UiT

NORGES ARKTISKE UNIVERSITET

SHO6261

Master's Thesis in Technology

Quality parameters in evaluation of renovation projects

(Kvalitetsparametere i evaluering av rehabiliteringsprosjekter)

Santosh Regmi

June 2016

UiT NORGES ARKTISKE UNIVERSITET

Tittle:

Quality parameters in evaluation of renovation projects.

Date:
30.06.16

Grading:

Author:

Santosh Regmi

No of Pages:
91

Attachements:

Faculty:

Engineering and Technology

Institute:
Construction, Energy and Materials Technology
- Master ion Integrated Building Technology.

Supervisor:

Bjørn R. Sørensen

Eigil Roaldset

Summary:

This research paper intend to compare different Nordic methodical inventory methods to evaluate quality parameters in the renovation process. For this purpose a comparative study between BREEAM and other Nordic inventory methods are carried out for evaluation of quality parameter.

Abstract:

The main aim of this research is to find out the major and minor differences in evaluation of the quality parameters from the study of BREEAM and other Nordic inventory methods. This paper will help to clarify the difficulties in finding the best practice renovation methods and tools which will ensure the quality renovation of buildings with focus on multi-family apartment.

Faculty of Engineering Science and Technology

Department of Building, Energy and Materials Science

Acknowledgement:

It is my pleasure to express thanks to my thesis supervisor ***Bjørn R. Sørensen*** and ***Eigil Roaldset*** of the Engineering and Technology Faculty at ***Norges Arktiske Universitet (UiT), Narvik*** for their for their kind help and co-operation throughout this assignment. I am very thankful for their valuable guidance and suggestions, without which this research would not be possible.

I would also like to express my gratitude to my friends for providing support and continuous encouragement throughout the process of researching and writing this thesis. I am gratefully indebted to all my friends and colleges for their very valuable comments on this thesis.

Furthermore, I would like to acknowledge for all those persons who were directly or indirectly involved in my research and writings of my thesis.

Norges Arktiske Universitet (UiT), Narvik.

June 2016.

Santosh Regmi

Hovedoppgave

Våren 2016

for

Santosh Regmi

UiT Norges Arktiske Universitet
IVT-fak.
Institute for bygnings-,energi-og materialteknologi
Integrert Bygningsteknologi

Quality parameters in evaluation of renovation projects

Background:
The evaluation of a renovation method needs to be based on several parameters such as:

- *Energy efficiency*
- *Moisture safety*
- *Indoor environmental quality (IEQ)*
- *Resource efficiency and environmental impacts across the life-cycle of buildings*
- *Cost effectiveness*
- *Architecture and conservation*

The project intend to compare different Nordic methodical inventory methods to evaluate the renovation process, for example those defined by BREEAM or those used in several other projects such as the Swedish SIRen and Finnish ENERSIS projects. A methodical inventory consists of several measures that should be addressed in order to provide an optimal renovation. The inventory include energy efficiency measures, energy simulations and performance validation, suggestions of technical solutions and evaluation of the result, including indoor environmental quality (IEQ). The knowledge of health effects due to energy efficient renovations are limited. It is important that these kind of measures do not imply a negative impact on the indoor air quality and health, as was the case in the 1970s when trying to save energy by reducing ventilation. The renovations effects on IEQ and health need to be evaluated. If finding suitable cases, the effect on IEQ and health will be investigated with questionnaires before and after renovation.

Tasks
The following topics and tasks should be prioritized in the project:

- Literature survey on renovation methods for residential multifamily buildings
- Case study on selected small to mid-sized renovation projects
- Map different approaches and methods that can be used to ensure good quality
- Identify different quality parameters and how to evaluate them in renovation
- Discuss best practice methods

- Develop suitable questionnaires for evaluation of renovation process

Limitation

Limitation of the scope must be approved by the supervisor, and discussed accordingly in the final thesis report.

Generelle opplysninger vedrørende gjennomføring og rapport

Innen 2 uker etter at oppgaveteksten er utlevert skal kandidaten levere en plan for gjennomføring av prosjektet. Planen skal inneholde fremdriftsplan med milepæler, som klart sier når ulike aktiviteter skal være ferdigstilte, samt gi en kort verbal beskrivelse av de ulike aktivitetene. Dette forutsetter oppdeling av oppgaven i relevante aktiviteter med klart angitte tidsmål og forventet ressursforbruk. Det forutsettes videre at kandidaten bruker prosjektplanen aktivt i prosjektperioden, som er verktøy for å evaluere status og følge opp fremdrift underveis. Det vil bli avholdt jevnlige oppfølgingsmøter hvor status i forhold til planen avklares.

Besvarelsen redigeres som en forskningsrapport med et sammendrag både på norsk og engelsk, konklusjon, litteraturliste, innholdsfortegnelse etc. Påstander skal begrunnes ved bevis, referanser eller logisk argumentasjonsrekker. Med henblikk på lesning av besvarelsen er det viktig at de nødvendige henvisninger for korresponderende steder i tekst, tabeller og figurer anføres.

Materiell som er utviklet i forbindelse med oppgaven, så som programvare eller fysisk utstyr er en del av besvarelsen. Dokumentasjon for korrekt bruk av dette skal også vedlegges besvarelsen. Oppgaveteksten skal også inkluderes i besvarelsen. Rapporten med tilhørende materiale skal leveres i en *u*innbundet signert original som lett kan kopieres, samt to innbundne kopier. Det skal benyttes standard forside som finnes på HIN's nett. Det henvises forøvrig til skrivet *Generelle retningslinjer for hovedoppgaven*, samt emnebeskrivelsen for hovedoppgave.

Oppgaveteksten skal vedlegges besvarelsen.

Dersom oppgaven utføres i samarbeid med en ekstern aktør, skal kandidaten rette seg etter de retningslinjer som gjelder hos denne, samt etter eventuelle andre pålegg fra ledelsen i den aktuelle bedriften. Kandidaten har ikke anledning til å foreta inngrep i den eksterne aktørs informasjonssystemer, produksjonsutstyr o.l. Dersom dette skulle være aktuelt i forbindelse med gjennomføring av oppgaven, skal spesiell tillatelse innhentes fra ledelsen.

Eventuelle reiseutgifter, kopierings- og telefon-/telefaksutgifter må bæres av studenten selv med mindre andre avtaler foreligger.

Hvis kandidaten, mens arbeidet med oppgaven pågår, støter på vanskeligheter som ikke var forutsatt ved oppgavens utforming, og som eventuelt vil kunne kreve endringer i eller utelatelse av enkelte spørsmål fra oppgaven, skal dette umiddelbart tas opp med Høgskolen i Narvik ved veileder.

Arbeidet skal resultere i en sluttrapport med vedlagt CD/DVD som er grunnlag for evaluering og karaktersetting. Rapporten med tilhørende materiale skal leveres i **èn uinnbundet signert original**

som lett kan kopieres, samt tre innbundne kopier (evt. ekstern(e) samarbeidspartner(e)s materiell kommer i tillegg og skal overleveres av studenten selv), samt ett eksemplar av rapporten i pdf-format, fortrinnsvis på vedlagt CD/DVD/minnepenn. Det skal benyttes standard forside som finnes på UIT's nett. Det henvises forøvrig til skrivet *Generelle retningslinjer for hovedoppgaven*, samt emnebeskrivelsen for hovedoppgave.

Rapporten med tilhørende materiale skal innleveres (evt. poststemples) senest innleveringsdatoen til avdelingskontoret ved Avdeling for teknologi ved UIT Campus Narvik.

