constructed building	41,4 kWh /m2 year		
	How good is the energy rating:				
		For the renovated building?	< 2010		X
		For the newly constructed building	2015 / 2020		
	Is renewable energy used for the cases?				
		For the renovated building?	Yes	X	X
		For the newly constructed building	Yes		
		If not, can renewable energy be incorporated in the building?			
	How much of the energy use is covered by renewable energy?				
		For the renovated building?	21,3 kWh/m2 year		X
		For the newly constructed building			

Indoor climate	How is the thermal comfort				
		In the renovated building	Class 3		X
		In the newly constructed building	Class 1		
	How high is the DF				
		In the renovated building	> 3 %	X	
		In the newly constructed building	3%		
	Which building has the largest risk of glaring?				
		The renovated building	Some risk		X
		The newly constructed building	Assumed no risk		
			Result	**2**	**6**

Figure 51: The results from step 5 - Case 2

The results from the performed simulations and calculations from the above presented programs are listed in the schemes belonging to the detailed calculations of the tool. As only a small part of the detailed calculations are performed in this case, only the regarded results are presented (see Figure 51). The whole scheme can be seen in Appendix S.

From the results it can be seen that the most points are achieved for the demolition scenario. A lower energy demand is reached and better indoor climate as well. A daylight factor of minimum 3 % is achieved by both scenarios, although glaring can be a problem for the renovated scenario. It is although not known how glaring will be avoided in the new building, but it is assumed that it will be regulated to a satisfying level.

It was tested if solar panels could contribute for the renovated building to achieve the requirements according to the 2015 regulations. This was although not possible and also here the scenario of demolishing and rebuilding the building is achieving a higher score.

Table 18: The results from the decision supporting tool – Case 2: Building 224 DTU

	Best case [x]	
	Renovation	Demolition & rebuilding
Result - simple	**18 (21) p**	**21p**
Result - detailed	**2 p**	**6 p**
Result - total	**20 (23) p**	**27 p**

The final scoring for the two scenarios can be seen in Table 18 above. Here the largest scoring is achieved for the demolition and rebuilding scenario. The two scenarios have a difference of 7 (or 4) points if the detailed calculations above are included. It is not known if the parameters not calculated in the detailed step would influence the final assessment, though a higher score would be achieved by both scenarios.

In this case there have been some uncertainties in the answers, which are defined with "(X) p". By including or excluding these points, the same result is still achieved, with the assessment weighting towards demolition.

All schemes from Case 2 can be seen in Appendix S

Conclusion: Case 2: Building 224 DTU

From the results of the simple questions and the detailed calculations of this case, it can be seen that the scenario of demolition and rebuilding has a higher score than the renovation scenario. It is although not a large difference and it can be discussed if it is enough to define one scenario above the other.

The difference in the scoring is although smaller if the uncertainties of the simple questions (X) are included in the results. The uncertainties in this case are founded on parameters that are not decided yet or lack of information. Although, these points would still not be enough for the cased to be assessed as a clear renovation project and it is unsure if the "missing" questions would bring any scoring to this side of the possible solution.

If a larger amount of the detailed calculations was made and a contact to specialists was created, the last step of the tool (the detailed calculations – step 5) could give further points towards the one or the other side of the possible solution. Although at this stage, both renovation and demolition is a possibility, with a small weighting towards demolition.

As it can be seen, satisfying results can be achieved both for the renovated and the new building for the detailed analyses by following the procedure of the tool. For this case, it was although not possible to achieve the minimum requirements for the renovated scenario. It is not known what measures should be taken in order to achieve the requirements, but based on the information by Lisbet Sand, DTU have chosen almost not to perform any renovation to the building envelope, which if improved could contribute to a much better analysis of the renovation scenario. A better insulation of the facades and better windows etc., could contribute a lot to a better evaluation of the renovated scenario.

For the new building it is assumed that the 2020 regulations will be the ultimate wanted solution. Based on the possibilities for renovation and the restrictions for the building, it is although not seen possible to achieve a 2020 regulation for this scenario. If this is wanted, demolition and rebuilding is the only solution.

Because of the large extent of the given answers for the first steps of the tool, there were not as many blank areas in the performance of the tool as for the previous case. It is therefore assumed that the assessment is well performed and that the result can be used as background knowledge for the assessment whether the building should be renovated or demolished and rebuilt.