Andre opplysninger

Kontaktinformasjon, student:	Santosh Regmi E-post: regsan49@gmail.com, sre031@post.uit.no Tlf: 46260592
Medveileder ved UIT (Narvik):	Eigil Roaldset E-post: eigil.roaldset@uit.no Tlf: 47 81 52 80
Faglig veileder ved UIT (Narvik):	Bjørn R. Sørensen E-post: brs@hin.no Tlf: 97 01 38 01
Utleveringsdato:	11.01.2016
Innleveringsfrist:	30.06.2016

__________________________ __________________________

Santosh Regmi, student/ UIT (Narvik) Bjørn R. Sørensen, Veileder/HIN

Abstract:

In renovation processes there is always a risk of underestimating environmental, cultural, and social values in favor of energy efficiency and economy. As well as while upgrading the building's exterior and interior it is very essential to study the physical sustainability of building element in the field climate condition. Therefore it is very important to follow scientific and systematic process for making decision about renovation measures. The main aim of this research is to find out the major and minor differences in evaluation of the quality parameters from the study of BREEAM and other Nordic inventory methods. This paper will help to clarify the difficulties in finding the best practice renovation methods and tools which will ensure the quality renovation of buildings with focus on multi-family apartment. The research methodology is based on comparative study to find out the major and minor differences in evaluation of the quality parameters from these different inventory methods and procedures. There are many methods and tools which can be used to evaluate the renovation process, for example BREEAM in UK, LEED in US, SINTEF in Norway, ENERSIS in Finland etc. which consists of several measures in order to provide optimal renovation. This paper will help in certain extent to clarify the difficulties in finding the best renovation methods and tools which will ensure the quality renovation of buildings.

This research investigate principles of the sustainable development emphasizing the renovation of apartment buildings and relevant sustainable building assessment systems via comparison. Although numerous rating systems have been developed around the world, the UK-developed Building Research Establishment – Environmental Assessment Method (BREEAM) is the most commonly used performance rating system in European countries.

Renovations activities also required to reach certain economic, social, and environmental goals. It is therefore, important to pursue the most optimal strategy available to achieve cost-effective energy usage while maintaining excellent indoor environments, without sacrificing architectural quality or minimizing the negative impact on the environment.

Abbreviations

EU	- European Union
CO_2	- Carbon monoxide
SO_2	- Sulphur dioxide
NO_2	- Nitrogen dioxide
HVAC	- Heat Ventilation Air Condition
BREEAM	- Building Research Establishment Environment Assessment
SINTEF	- Stiftelsen for Industriell og Teknisk Forskning
BRS	- Building research series
NS	- Norwegian Standard
LEED	- Leadership in Energy and Environmental Design
NGBC	- Norwegian Green Building Council
CASBEE	- Comprehensive Assessment System for Building Environmental Efficiency
LTR	- Light Touch/Refresh Refurbishment
MIR	- Medium Intervention Refurbishment
EIR	- Extensive Intervention Refurbishment
CR	- Comprehensive Refurbishment
BPIE	- Buildings Performance Institute Europe
EED	- Energy Efficiency Directive
ESCO	- Energy Services Company
EPC	- Energy Performance Contracting
Twh	- Terawatt hour
EPBD	- European Building Directive
nZEB	- Nearly Zero Energy Building
IEQ	- Indoor Environment Quality
IAQ	- Indoor Air Quality
PMV	- Predicted Mean Vote
PPD	- Predicted Percentage Dissatisfied
BPIVS	- Building Integrated Photovoltaic System

VE	- Value Engineering
LCCA	- Life Cycle Cost Analysis
LCA	- Life Cycle Assessment
PBA	- Planning and Building Act
WHO	- World Health Organization
POE	- Post Occupancy Evaluation
RSM	- Responsible Sourcing of Materials
EPD	- Environmental Product Declarations
HSE	- Health Safety and Environment
WBEM	- Whole Building Energy Model
NCM	- National Calculation Methodology
EPR_{NDR}	- Energy Performance Ratio for Non Domestic Refurbishment
ELEM	- Elemental Level Energy Model
LZC	- Low & Zero Carbon
VOC	- Volatile Organic Compound
TVOC	- Total Volatile Organic Compound
TRV	- Thermostatic Radiator Values
BIMLCA	- Building Information Model Life Cycle Assessment

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction:

1.1Background:

Today, buildings play a significant role in development of every societies. Not only huge amount of financial resources are spent in this sector, but also buildings are responsible for 40% of energy consumption and over one third of CO_2 emissions in the EU. Renovation of the existing building stock is therefore key to meet long term energy and environmental goals. However this is very challenging in practice due to a variety of technical, regulatory and other barriers. Therefore it is essential for more research and creation of new innovative solution in renovation activities.

The methods of renovation process can be different worldwide depending upon geographical area, climatic condition and economic strength of a country. Both new construction and rehabilitation work of building stock have a strong impact in material and energy demands. Therefore, a deeper understanding of suitable method of renovation is very important to address these problems.

A typical building in Nordic countries like Norway, highly concentrates with energy measures, moisture safety and indoor air quality. But these qualities become weaker along with time and demands proper renovation without destroying the performance of building and it is very crucial to apply best method of renovation at that time. Many research based measures and tools were developed for quality and cost effective renovation which are being using in a present day but it is important to select the measure which provides optimal renovation and minimum impact on environment. This paper will intend on to compare different Nordic inventory methods and tools with BREEAM to evaluate quality parameters in renovation process.

1.2 Definition of renovation:

***What is Renovation**?*

Renovation (also called remodeling) is the process of improving a broken, damaged, or outdated structure. Renovations are typically either commercial or residential. In other words renovation is to make changes and repairs to (an old house, building, room, etc.) so that it is back in good condition. The term "Renovation" can be divided in to three `Rs` forms which is;

a) Repair and maintain,
b) Refurbish and enhance
c) Rebuild.

Repair and maintenance:

Cleaning, repairing and maintaining a property are the cheapest and easiest ways to make a property seem like new again. Maintenance is the work undertaken to restore or improve every facility in every part of a building, its services and surroundings to currently accepted standards and to sustain utility values of the facility. Repair is defined as the process of restoration of a broken, damaged, or failed device, equipment, part, or property to an acceptable operating or usable condition or state. Repairs are NOT replacements; they are simple things like re-siliconing the edge of a kitchen sink, patching a rusty hole in an iron roof, repairing a cracked tile in a bathroom, repair of cracks in walls caused due to separation of joints, development of fissures , shearing, separation of members built with different materials .

There are essentially two types of maintenance:

- **Scrub-up maintenance**— Jobs that are done infrequently but make a difference to the way a property looks.
- **Regular maintenance**—these are the tasks that need to be undertaken on a daily, weekly or monthly basis to keep the property looking neat and tidy.

Refurbish and enhance:

Refurbishment is a work such as painting, repairing, and cleaning that is done to make a building look new again. This is the most common form of renovation which involves stripping out old fittings and fixtures like kitchen cabinets or light fittings and replacing them with something newer. There are no structural alterations and it is the most visually effective form of renovation, but it does not includes structural alterations and cure of any structural faults.

Rebuild:

Anything that involves demolition and demands new structures is rebuild. Rebuilds are most difficult renovations to tackle, but with good planning they can be done relatively smoothly and cheaply. Rebuilds are unavoidable if there are major structural issues to fix. Some of the examples of rebuilding are:

- moving doors
- moving windows
- removing walls
- removing floors
- replacing structures such as roof supports, walls, footings or decks
- rewiring electricals
- replacing old plumbing
- Demolishing structures etc.

1.3 Why renovation?

There are several benefits which can be addressed in renovation projects. It can be physical, environmental, social, economic, aesthetic and other qualities. Risk can be minimized with proper plan and good communication between consultants and owner. Experienced engineers and other specialist has good knowledge in technical issue and can fix most of the problems. Following are some benefits of renovation.

- Low investment cost as compare to build a new one.
- Payback period of investment is shorter because of low investment cost.

- Can get Improved rental and yield values at a minimum cost and capital investment
- Design life of existing building can be increased.
- Improvements to a building's sustainability credentials and performance
- Opportunities to increase floor area
- Can do in short time period as compared to build new one.

1.4 Advantages and Disadvantages of Renovation

Advantages:

Renovating of existing home is a great way to enhance the quality of building. Renovations could add value to the sale price and make it more attractive to potential buyers and can also give benefit by lowering the energy cost. There are several benefits of renovation, some of them are as follows:

***Improving the comfort and functionality of a house*:** Building renovation projects allow to customize a house according to owner needs. This is an opportunity to create a dream home or at least make the space more enjoyable and useful.

Lowering energy costs: During house renovation, house owner can upgrade the insulation, install new windows, and eliminate drafts and other leaks. It is also possible to reduce energy consumption by upgrading the appliances and making other changes to the systems.

Boosting/ raising the Property Value: Renovation can make the property much more attractive and valuable to potential buyers. Owners can increase the value of their home by making it more aesthetically appealing, upgrading fixtures, adding a new coat of paint, replacing any old or worn flooring, and making other design changes. Buyers also appreciate homes that offer more in terms of functionality, and appreciate newer HVAC systems, appliances, and additional living space.

Disadvantages:

Renovation work can sometimes be stressful and in some cases final result can be different from originally planned. Renovation is quite challenging and has financial risk if proper study and planning is not done. In most of the cases extra costs should be implemented due to unforeseen problems. Reasons behind not doing refurbishment can be one or more of following points

- If the existing building has week stability and very less expected design life.
- If the purpose for use of building is changed and cannot only done by refurbishment.
- If it is difficult to meet minimum requirement in building code/law.
- If the existing building cannot be refurbished to a competitive level of quality.
- If it is not much difference in refurbishment cost and new build cost.

1.5 General Theory on housing stock in Norway.

History of residential buildings in Norway

In Norway a renovation project mostly starts with a need for a larger maintenance. Most of the homeowner concentrates on external and internal refurbishment rather than on energy measures. In Norway, many houses from 1960 -1980 have a great potential for implementing energy upgrading. Most of the multifamily apartment buildings those are built from 1960 to 1980 and are made up of the construction system consists of load-bearing concrete elements, with filled-in wooden construction in the long facades. Poorly insulated concrete sandwich elements can be found in the gable and walls, and the roof is made up of wooden insulated construction above the concrete slab.

Composition of the current housing stock in Norway

Today's housing stock in Norway has a significant age-related diversification. Some houses are good maintained while other needs high upgradation.

The following table shows that 50% of the current Norwegian housing stock is over 50 years old, 20% are older than 70 years. Is it necessary to demolish all the buildings over 70 year, or 6.5% of our buildings that are more than 100 years old? Of course not, but the older a building is, the more intrusive are needed for rehabilitation / renovation / modernization. We cannot preserve everything but we can change it in living standard by renovation.

Period	**Number of residential Buildings**	**Percent**
1900 and before	127 366	6.5%
1901–1945	289 090	15 %
1946–1960	358 209	18,30 %
1961–1970	308 484	15 %
1971–1980	374 184	19 %
1981–1990	294 013	15 %

Table 1 No of resident buildings built in Norway from 1900 to 1990.

The total number of dwellings in Norway was around 2.2 million in 2005. These can be categorized into three main groups:

- 57 % are single-family houses
- 21 % are divided houses in a row
- 22 % of the dwelling stock is multifamily apartments

1.6 Should a building be renovated/ rehabilitated or demolished? What determines it?

Before making decision on a building should be rehabilitated or demolished, it is important to study general building structure, stability and fundamental capability of a building. Lifespan of a main structure is a key term which should be studied and can be taken as a function of building`s ability to withstand numbers of changes and the future securement.

Engineers and consultants can be asked for advice by a client for the purchase of old buildings, whether it is purpose for rehabilitation or direct occupation, which can be a problem for them without planning and studying in detail about the building stability and future sustainability.
It is far difficult to conduct a rehabilitation process, than to build a new one, especially at older buildings. Rehabilitation also involves often a much greater financial risk but it can be minimized going systematically through all the work operations, and look at the various challenges inherent in them. Therefore it is very important for proper designing and planning in rehabilitation process.

	Building Condition				
Building performance		Excellent	Good	Poor	Very Poor
	Excellent	Maintain	Level 1	Level 2	Level 3
	Good	Level 1	Level 2	Level 3	Level 3
	Poor	Level 2	Level 3	Level 3	Level 4
	Very Poor	Level 3	Level 3	Level 4	Level 5

Figure 1: Different level of refurbishment according to building performance and condition

1.7 Research Aim and Methodology

The main aim of this research is to study the different inventory methods for the evaluation of quality parameters in renovation process. This paper will focus to make a comparative analysis of quality parameters between Nordic methods and BREEAM, concerning sustainability issues in the housing sector, especially on technical and environmental aspects. Renovation of existing housing stock is considered as a significant contribution to substantial savings in new construction costs, natural resources and energy consumption. In all type of renovation activities, a significant amount of energy, materials and finances are consumed, as well as the environmental impact exists, however it will benefit in future by consuming less energy, less CO2 emission and low environmental impact.

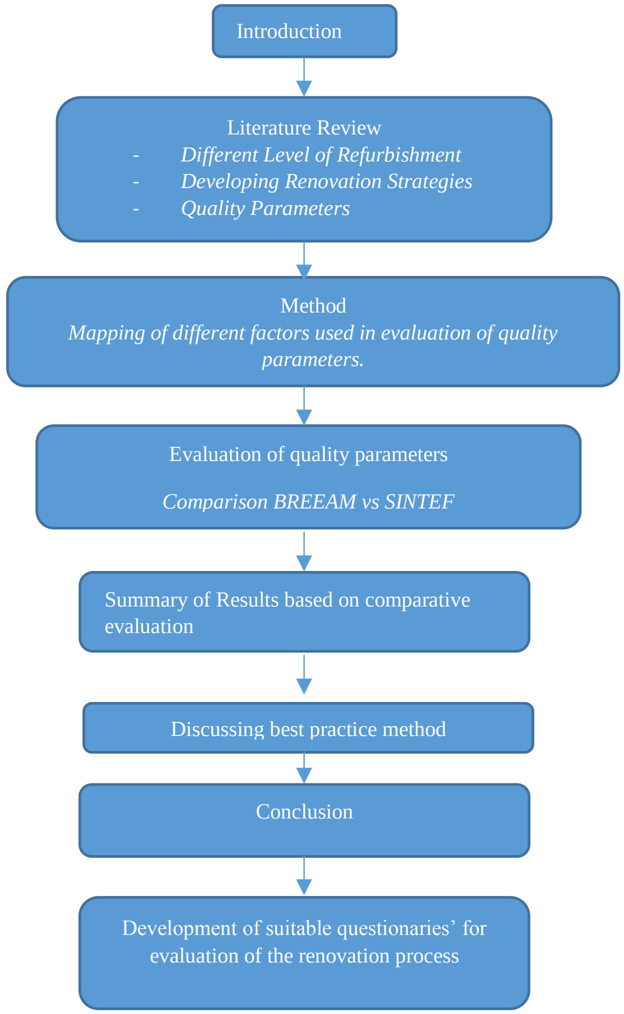

Figure 2 Outlining of Task

1.8 Limitation of the study:

In this research only the competent factors are selected for the evaluation of quality parameters. Therefore, the research study is limited on the surface knowledge of the different methods and tools in evaluation of quality parameters. Depth study including design parameters can be performed but it demands huge amount of time and other resources. However, this paper attempt to cover wide range of factors which are primary for evaluation of quality parameters in provided time and resources.

1.9 Short description of BREEAM and SINTEF

BREEAM (U.K.): BREEAM was established in the U.K. in 1990 as a voluntary measurement rating for green buildings by BRE (Building Research Establishment). Since then, its importance has grown a lot and especially in Europe. BREEAM is the worlds oldest and Europe's leading environmental rating tools. BREEAM has developed assessment tools and manuals for various types of buildings that can be used for both existing buildings and new construction. The building's environmental performance are judged by a number of different environmental areas. There are minimum requirements for achieving points in areas such as project management, energy, indoor climate, location in relation to public transport, the choice of materials and waste disposal. For each area, it is considered so out what proportion of the total points achieved by the project. Totals form the basis of obtained classification level. The different classification levels are: PASS, GOOD, VERY GOOD, EXCELLENT and OUTSTANDING. BREEAM NOR is a Norwegian adaptation of BREEAM with the possibility of certification through the Norwegian Green Building Council (NGBC).