By the results achieved from the decision supporting tool 20 (or 23) points are achieved for the renovation scenario and 27 for the demolition and rebuilding. Based on the tool, it can thereby be assessed that a demolition and rebuilding would be the best solution. The difference in the scoring is although not very large and either scenario could be chosen. The final decision should be made by the contractor with the assessment created by the tool (and the achieved scoring presented above) as a background analysis.

5.2.3 Case 3 – a fictitious building (inclining towards renovation)

The previous cases incline towards demolition and rebuilding. In order to evaluate, if the tool at all would incline towards renovation in any cases and how much is needed for this, a fictitious case was made. This case was based on the previous Case 2 – Building 224, though the amount of answers that was given was seen as useful for a fictitious case. The answers from Case 2 were therefore changed, in a way that seemed trustworthy and possible in order to achieve a larger scoring for the renovation as a solution.

Execution of the tool

It was seen important that the changing of parameters that would incline the case towards renovation was realistic and that it was parameters, which in a real situation could give this outcome. A lot of thought has therefore been given to which parameters should be the resulting ones. Many of the assumptions were achieved through the meeting in the previous cases.

Only a few parameters were changed such as materials, the construction site and the effect on building users or others, flexibility and glaring.

The reasons for these to be the changed parameters are because it is assumed that more materials can be reused in a renovation scenario depending on the level of renovation. It is further assumed that reusing from a demolishing scenario will demand more sorting and a larger effort in order to be able to reuse the material. A large benefit for the renovation scenario is the possibility of use the building while renovating. In many cases the building is renovated through several steps and thereby work can be allowed in other parts of the building, which limits the impact on the building users. Also, the disturbance towards nearby buildings is limited for a renovation project.

The analyses and procedure is explained in the following section.

Results: Case 3

	Question		Answer	Best case [x] Renovation	Demolition & rebuilding
Energy	How is the energy rating performance?				
		If the building is renovated:	<2015	½	X
		If the building is demolished and rebuild	2015		
	Is renewable energy used for the building?				
		If the building is renovated:	Yes*	X	X
		If the building is demolished and rebuild	Yes		
		Can renewable energy technology be implemented in the building?	Yes	X	
	How large is the production of energy by renewable energy?				
		For the renovated building			X
		For the newly constructed building	Largest		
	Will different energy sources be used for the two types of building?				
		If yes: which energy source is chosen for renovation of the building?	District h.	X	X
		If yes: which energy source is chosen for the new building?	District h.		
		Which of the two energy sources contributes with the least emissions?			
Materials	Is environmental proved materials used?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
	How much of the material?				
		For the renovated building	Most*	X	
		For the newly constructed building			
	Is the building materials reused?				
		For the renovated building	Most*	X	
		For the newly constructed building			
Water	Is green roofing used to absorb rainwater?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
		Is green roofing a possibility to implement on the building?	yes	X	
	Is collected rainwater used for toilets etc.?				
		For the renovated building	No		X
		For the newly constructed building	Yes		
	Is water recycling used?				
		For the renovated building	Yes	X	X
		For the newly constructed building	Yes		
	Is hot water reused for heating?				
		For the renovated building	yes	X	X
		For the newly constructed building	yes		
	Can possible moist and fungus problems (if existing) be solved by				
		Renovation of the building			
		By demolition and rebuilding of the building			
Hazardous materials	Is there sealed PCB in the building materials:				
		In the renovated building?	No - small ammount*	X	X
		In the newly constructed building?	No		
	Will there be asbestos				
		In the renovated building?	No	X	X
		In the newly constructed building?	No		
	Is the building sealed for Radon?				
		In the renovated building	Yes	X	X
		In the newly constructed building	Yes		
Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?	Yes	X	
		Are other locations nearby usable without great inconvenience?	Yes	X	
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?	Yes		X
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]			
	Are other buildings nearby affected?				
		By the renovation	No	X	
		To what extent? [1(very litte) - 5 (very much)]			
		By demolition and rebuilding	Yes	X	
		To what extent? [1(very litte) - 5 (very much)]	5	X	
Building plan & flexibility	How efficient is the building plan (work places / m2)				
		In the renovated building	Lower		X
		In the newly constructed building	Higher		
	Is the building flexible?				
		In the renovated building	Yes	X	
		In the newly constructed building	No		
Indoor climate	Is the thermal comfort sufficient:				
		In the renovated building?	Yes	X	X
		In the newly constructed building?	Yes		
	Is the DF sufficient:				
		In the renovated building?	Yes	X	X
		In the newly constructed building?	Yes		
	Can the facade / glass proportion be changed:				
		In the renovated building?	Maybe*	X	X
		In the newly constructed building?	Yes		
	Is there a risk of glaring:				
		In the renovated building?	No	X	
		In the newly constructed building?	Yes		
		Is the used solar shading the best solution for the **renovated** building?			
		Is the used solar shading the best solution for the **new** building?			
			Result	**24**	**17**

Figure 52: The results from step 4 - Case 3. A readable size can be seen in Appendix T.