SINTEF (Nordic inventory methods): SINTEF (Scientific and Industrial Research in Norwegian Institute of Technology) is a research group that sells research-based knowledge and associated services based on knowledge of technology, science, medicine and social sciences. This Group is Scandinavia's largest industry which is a non-profitable organization which invests most of its profit in laboratories research and scientific equipment’s.

Headquarter of SINTEF is in Trondheim which has approximately more than 300 employees in capital city Oslo. Furthermore, it operates in Bergen, Alesund, Tromso and Raufoss and has offices in Houston, USA and Rio de Janeiro, Brazil. In addition to this it has laboratory in Hirtshals in Denmark.

Its research is aimed at finding solutions to major societal challenges, as partly described in national planning documents and the EU’s Horizon 2020. SINTEF is continuously developing numbers of research papers which is named as Building Research Series (BRS).

Building Research series (BRS): BRS is an updated and accepted aid in the construction industry. It is used as an important source of documents for the fulfillment of TEK regulations and requirements. BRS is a solution based manual which helps to meet the functional requirements of technical regulations under the Planning and Building Act and the performance level specified in the guidelines for these regulations. BRS consists of over 700 papers divided into three sub-series:

1. Building detail, covering architectural details that are applicable for new construction, from foundation to roofing and industrial installations.
2. Construction Management, discusses the operation and maintenance of existing buildings, rehabilitation, reconstruction and the likewise.
3. Planning, discusses process planning and building design, building permits, land use and sizing and design of rooms and outdoor spaces.

2.0 Literature Review:

2.1 Different level of refurbishment:

Level 1 Maintenance renovation i.e. light touch/refresh refurbishment (LTR)

Level 2 Minor renovation i.e. medium intervention refurbishment (MIR)

Level 3 Major renovation i.e. extensive intervention refurbishment (EIR)

Level 4 Deep renovation i.e. Comprehensive refurbishment (CR)

2.1.1 Level 1 Maintenance renovation i.e. light touch/refresh refurbishment (LTR)

It is a quick and easy approach of refurbishment and the scope of work includes decorating, changing carpet tiles, replacing ceiling, repairing and upgrading minor element from the building. Some examples of light touch refurbishment are

- Upgradation in common areas
- Optimization in core and toilets

- New lighting and finishes to building entrance
- General upgradation of building appearance

In LTR there is lowest investment risk and have least opportunity to generate value from the potential improvements to the building. The common areas like lifts, toilets, entrance and corridor are the main part that is particularly suited to the light touch approach as less effort is required to improve them. A little change in external appearance can do noticeable attraction to staff, visitors and potential tenants.

LTR is usually done when building has good condition and performance. It is generally done to upgrade esthetic value of a building as well as to save a building from further degradation due to outside weather condition and internal human activities. It includes work that changes the interior arrangements or other physical characteristics of an existing facility or installed equipment so that it can be used more effectively for its currently designated purpose or adapted to an alternative use to meet a programmatic requirement. LTR works doesn't have a strong influence on the quality parameters of a building, and refurbishment work is relatively very small compared to the other level of refurbishment. LTR is the cheapest and easiest type of renovation where house owner can take decision by himself on every changes on the building.

2.1.2 Level 2 Minor renovation i.e. medium intervention refurbishment (MIR)

This include the works as outlined in LTR plus the replacement of building service in the part of building cores, small upgrades and revised workspace strategy. In medium intervention process replacement of fixtures, materials and fitting is done. This could include the replacement of sanitary wares, new lighting, replacement of floor tiles, false ceiling, entrance fixtures etc. Some examples of medium intervention renovation are

- further additional changes as compared to light/touch
- Enhancement in branding with new features
- Upgraded to current Building Regulations
- Creation of additional floor space
- Services upgrade

2.1.3 Level 3 Major renovation i.e. extensive intervention refurbishment (EIR)

It include the work defined in MIR plus a full replacement of building services, change in building outlook, possible extension to the floor plates and remodeling of certain area. The enhancement should be carefully done only to the most appropriate improvements necessary to meet Building Regulation. An 'Extensive Intervention' delivers an upgrade that takes a building though a further 15 - 20 year lifecycle, which should then represent an enhanced asset in the developer's portfolio and enable it to complete with an average new build product in the local market. Buildings that are multi-occupied are often suited to this approach.

2.1.4 Level 4 Deep renovation i.e. Comprehensive refurbishment (CR)

This level is a most complicated and most expensive part of renovation. However it creates a best opportunity to capitalize on the improvement in asset value. This level includes all the work in EIR plus the development of exterior part of a building. The work will upgrade the building in higher standard and ensure the building sustainability for 20 to 25 years. The ability to extend the building and adding floors is carried out in this level of refurbishment. In addition development of land associated with the building can be considered. Some examples of comprehensive refurbishment are

- further major changes in medium intervention
- Change in building exterior with new materials
- Elongation of building design life to 25 years
- New core and services replacement throughout
- Use of new brand building materials
- Higher rental value targeted

"Deep renovation" is an ambitious renovation which will reduce the U-values of building components up to 30%.

This level of refurbishment intervention and the associated levels of investment can extend the lifespan of a building by bringing all elements up-to-date and ensure the building is competitive with high value in the local market. The ability to extend the building and add floors is often considered at this level of refurbishment. In addition, development on land associated with the building, such as air-rights development above surface car parking, can be considered. This will enhance the value of the site and help deliver more area, potentially a wider range and mix of uses, and increased environmental credibility.

Each of the above refurbishment options provides an opportunity to increase both the rental and asset value of an existing building, at differing degrees of risk, that can offer more return than demolishing the building and starting from scratch.

2.2 Developing Renovation Strategies:

The development of a renovation strategy can be divided into 5 phases:

1. Identifying Key Stakeholders & Information Sources
2. Technical & Economic Appraisal
3. Policy Appraisal
4. Drafting & Consulting on the Renovation Strategy
5. Publication & Delivery

Short description of work can be categorized as following

Phase 1	Identify key stakeholders
	Identify information sources
Phase 2	Building stock characterization
	Economic appraisal of renovation
	potential Identification of energy and non-energy benefits
	Quantification of investment requirements and funding sources
Phase 3	Comprehensive appraisal of barriers
	Assessment of range of policy measures
	Development of holistic policy package
Phase 4	Draft renovation strategy
	Consultation on draft strategy
Phase 5	Publish final strategy
	Commence policy implementation process
	Establish monitoring and evaluation procedures
	Review and update strategy every 3 years

Table 2 Different phases of Renovation strategies

With the detail description of activities in each phase of renovation, an indicative time scale is prepared.

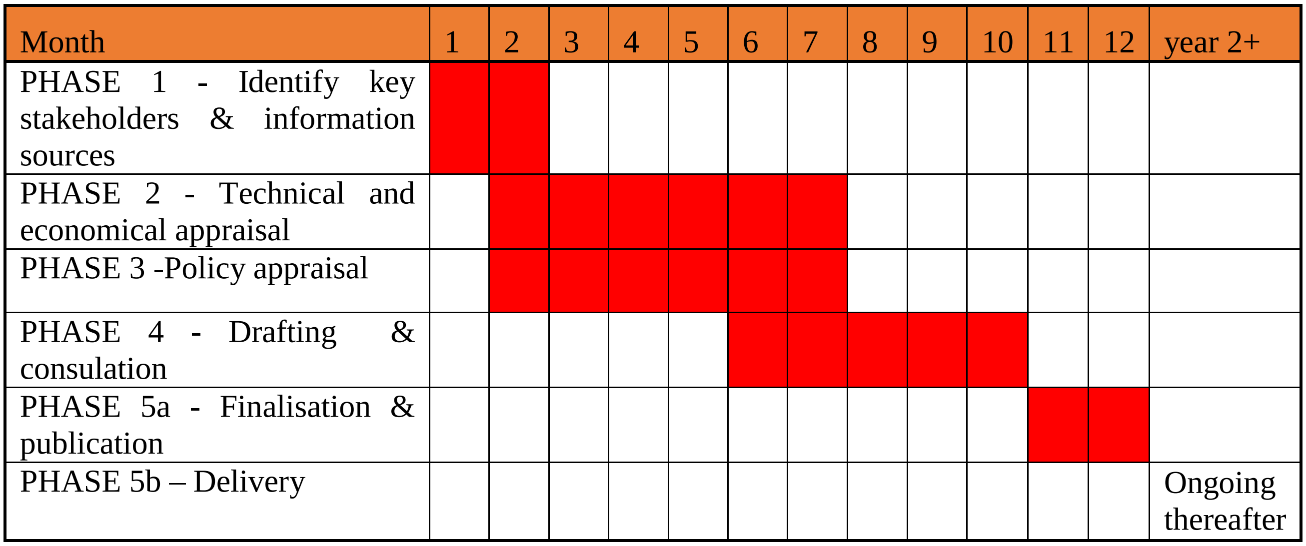

Figure 3 Example of indicative time scale for implementaion of renovation strategies.