It is only the simple questions that are used in this case, though the Stop/Go scheme and the boundaries are assumed and necessary to let the tool be further used in order to make this analysis.

The changed parameters are marked with a red color. It can be seen that only 9 questions are changed, or added in some cases.

Table 19: Results for the fictitious case, by changing a few parameters

Result	Renovation	Demolition and rebuilding
	24 p	17 p

It is seen by changing a few parameters that the score for this case is 24 p for a renovation and 17 p for demolition and rebuilding. It is here by noticed that the scoring can become beneficial for the renovation scenario and furthermore, that the difference in the amount of points can be much larger than seen in the other cases.

The scheme with the changed parameters and the result can be seen in Appendix T.

Conclusion: Case 3

It is hereby seen, that small changes in the parameters for the simple questions, equals the benefit of a renovation project. It is hereby also evaluated that it is possible for the result to incline towards the benefit of a renovation and not always towards demolition and rebuilding. This is although only one possibility and a fictitious case. Other cases can assess the questions different in favor of renovation. As mentioned earlier, the final decision shall although be taken by the contractor.

5.2.4 Case 4 – Oslo Building

This case is based on "the Nordic Built challenge – competition for a more sustainable built environment" [Nordic Innovation, 2012]. The case is based on the competition proposition by COWI and is for an office building in Oslo, Norway. The existing building, which is the base for the competition, is built in 1975 but was given a large renovation in 2001. The building was though not according to today's standards for environmental sustainability and functionality and a new renovation is thereby wanted for the building [Nordic Innovation, 2012]. COWIs suggestion for the building is "the Urban Mountain" – a renovation that provides green areas, material reuse and environmental strategies that is sustainable to the building.

Execution of the tool

The case is executed by the use of the competition material, obtained on the Nordic innovation website [COWI, 2012]. Here most of the questions are answered, although this is only for the renovated scenario. For some parameters in the tool, assessments and assumptions were necessary and in several cases no answer was possible to achieve, due to the limited information.

Results Stop/Go, Boundaries and Simple questions

Questions		Answer	Consequence Stop	Consequence Go
Is the economy good enough to be capable of a large renovation or to demolish and rebuild the building?		Yes		X
Is the building listed?		No		X
Is there any restriction in the area, towards actions that may be taken to the building?		No		X
	Does the area demang a specific design?	No		X
	Is there a limitation according to safety measurements?	No		X
	Is there a communal restriction for renovation or new buildings?	No		X
	Can these restrictions be worked around?			
Is there an architectural restriction that limits the possibilities for the building?		No		X
Is the architecture of the building special, well performed and worth preserving?		No		X
Is the building attacked with fungus or mold?		(no)?		X
	Will this affect the process?			
Is there Asbestos in the building?		(no)?		X
	Will this affect the process?			
Is there other hazardous materials in the building? (PCB)		(no)?		X
	Will this affect the process?			
Is the existing building in risk of flooding?		No		X
	Will the building always be in risk on this site?			
	Can measures be taken to reduce the impact on the future building?			
Does the building meet the requirements from the Danish Building regulation?		(yes)?		X
	If not: is it possible to achieve in this building?	Yes		X
Is there enough height to improve / implement installations in the building and thereby reach the energy requierement?		Yes		X
Is the daylight factor high enough for office work?		Yes		X
	If not: is it possible to adjust the facade to achieve a higher DF?			
Will a renovation or rebuilding affect other buildings attached to - or around the building?		Yes		
	If yes: is it acceptable?	Yes	X	X
		Result	**1**	**17**

Figure 53: The results from step 1 - Case 4. A readable size can be seen in Appendix U.

From the achieved material the Stop/Go scheme was evaluated. Here, only one of the parameters resulted in "Stop". This parameter was regarding other buildings around and the affect the renovation or rebuilding would have on them. As the building is placed in central Oslo, it is assumed that the surrounding buildings will be affected in some way or another. Although, as the renovation is ordered, it is assumed that the impact will be tolerated.