2.2.1 Phase 1: Identifying Key Stakeholders & Information Sources

Identifying Key Stakeholders & Information Sources has a vital role in planning, preparation and leadership to achieve renovation strategy. Involvement of stakeholders can provide creative solutions and the intensive exchange of ideas. Therefore, it is very important for early involvement of stakeholder and the creation of integrated teams by identifying and consolidating the different levels, roles, and responsibilities. A strategy development team needs to be pulled together to include input from representatives of Government ministries with responsibility for policy on energy, the building sectors, regions, industry, finance and the economy. In this phase the responsibility of stakeholders is clarified and the financial community is prepared. Establishing a project team and gathering information and data about a project is a key activity in this phase. The execution of this phase include following subsequent phase:

- Existing building condition and the barriers should be studied
- The effectiveness of the action for sustainable improvements in the building should be studied
- Identification of relevant stakeholders

Frequent communication between house owner and technical personal is very important in planning, designing and re-construction process. In depth information helps renovators to motivate in achieving better results. House owner should have responsibility to watch and be connected with designer/builders for better execution of refurbishment projects.

2.2.2 Phase 2: Technical & Economic Appraisal

In this phase, range of renovation options appraised and cost estimation is carried out, and the technical potential for improving the quality parameters of the building stock is determined. First of all a full understanding of the building stock through a bottom-up summation of the different building typologies, construction styles, ages, climatic zones, occupancy, ownership patterns is made. Field study of existing building and analyzing the possible solution from different possible renovation measures to provide technical potential for sustainable renovation is made. After this the total estimated cost of renovation from different renovation measures are determined. In economic appraisal process, the investment cost and future benefits from the renovation is studied, which can determine the feasibility of the project. It is often seen that the other benefits are discussed largely on the society rather than investment but it is very important that the stakeholders should be careful about it. In addition quantifying the benefits of renovation into the economic appraisal of the renovation strategy at a national level should be done. The evaluation of discount rate and the rate of return applied is a very significant consideration in this phase. The range of potential measures is discussed more fully in Phase 3. In summary, the detailed steps of the technical & economic appraisal are:

- Building stock analysis;
- Cost effectiveness appraisal of renovation options;
- Quantification of energy saving potential;
- Development of a long term investment horizon; and
- Quantification of other benefits.

2.2.3 Phase 3: Policy Appraisal

In this phase, review of policy affecting building renovation is done. In addition, identifying the changes in policies and additional policies in the building renovation market are studied. According to national circumstances, the specific policy that deliver the long term renovation strategy can vary from country to country. According to BPIE analysis, measures that delivers the long term renovation strategy will require a fundamental review of the policy landscape.

BPIE has developed a checklist of possible actions which, together, provide a solid policy framework on in developing the renovation strategy. This checklist of renovation strategy measures may not be applicable in all European countries, and it is unlikely that all could be introduced within a single policy cycle. But, this checklist explains many of actions that should be given serious consideration to facilitate a successful delivery of the renovation potential. Actions that is undertaken in renovation strategy can be divided into following.

- Strategic action:
- Legislative and Regulatory
- Technical action
- Financial Actions
- Communication/ capacity Building Action
- Research and development (R&D) action

2.2.4 Drafting and consulting on the renovation strategy.

This phase brings together the technical and economic appraisal undertaken in phase 2 with the review of policy options in phase 3 in order to generate a range of possible future pathways or roadmaps for the long term renovation of the national building stock. Depending on the time and strength of different policy levels, different rates of renovation can be modelled and the resulting investment and benefits are quantified.

Based on the analysis undertaken in the previous phases, the renovation strategy should aim to be a comprehensive document that brings together, in a strategic and united way, the full range of levers and tools that can be brought to bear in order to effect a significant and sustained increase in both the rate and the depth of renovation of the national building stock to improve its performance. Once the strategy has been drafted, perhaps with a range of options, it is highly recommended that a consultation exercise be undertaken with the key national stakeholders. Representatives from the entire value chain, from the research community and professional service providers through to energy utilities, equipment manufacturers, installation companies and bodies representing skills and training, need to be included within the scope of the consultation.

2.2.5 Phase 5: Finalization, Publication, and Delivery

The new strategic measures is sent to the government level and for revision process. It can take several months or even year depending on the particular legislative mechanisms in a given country or region for finalization and publication. At the time when new legislation to be developed, government will make clear to stakeholders for the intentions regarding to delivery and implementation of the renovation strategy, and demonstrate their own commitment and contribution to the strategy by instigating the renovation of the public building property.

2.3 Quality Parameters:

2.3.1. Energy efficiency

The energy consumption in buildings stock in Norway was in total about 78 TWh in 2013. The household sector cover 46% of total energy consumption and other tertiary sector cover 32% of total energy consumed. The total energy consumption was increased by 6 Twh in period of 3 years from 42 Twh in 2010 to 47 Twh in 2013. Electricity is a most used energy source in Norway, almost 81% of total energy used in residential sectors and 79% in tertiary sectors is covered by electrical energy. The electricity consumption was increased by 7% in the household sector and increased by more than 20% in the tertiary sector in 2013 compared to 2000. While the other energy source such as bio energy, district heating, gas and oil products which covers 20% of total energy consumption in building stock.

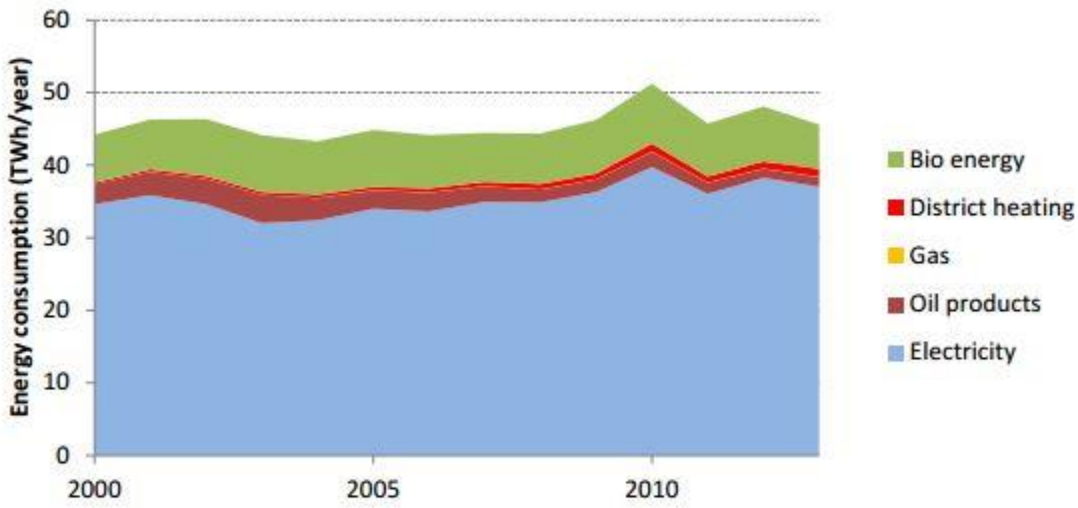

Figure 4 Final resident energy use by energy carrier (not climate corrected), 2000-2013 (TWH/year).