Lower limit		Parameter		Upper limit
<		[XX]		>
		Price		"no limit"
		Time		
		Building envelope changes		
		Hazardous materials (ammount)		
		Impact on users		3-4 levels at a time
		Necessary functionality		Almost same function

Figure 54: The results from step 2 - Case 4. Can also be seen in Appendix U.

Some of the parameters for the boundaries could not be answered. Although it was found that there are no great limitations for the building and that the renovation will be processed for 3-4 levels of the building at the time. This will reduce the working area of the building for a renovation, although it would not be impossible. As the material for this competition only is regarding a renovation, the tool will be further processed, to evaluate if a renovation is assessed to be the best solution for this building.

	Question		Answer	Best case [x] Renovation	Best case [x] Demolition & rebuilding
Energy	How is the energy rating performance?				
		If the building is renovated:	same	X	X
		If the building is demolished and rebuild	same		
	Is renewable energy used for the building?				
		If the building is renovated:	Yes	X	X
		If the building is demolished and rebuild	Yes		
		Can renewable energy technology be implemented in the building?	Yes	X	
	How large is the production of energy by renewable energy?				
		For the renovated building	same	X	X
		For the newly constructed building	same		
	Will different energy sources be used for the two types of building?				
		If yes: which energy source is chosen for renovation of the building?	district heating		
		If yes: which energy source is chosen for the new building?			
		Which of the two energy sources contributes with the least emissions?			
Materials	Is environmental proved materials used?				
		For the renovated building	Yes	(X)	
		For the newly constructed building			
	How much of the material?				
		For the renovated building			
		For the newly constructed building			
	Is the building materials reused?				
		For the renovated building	Yes	(X)	
		For the newly constructed building			
Water	Is green roofing used to absorb rainwater?				
		For the renovated building	Yes	(X)	(X)
		For the newly constructed building	(Yes)?		
		Is green roofing a possibility to implement on the building?			
	Is collected rainwater used for toilets etc.?				
		For the renovated building	Yes	(X)	(X)
		For the newly constructed building	(Yes)?		
	Is water recycling used?				
		For the renovated building	Yes	(X)	(X)
		For the newly constructed building	(Yes)?		
	Is hot water reused for heating?				
		For the renovated building	Yes	(X)	(X)
		For the newly constructed building	(Yes)?		
	Can possible moist and fungus problems (if existing) be solved by				
		Renovation of the building	Yes	X	X
		By demolition and rebuilding of the building	Yes		
Hazardous materials	Is there sealed PCB in the building materials:				
		In the renovated building?	(No)?	(X)	X
		In the newly constructed building?	No		
	Will there be asbestos				
		In the renovated building?	(No)?	(X)	X
		In the newly constructed building?	No		
	Is the building sealed for Radon?				
		In the renovated building			
		In the newly constructed building			
Construction site	Will the **renovation** affect the users?				
		Can the building be used during renovation?	Yes	X	
		Are other locations nearby usable without great inconvenience?	?		
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]	2	X	
	Will a **demolition** and rebuilding affect the users?				
		Are other locations nearby usable without great inconvenience?	?		
		How much inconveinience will this cause for the users [1 (non) - 5 (a lot)]	5	X	
	Are other buildings nearby affected?				
		By the renovation	Yes		X
		To what extent? [1(very litte) - 5 (very much)]	3	X	X
		By demolition and rebuilding	Yes	X	
		To what extent? [1(very litte) - 5 (very much)]	5	X	
Building plan & flexibility	How efficient is the building plan (work places / m2)				
		In the renovated building	Verry	X	
		In the newly constructed building			
	Is the building flexible?				
		In the renovated building	Yes	X	(X)
		In the newly constructed building	(Yes)?		
Indoor climate	Is the thermal comfort sufficient:				
		In the renovated building?	Yes	X	X
		In the newly constructed building?	Yes		
	Is the DF sufficient:				
		In the renovated building?	Yes		
		In the newly constructed building?	Yes		
	Kan the facade / glass proportion be changed:				
		In the renovated building?	Yes		
		In the newly constructed building?	?		
	Is there a risk of glaring:				
		In the renovated building?	No		
		In the newly constructed building?	(No)?		
		Is the used solar shading the best solution for the **renovated** building?			
		Is the used solar shading the best solution for the **new** building?			
			Result	**22**	**14**

Figure 55: The results from step 4 - Case 4. A readable size can be seen in Appendix U.

Also for the simple questions – step 4, the competition material was used to fill in the scheme of the tool. It is seen, that some questions couldn't be answered, but the majority of the parameters were evaluated.

Table 20: Results from Case 4 - Building in Oslo

Result	Renovation	Demolition and rebuilding
	22 p	14 p

In this case the result was in favor of renovation of the building, as can be seen in Table 20. Not much information was possible to obtain if the building should be demolished and rebuild. Most answers were regarding the renovation scenario. For some parameters, both renovation and demolition was assessed as a possibility. The majority of points in this case are although for the renovation scenario.

All the schemes from Case 4 can be seen in Appendix U.

Conclusion: Case 4

Based on the results, it is asses that renovation would be the preferred solution for this building. As this also is the real solution for the building, the two assessments can be assumed as good matches. Although, if more information were possible to achieve it is not known if more points would be given to the demolition scenario. In this case the material only handled the renovation scenario, which immediate could incline that most of the points would be achieved by the renovation scenario. Furthermore the building is situated in central Oslo, near the train station and is an important landmark for the city. Based on this, renovation would possibly also be the most preferred solution.

6 DISCUSSION

Reflection on the performed cases and the use of the tool:

The four cases resulted in two, with the assessment inclining towards renovation and two, towards demolition and rebuilding. In Case 1, the tool resulted in demolition and rebuilding as the best solution for the building, although a renovation was decided by DTU. It would thereby be interesting to compare the performed case with the analysis made by DTU, to see where the differences are for the decision, or if economy has been the decisive parameter. In Case 4, the tool resulted in the same solution as is being executed on the building, a total renovation. This shows how realistic the tool is and that the results are trustworthy.

The fictitious case was seen important in a moment where none of the performed cases were inclining towards renovation. By using the previous case (case 2) simple changes could be made in order to achieve a different result. It was found rather simple to evaluate which questions that could be answered differently. By the simplicity of the tool, the changes were found realistic and were evaluated to be possible in a real case. It was thereby found, that the tool could result in an assessment of renovation as the preferred solution.

In **case 2** it was noticed how large an amount of work that is needed in order to complete all the steps of the tool, including the detailed analyses and the needed calculations. Despite only having performed a few of the possible calculations in step 5, it was noticed the level of needed engineer work and how close this step is to a performed sustainable certification. This step could therefore be a good documentation for a thoroughly analysis of the regarded case, if this is wanted and can contribute to a beginning of a sustainable certification.

It would be preferred to have performed **more cases** to have a larger foundation for analyzing the tool. Cases were more of the visions for the two scenarios were prepared and where the only missing part was the decision between the two. In the performed cases, the decision was already made or a vision for another possible scenario, except the one decided upon, was missing.

By the performed cases it is evaluated that the **tool is a quick and easy** method of assessing whether a building should be renovated or demolished and rebuild. This was seen by the execution of step 4 - the simple questions. This step was completed in an hour for all the cases, which really showed the efficiency in the decision supporting tool and how quick it can be performed.

By having the possibility in an early stage of evaluating if the whole tool should be processed, or if another solution should be performed for the building, a lot of **time can be saved** and questions answered from the very beginning. The Stop/Go and the Boundaries are a fast evaluation for this and has proved to be a good start for the use of the tool.

The **simple questions** – step 4 of the tool, were **easy to use** and many parameters which were seen important for the decision were included. By the conversations with Lisbet Michaelsen and Lisbet Sand it came to the impression that a lot of questions they were having for the two possible scenarios were answered by using the tool, questions that wasn't analyzed yet. This again proved the large parameter space the tool covers and how well it performs good decision supporting analyses.

The cases also showed the **separation of the tool**; one part that gives a preliminary decision with a low cost (step 1 – 4) and the last part (step 5) which brings a more final decision with a higher cost., a separation that allows the regarded case to choose its level of analyzing. It was also, as stated before, noticed how the final step could be used as an alternative to a sustainable certification.

In step 5 – some of the questions are marked [*], as a symbol of the necessity for the contractor to **discuss the specific question further**. The given answers for these aren't necessary to incline towards a specific result, though the meaning of the question could be different from case to case. The contractor is therefore given the opportunity of evaluating and defining which scenario should achieve a point. This complicates the tool a bit and demands a great deal of thought and discussion for the contractor, but it also makes the tool more flexible and **user-friendly**, although many of the questions can be twisted to fit the regarded case and the interest of the contractor.