According to Oliver Rapf, Executive Director, BPIE *"I believe that renovation of buildings to high energy performance standards could be one of the most cost effective investments a nation can make, given the benefits in terms of job creation, quality of life, economic stimulus, climate change mitigation and energy security that such investments deliver".*

Implementing energy saving measures on building envelope, heating system and interior lighting add more possibilities for additional gains like

- increased availability and more functional solutions
- better daylight conditions and connection / visibility for outdoor environments
- better indoor environment, indoor air quality, comfort, acoustics
- lower heating costs
- lower power requirement and less heat sources
- greater flexibility in energy supply and the placement of heat sources
- renewed architectural expression
- higher value and better energy efficiency
- a house you can be proud to live in

Benefits of improving the energy efficiency: There is wide range of benefits which can be accomplished by sustainable energy renovation of housing, which are summarized as below.

- Environmental benefits
- Social benefits
- Economic benefits
- Energy system benefits

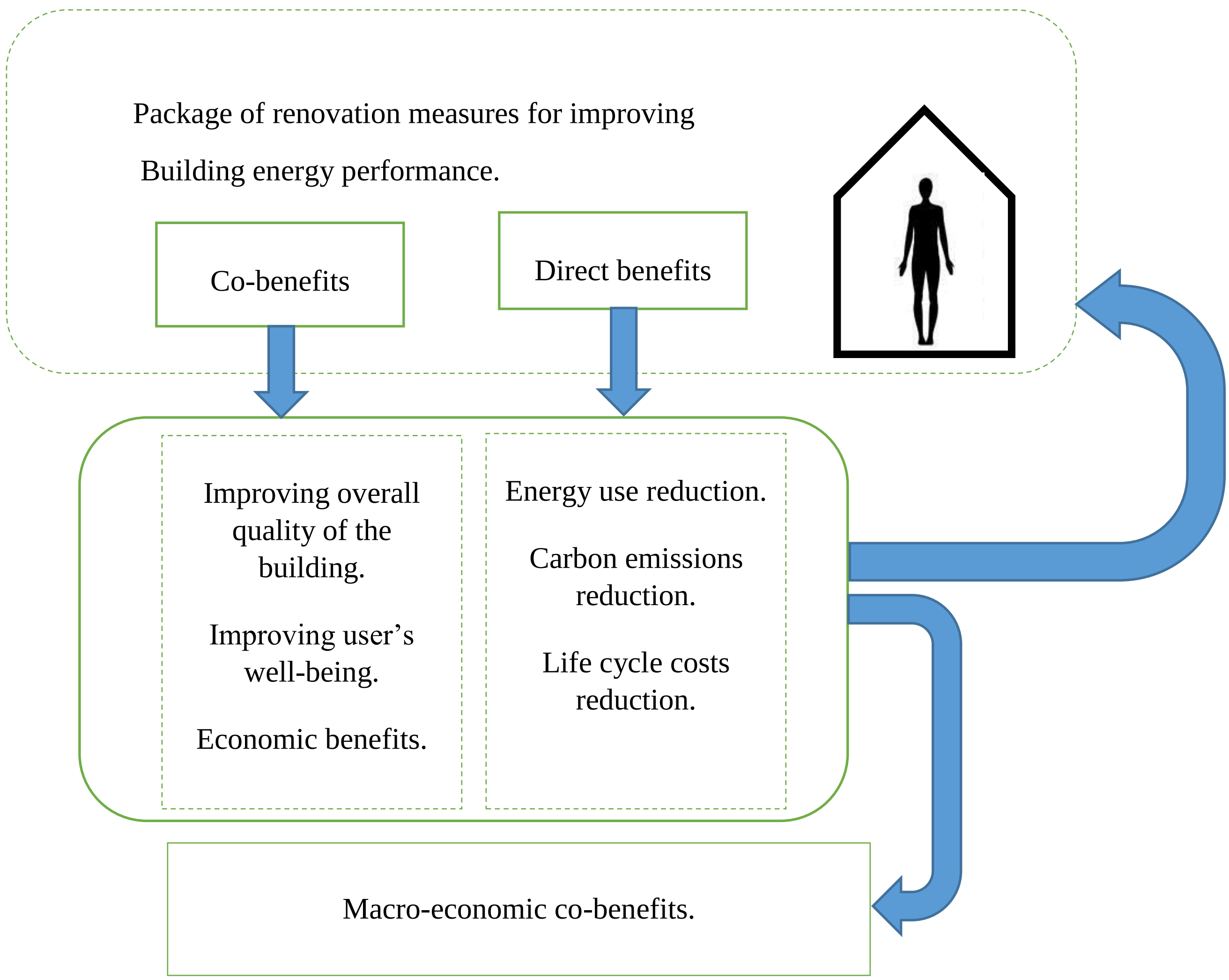

Figure 5 Benefits of sustainable energy renovation of housing.

Environmental Benefits: Energy efficient renovation of buildings can help to reduce CO2 emission which occur due to over use of energy. Global warming due to excessive CO2 production is becoming a huge problem in present world resulting the increase in earth`s temperature exceedingly in every year. Accumulation of carbon dioxide in the atmosphere, released from burning of fossil fuel, contributes to global warming and triggers changes in surrounding environment and, ultimately, on our social and economic realities.

The amount of CO_2-emmision and energy saving measures can be calculated as per source of energy used, renovation rate of building and depth of renovation. Where renovation rate of the existing building can be calculated with relation of the parameters like age of a building and life time of the building elements. The total number of building stock in a country can be categorized as single family building, multifamily apartments, and the building for other purposed and the construction period of each building classes. The annual renovation rate of a building can be calculated using the Weibull-distribution with the renovation rate λ (t) in year t,

$\lambda(t) = \beta/T * (t/T)\beta - 1$

Where,

λ(t)= Renovation rate

t= time period of rating = 1, for annual rating

T= characteristic life time

B= shape factor

By the level/depth of renovation, it can be analyzed which renovation technique or method is going to be applied in the particular building. Before renovation of any type of building, the final energy demand with different renovation methods is calculated and the best renovation practice is implemented with the help of corresponding difference in energy demand. Furthermore the net present value of each renovation option is calculated. The energy efficient renovation also helps to reduce air pollution because of low consumption of fossil fuels like oil and gas. This can bring more awareness to people to build energy saving houses and save their earth from excessive SO_2, NO_2 and other harmful gasses for health and environment.

Social Benefits: Energy efficient renovation can help for health and well-being of the occupants because it can reduce symptoms of respiratory and cardiovascular conditions, rheumatism, arthritis and allergies, as well as fewer injuries particularly for children, elders and those with preexisting illnesses. Furthermore, the warmer houses can result improved indoor quality which will give very good impacts on occupants both mentally and physically. Many researchers has found that the health benefits from energy retrofits could be worth more than the value of the saving in energy costs.

Improved energy efficiency in the building is not only limited on health and indoor air equality, it provides a variety of benefits of particular importance for emerging economies and developing countries as they seek to exploit their resource base to reduce poverty and support sustainable growth. It will save energy from being wasted and can help countries in the economic growth by supplying excessive energy in the development activities. By reducing the energy bills energy efficient renovation can increase the affordability of energy services for poor families by reducing the per-unit cost of lighting, heating, refrigeration and other services. In addition, energy efficient buildings reduces the amount of energy assets exposed to extreme weather conditions. As well as the occupants can get a greatest improvement in terms of increased comfort because of flexibility to adjust overheating in summer and under heating in winter.

Economic benefits: Energy efficient renovation has a significant effect on economic growth of a country. In a sustainable renovation process it is found mostly the cost of investments is lower than the value of benefits. The figure below shows the annual gross benefits to society from energy efficient renovation of buildings.