Architecture is a parameter that is very individual and could have a great influence on the outcome of an assessment. Many buildings have a specific design and is the characteristic of a building which is remembered. In many situations architecture is a crucial element for the assessment of what should be done to a building. In some cases, architecture could have the same influence as economy, as it is the face towards the world – the first impression of a building. By this it could be discussed if **architecture should have a larger part** in the decision-making. It is excluded due to the limitations it would create (the same as economy – it would be too decisive) but also due to the fact that most buildings where architecture are considered, are older and domestic buildings. In some circumstance, architecture is tried to be incorporated in the tool, with parameters such as restrictions to the design and the area etc. This is seen as important questions and much more versatile, though architecture can be very individual and thereby a hard area to evaluate.

Further development of the tool – suggestions:

Based on the performed cases and the development of the tool, some possible changes and further improvements were found during the development of the method. These should only be seen as suggestions to make the tool more versatile and wide-ranging.

In this thesis, three sustainable certifications were chosen through analysis in the early stage of the process. To **extent the flexibility** of the tool **and the user individuality**, a system could be made in the beginning for the contractor to choose which sustainable certification he wishes to have the tool developed upon. This could give other parameters for the assessment of the building and other analyses to perform.

The tool is developed based on Danish regulations, lists and recommendation together with international sustainable certifications. In case 4 – Oslo building, the tool was used on a Norwegian building. This was possible though it was assessed as a Danish building. To make the tool **possible for international use**, the parameter space should be analyzed according to this. Some of the parameters in the tool can be assessed differently in other countries, which gives another way of analyzing the regarded question.

It is seen by the performed cases that the tool is easy to use, quick to perform (without the detailed calculations) and gives a good background analysis for the assessment whether a building should be renovated or demolished and rebuild. In order to make the tool more functional and individual according to the specific case, it would be interesting to make it possible for the tool to be **adjusted to the regarded building** and thereby create a multiple function for the building. By having the possibility of adapting the tool to the specific case, a multi-use of the tool can be created, instead of only considering office building, as done in this thesis. In order to make this adaption, parameters should be found – specific for these categories and an analysis in the beginning of the tool should make it possible to combine the parameter space of the tool for the regarded case. This would demand a much larger parameter space and many more analysis of the building. This adaption can although be difficult as there can be many personal feelings and interests in for example domestic buildings. It should therefore be evaluated, how and if these should be incorporated in the tool, or if there should be a limitation specific for domestic buildings.

In the sustainable certifications, **weightings** are created for the different parameters though some are seen "more important" than others. If this was created in the presented tool, the assessment of whether the regarded case should be renovated or demolished and rebuilding could be changed. If functionality and material reuse is seen more important by the contractor, the results could bring another solution for the regarded case – though more points would be achieved for the "winning" scenario. Furthermore – if this weighting would be defined by the contractor, a larger flexibility towards the specific building and future use would be accomplished together with a larger flexibility of the decision supporting tool. This would also reduce the need of evaluation every question, though this weighting would perform the evaluation instead.

It could furthermore be interesting to incorporate the thinking of "svanemærket". Svanemærket has a limit for its parameters and analysis of materials, which is **redefined and updated constantly**. This creates a need for always improving elements and to make them more sustainable as time goes on. By including this in the decision supporting tool, the assessment of a building would constantly be updated and the newest requirements would be incorporated. This would demand a constant work with the progress of the tool and knowledge about changes to the sustainable certifications and the requirements for the performance of a building. As a result of this, it would ensure the best sustainability assessment of a building and always give a result that can be trusted in its quality.

This method is created to be an assessment whether a building should be renovated or demolished and rebuild. It is not to be seen as the **final solution** or decision-making for the regarded case. The final decision should be made by the contractor. The tool can be used as a basis and background analysis for the decision. Many aspects are considered, evaluated and in some cases calculated (if the detailed analyses are performed). To achieve a final decision by using the tool – very specific parameters should be put up which can define the precise case. It would demand a much more detailed tool and a much clearer vision for the regarded case.

7 CONCLUSION

The decision suporting tool is shown to be **working and very functional** due to the simplicity of it and the flexibility, when assessing whether a building should be renovated or demolished and rebuild. This is concluded based on the performed cases and feedback from consulted persons. Each case was performed in less than an hour and resulted in both possibilities for renovation and demolition, which shows a large variety in the possible solution by using tool.

The tool creates a good background analysis for the decision making and should thereby not be seen as the final decision for the regarded building, but as decision supporting assessment where the final verdict is made by the contractor.

The **important parameters** for the assessment between renovation and demolition are found to be incorporated in the fundamental sustainability parameters. By the selection of parameter space it was evaluated that the environmental and economic sustainability could be used both for a renovation scenario as well as for a demolition and rebuilding. Furthermore, these parameters were included in the lists and requirements which the parameter space was compared to, during the selection process. It was also found that social sustainability wasn't an important parameter and was therefore deselected. The social sustainability factors couldn't contribute to the selection process as many of the parameters couldn't be change due to the already selected site and function of the building etc.

It is analyzed that **sustainable certifications are a good basis and are including the relevant parameters** for creating a parameter space appropriate for the assessment between renovation versus demolition and rebuilding. Through analyses of the sustainable certifications together with comparison of lists, regulations and requirements it is found that many of the important parameters for a renovation scenario are included in the certifications. Furthermore, the fundamental sustainability parameters are also included in many aspects of the certifications. This ensures a large and important area of sustainability covered and enhances the level of sustainable building. By evaluating the possibility for assessing between renovation and demolition when selecting the parameter space, many aspects were found included in the certifications, which would make this assessment possible.

Overall, the **sustainable certifications did provide with the necessary parameters** for this type of assessment. Through the sorting of the parameter space and the development of the tool, it was found that some additional parameters were needed in order to decide if the building should use the decision supporting tool for assessment at all. It was evaluated, that some basis parameters such as restrictions towards the building or the urban area, as well as economy, would set the foundation for what would be possible to do with the regarded building. These questions were therefore added to the tool as they were seen important for the decision process of the tool.

The decision supporting tool is proved to be quick and simple and by the possibility of choosing the level of detailing, **large cost and needed specialists can be reduced or eliminated.** By an early sorting process of the regarded case, the building can be sorted into categories of whether further use of the tool should be taken, or if a specific solution is the only possibility. Here a lot of time and effort can be saved and focus can be given to the important interventions immediately. The different level of detailing in the tool gives the contractor an opportunity to choose how much time he intends to use on the analyses, the amount of money that is to be used and how deep analyses he wishes to perform. The level of detailing is created by dividing the tool in several steps, some easy and quick, and another more detailed. The simple steps are easy enough for the contractor to make the assessment within an hour. This reduces the complicity and enhances the user-friendliness of the tool and makes it more applicable. The more detailed part gives a various chance to evaluate the regarded case further and makes a sustainable certification more achievable though many of the parameters are analyzed and answered in the decision supporting tool. The possibility to choose the level of detail, can also give the contractor a possibility to choose if, which and how many specialist would be needed for this assessment.

Because of its simplicity, **the tool can be used by all** who has some insight in building performance and construction and who has a need for assessing whether a building should be renovation or demolished and rebuild. This could be engineer, architects or contractors etc. If the more detailed analyses are whished, specialists can be hired in the amount that is needed.

The tool is developed **to be used in the early stage of a project**, when the first assessment whether the existing building should be renovated or demolished and rebuilding is to be made. By this, a vision should be made for the building, both for a renovation scenario and for a possibility of a new building. The two scenarios should have been evaluated to an extent, where an idea of what is needed and wanted is achieved.

The tool is fully developed and complete for use. The steps are developed to guide the user through the tool and by this contribute to the decision of the regarded case. The enclosed user guide is developed to be used "in the field" with the needed schemes, explanations and definitions of the included questions. By using this tool, the contractor has every possibility of making a satisfying assessment whether the building should be renovated or demolished and rebuilding.

8 SOURCES

[BDR Faq’s, n.d.]
BREEAM Domestic Refurbishment. *BREEAM Domestic Refurbishment FAQ’s*. n.d.

[Birgisdottir et al., 2010].
Birgisdottir, Harpa et. al. Byggeriets Evaluerings Center. *Bæredygtigt byggeri*, Afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri. June 2010

[Bossow, Jensen; 2005]
Bossow B., Jensen M.L. DTU. *Energioptimering af bygning 118*. Eksamensprojekt foråret 2005. June 2005.