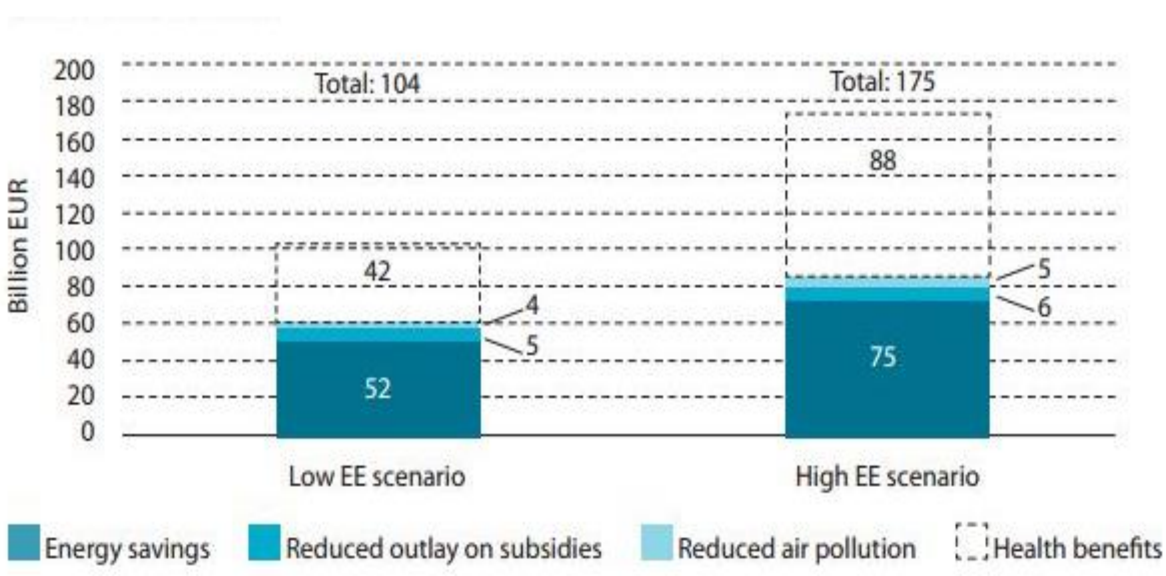

Figure 6 Annual gross benefits to society from energy efficient renovation of buildings(2020)

Energy system benefits**:** Energy efficient measures in renovation projects in energy system for example it can avoid new energy generation capacity, increase energy security, reduce peak loads.

2.3.2 Moisture Safety

Structural dampness is the presence of unwanted moisture in the building structure, either the result of imposition from outside or condensation inside a structure. Moisture problems are one of the most important challenges in the construction industry and in every building construction project high emphasis to moisture safety is given. Many buildings, both new and old, suffer from moisture-related problems with negative consequences on health, costs for rebuilding, and loss confidence in the building trade. These problems could be avoided if moisture issues are focused on and observed throughout the construction process. To avoid moisture problems architects and design engineers should follow lists of references, checklists, and design examples to use for dry building design. For contractors, a number of routines for moisture control during construction have been developed. There are many methods to avoid moisture damage in buildings which should be implemented. However, one of the important tasks of the building sector is to formulate these methods, so that it can be applied by everyone. Excessive humidity, rain penetration and condensation are the three major cause for dampness inside a building.

A Visual Guide to Damp, Mold and Indoor Pollution stated that

"Excess moisture leads – on almost all indoor materials – to growth of microbes such as moulds, fungi and bacteria, which subsequently emit spores, cells, fragments and volatile organic compounds into the indoor air. Moreover, dampness initiates chemical and/or biological degradation of materials, which also causes pollution of the indoor air. Exposure to microbial contaminants is clinically associated with respiratory symptoms, allergies, asthma and immunological reactions. Dampness has therefore been suggested to be a strong and consistent indicator of risk for asthma and respiratory symptoms such as cough and wheeze."

2.3.3 Indoor Environment Quality (IEQ)

According to building design, operation and provision of quality indoor environment, energy consumption can vary in a huge amount while designing indoor environment. Therefore it is very important to consider energy consumption while designing housing stock but it should not have negative impact due to poor indoor environmental quality (IEQ). Many research studies shows that saving energy by making poor IEQ can be harmful in both social and financial accepts. A good indoor environment can improve working productivity, learning ability and help to reduce negative impact on health of the occupants. Beside this, a good indoor environment creates new charm and relax to the occupants and helps them to keep them out from being bored and lazy. Therefore, it has no meaning of saving energy by making poor indoor environment quality but it doesn't mean that it is impossible to build energy saving houses with good IEQ. There are many design solution to build energy saving building and keeping the good IEQ and it needs specifying criteria for the indoor environment for design, energy calculations, performance and operation of buildings. A short description of subsequent parameters for good indoor environment quality are as follows.

Thermal comfort: Thermal comfort is "that condition of mind which expresses satisfaction with the thermal environment". Thermal comfort is a condition when occupants in a building feels neither warm nor cool. Thermal comfort include four environment factors and two personal factors. Environmental factors are air temperature, radiation temperature, humidity and personal movement while personal factors are activity level and clothing. The indices predicted mean vote (PMV) and predicted percentage dissatisfied (PPD), which make it possible to predict the mean thermal sensation and mean satisfaction with thermal conditions of a group of people.
Low air temperature can increase the risk of rheumatic diseases. Low and high air temperature reduces muscle function and results to feel discomfort and reduce work performance. Therefore it is important that the building occupants should feel comfortable in a wider range of conditions than the conditions prescribed by applying the PMV index. To find out thermal comfortability. It is developed comfort equation where measurements were combinations of skin temperature, core body temperature, perspiration and activity level that results in a thermally neutral feel for the "average person." Which is given as

$$M - W = H + E_C + C_{res} + E_{res}$$

Where,

M: Heat produced in the body by metabolism. The heat production increases with activity levels,
W: Efficient mechanical work
H: Dry heat loss from the body by convection, radiation and conduction
E_C: Heat loss by evaporation of moisture from the skin (by thermal neutrality)
C_{res}: Dry heat loss by respiration
E_{res}: Heat loss by evaporation of moisture in the respiratory

Visual comfort: Maintaining visual comfort means ensuring that people have enough light for their activities, the light should be in right quality and balance, and people should have good visual comfort. Visual comfort is defined as "a subjective condition of visual well-being induced by the visual environment". Although the definition implies that there is a psychological dimension of comfort, a number of physical properties of the visual environment are defined and used to evaluate its quality in an objective way. Visual conditions are characterized by such parameters as luminance distribution, illuminance and its uniformity, glare, color of light, color rendering, flicker rate and amount of daylight.

Acoustic comfort: The acoustical environment is typically given little or no attention during project planning and design however the quality of the sound environment is linked to numerous physical parameters, which include both the physical properties of sound itself and the physical properties of a room. Sound is characterized by the sound pressure level in a short-term and for long-term period it is characterized by sound frequency. The acoustic environment is influenced by physical room properties such as sound insulation, absorption and reverberation time.

Good indoor air quality: Besides considerations of thermal comfort, indoor air quality means that the chemical composition of indoor air is clean and fresh. This means avoiding chemical pollutants, particulates, pollen, mold and mildew, pathogens, and other unwanted substances in the air, as well as bringing in new air at an adequate rate. The term comfort is not commonly used in relation to indoor air quality and it is mainly linked with the lack of comfort due to odor and sensory irritation. Acceptable air quality is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction". Consequently most of the standards providing the requirements for indoor air quality define the conditions by providing the minimum percentage of persons dissatisfied with air quality. They are mainly based on the discomfort and annoyance caused for visitors to indoor spaces. Recently, some standards also deal with the requirements for occupants.