[Robinson J, 2003]
Robinson J. *Squaring the circle? Some thoughts on the idea of sustainable development.* October 2003

[BREEAM, 2013].
BREEAM. *Comparison of BREEAM Domestic Refurbishment 2012 with EcoHomes 2006*. January 2013

[BREEAM n.d.]
BREEAM. *BREEAM in numbers*, n.d.
Code of Conduct: http://www.breeam.org/page.jsp?id=559. Visited: 8. April 2013

[BREEAM Domestic Refurbishment, n.d.]
BREEAM Domestic Refurbishment. BREEAM Domestic Refurbishment will help improve the sustainability and environmental performance of existing dwellings in a robust and cost effective way.
Code of Conduct: http://www.breeam.org/filelibrary/BREEAM%20Refurb/KN4613_-_BREEAM_Domestic_Refurbishment.pdf .Visited: 7 August 2013

[Brundtland, 1987]
Brundland, Gro Harlem, The World Commission on Environment and Development, *Our Common Future*, Report of the World Commission on Environment and Development, United Nations 1987

[BvB, 2007]
Byggeskadefonden vedrørende Bygningsfornyelse (BvB). *Logbog*. 3. edition, June 2007

[Bygherreforeningen et.al., 2013]
Bygherreforeningen, Viegand Maagøe og InnoBYG. *Hvidbog om bæredygtighed I byggeriet*. Et overblik over eksisterende viden og nye initiativer. April 2013

[DBR, 2013]
Energi Styrelsen. Bygningsrelementet. *Danish Building Regulations*. January 2013

[DS, 2007]
Dansk Standard. *Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*. DS/EN 15251. 1. edition. 2007.

[Fowler, Rauch; 2006]
Fowler M. K., Rauch M.E. *Sustainable building rating systems summary*. July 2006

[GBCD, 2012]
Green Building Council Denmark. *An introduction to DGNB*. Ensure the quality of your sustainable buildings in planning, construction, and operation. The DGNB system helps you get there. 2012.

[GBCD, n.d.]
Green Building Council Denmark. *Code of Conduct*.
Code of Conduct http://www.dk-gbc.dk/. Visited: 8. April 2013

[GBCD code, n.d.]
Green Building Council Denmark. *Code of Conduct*.
Code of Conduct http://www.dk-gbc.dk/om-gbc/code-of-conduct.aspx. Visited: 8. April 2013

[Hansen T, 2009]
Hansen, Ring, T.H. Rambøll. *Dansk Certificeringssystem for Bæredygtig Byggeri på vej*. 6 October 2009

[Havelund M, 2011]
Havelund, M. *Hvidbog om bygningsrenovering*, Et overblik over den eksisterende viden og de væsentlige studier af renoveringseffekter. August 2011

[Kats G. H., 2003]
Kats, Gregory H. *Green building costs and financial benefits*. 2003

[Københavns kommune, 2012]
Københavns kommune, Teknik- og Miljøforvaltningen. *Inspirationskatalog: Om Lavenergibyggeri i nye byudviklingsområder*. May 2012

[MacIntyre, n.d.]
MacIntyre, Rachel. Teknik- og Miljøforvaltningen, Center for Bydesign. Københavns Kommune. Bæredygtig Boværdi Barometer. n.d.

[Ma Z et. al., 2012]
Ma Zhenjun et. al. *Existing building retrofits: Methodology and state-of-the-art*. August 2012

[MBBL, 2012]
Ministeriet for By, Bolig og Landdistrikter. *Vejledning til spørgeskemaet*. BæredygtigBoværdigBarometer. 2012

[Nordic Innovation, 2012]
Nordic Innovation. COWI. *Urban Mountain Stage 1 proposal*.
Code of Conduct: http://www.nordicinnovation.org/da/nordicbuilt/the-challenge/#the-buildings. Visited: 7 August 2013.

[COWI, 2012]
COWI. Urban Mountain.
Code of Conduct: http://www.nordicinnovation.org/nordicbuilt/finalists/finalists-norway/urban-mountain/. Visited: 7 August 2013

[Summerson, 2011]
Summerson G.M. *Lessons learnt from Piloting BREEAM Domestic Refurbishment*. July 2011

[USGBC, 2011]
USGBC, Environmental Leader. *LEED certified Buildings in the U.S., by Level 2001-2010*, March 2011
Code of Conduct: www.environmentalleader.com/assets/charts/chart/LEED-certified-buildings-by-level-2001-2010.gif, visited: 6. August 2013

[USGBC, 2012]
USGBC. *LEED 2009 for existing buildings operations and maintenance*. July 2012

[World GBC, n.d.]
World Green Building Council.
Code of Conduct: www.worldgbc.org. Visited: 7 August 2013.