2.3.4 Recourse efficiency and environmental impacts across the life-cycle of buildings

Resource efficient development allows the economy to create more with less, delivering greater value with less input, using resources in a sustainable way and minimizing their impacts on the environment. Resource efficiency in the context of moving towards more sustainable buildings is understood as the broad concept aiming to reduce resource use and limit the environmental impacts from buildings throughout their lifecycle - from material extraction for use in the construction phase, through resource use during occupancy and maintenance, to material recovery at demolition. The different types of resource used in building sectors can be building materials, energy (embodied) and related GHG emissions, water, land and biodiversity impacts. However, this resource efficiency excludes the consumption and impacts, from energy consumption in the use phase of buildings lifecycle. The lifecycle of buildings extends from the extraction of raw materials, through the construction and use phases to demolition and eventual waste disposal and/or reuse. Resources are used, and environmental impacts created, throughout the lifecycle of buildings. Environmental impacts of (any kind of) resource use is understood as the quantified or qualified impacts associated with the actual use of resources. The environmental impact of the use of material resources in buildings arises at various stages of the building life-cycle, from the impact associated with the material extraction, through to processing and production of construction products, transport, construction itself, the use of the building including renovation and maintenance and eventual demolition and reuse or disposal. Each of these stages has an associated environmental impact. One short example of resource efficient implementation and its benefits is given below

Principal Options Implimented	**Resource Used**	**Pollution Generation**
Water: operating equipment at full capacity, investing in new equipment, segregation of waste water flows and installing new filters and water reuse	Reduction of water consumption by ~ 6,500 m3	Reduction of waste water by > 6,100 m3
Energy and GHG emissions: replaced light bulbs, control of chiller water temperature, controlled steam flow. Carbon off set through 80ha fore's	Energy use reduction of 551,000 MJ	GHG neutral
Waste: segregation of waste into 16 categories, composting of organic waste, return or return packaging		waste reduced by 6 ton

Table 3 Example of resource efficient implementation and its benefits.

2.3.5 Cost effectiveness:

In case of building construction or refurbishment project, cost effectiveness is seen from following perspectives

- the lowest first-cost structure that meets the program
- The design with the lowest operating and maintenance costs.
- The building with the longest life span.
- The facility in which users are most productive.
- The building that offers the greatest return on investment.

Calculation of cost-effectiveness requires a life-cycle perspective where all costs and benefits of a given project are evaluated and compared over its economic life. In economic terms, a building design is said to be cost-effective if it results in benefits equal to those of alternative designs and has long-lasting building components and equipment's. For example, if a HVAC system alternative that satisfies the heating and cooling requirements of a building at the minimum whole life cost, it is cost-effective HVAC system of choice. Components of the whole life cost include the initial design and construction cost, on-going operations and maintenance, parts replacement, disposal cost or salvage value, and the useful life of the system or building.

For cost effectiveness it is essential to utilize cost and value engineering throughout the Planning, design, and development Process. It is always challenging to find out true cost and true benefits of alternative decision. For example, what is the economic value in electric lighting savings and productivity increases of providing daylight to workplace environments? Or, what is the value of saving historic structures? Alternately, what is the cost of a building integrated photovoltaic system (BIPV), given that it may replace a conventional roof?

There are three principles associated with ensuring cost-effective construction to define costs, benefits, and basic economic assumptions in an appropriate way.

- Utilize cost and value engineering throughout the planning, design, and development process.
- Use economic analysis to evaluate design alternatives.
- Consider non-monetary benefits such as aesthetics, historic preservation, security, and safety.

2.3.6 Architecture and conservation:

Some building has the historical importance and need to preserve its historic value by restoring its shape, size and other parameters by keeping the outlook same like before. Renovation simply means to make an object look like new where the object, material and method of construction and historical importance is not crucial in this process. Therefore the activities done in architecture and conservation is defined by words like restoration, preservation and conservation.

Webster's New Collegiate Dictionary (1975) defines restoration as, "a bringing back to a former position or condition." In restoring an art object, piece of furnishing, or architecture, the most important requirement is the final appearance. The client and restorer determine the most desirable period of an object's life; and the restorer does whatever is necessary to return the object's appearance to that period.

Preservation is the activity of protecting something from loss or danger. The word preservation is most commonly used in relation to architecture and built environments.

Preserving an object places additional layers of requirements on the decisions regarding materials and methodology. In preservation, the final appearance is no longer the prime factor, but rather, retaining the maximum amount of building fabric.

Conservation is the act or an instance of conserving or keeping from change, loss, injury. The absolute maximum amount of the original material, in as unaltered a condition as possible, is preserved. Any repairs or additions must not remove, alter or permanently bond/cross-link to any original material. All repairs or additions must be reversible and removable without affecting the condition of the original material now, and in the future.

2.4 Technical requirements regarding measures on existing buildings in Norway

According to PBA § 31-2, the measures on existing structures, applies basically the same measures as for new building. It is the developer who is responsible for identifying and defining the measure, also determining the requirements that should apply for conditions of exception.

The municipality do study on the case and check the information from the developer and find out whether the measures meets the relevant requirements or not.

The list below gives an overview of the documentation that must accompany the application:

- Reporting/clarifying of the planned work.
- Confining the works in relation to the type of measure
- Identifying technical requirements to the work which are going to be carried.

Planned work limited to measures set out in PBA § 20-1:

- adding floors over existing building
- Adding another structure to the existing building
- Adding of substructure
- Significant changes in the building (the renovation)
- Significant changes of ceiling
- Facade change
- Change in use of building
- Construction of technical installations
- Change and repair of technical installations

Working as normal maintenance is not included in PBA § 20-1, and can be performed without application and permission from the municipality. For the purpose of maintenance of building elements suitable and certified materials should be used.

Exceptions to the technical requirements:

Building technical regulations (TEK) includes all requirements and guidance required for existing buildings. But in some cases all the requirements do not always adaptable in existing structures in a good order. This issue becomes more and more difficult as the building become older. Therefore, it is common that the requirements TEK has changed considerably over time, and there is many differences in the set of quality requirements for older building and the today's new building. Planning and Building Act § 31-2 fourth paragraph therefore initiated to issue permits without following minimum requirements of TEK.

If the measure does not meet the technical requirements set out in the PBA, the owner can apply for exemptions from requirements. PBL § 31-2 forth paragraph says that,

«Kommunen kan gi tillatelse til bruksendring og nødvendig ombygging og rehabilitering av eksisterende byggverk også når det ikke er mulig å tilpasse byggverket til tekniske krav uten uforholdsmessige kostnader, dersom bruksendringen eller ombyggingen er forsvarlig og nødvendig for å sikre hensiktsmessig bruk. Kommunen kan stille vilkår i tillatelsen.»

The owner must submit sufficient documentation showing that the conditions for exemption according to PBL § 31-2, are fulfilled. Paper/ documents that should be submitted to get permission for this measures are as follows:

- Document that shows the unreasonable cost to fulfill expected requirements.
- Document that shows renovation / rehabilitation / reconstruction is justifiable to ensure future use.
- Document that shows about the change / rehabilitation / reconstruction is needed to ensure appropriate use.

3. Mapping different factors and methods that can be used to ensure good quality

In this part, comparison of different inventory methods is done to find out the similarities and dissimilarities in the method used to evaluate renovation process. Where BREEAM (Building Research Establishment Environmental Assessment Method) is developed in UK and is using worldwide for the sustainable development of building and SINTEF "The Foundation for Scientific and Industrial Research" is the largest independent research organization in Scandinavia.

3.1. Management

Project brief and design

- Stakeholder consultation (2 credits)

  BREEAM: Stakeholder consultation covering project delivery and relevant third parties.

  SINTEF: NS 3420 used as the basis for preparation of project descriptions for construction contracts.

Life cycle cost and service life planning

- Elemental life cycle cost (2 credits), Component level life cycle cost (1 credit), Capital cost reporting (1 credit)

  BREEAM: Recognizing and encouraging the use of life cycle costing and service life planning and the sharing of data to raise awareness and understanding.

  SINTEF: Norwegian standard for lifecycle for building work (NS 3454) includes capital costs, management costs, operating costs, maintenance costs and development costs.

Responsible construction practices

- Environmental management (1 credit), Sustainability Champion (1 credit)

BREEAM: The principal contractor demonstrates sound environmental management practices and consideration for neighbors across their activities on-site.

SINTEF: Documentation requirements for environmental assessment in buildings are described in BRS 241.070. Detection and remediation of asbestos are described in BRS 773.340 and 773.341.

- Considerate construction (up to 2 credits), Monitoring of construction-site impacts (2 credits)

  BREEAM: Site related energy, water and transport impacts are monitored and reported to ensure ongoing compliance during the Refurbishment, Handover and Close Out stages and to improve awareness and understanding for future projects.

  SINTEF: BRS 511.211 describes common contaminants that pollute the ground, how to identify the contaminants and how to handle.

Commissioning and handover

- Commissioning and testing schedule and responsibilities (1 credit)

  BREEAM: Schedule of commissioning including optimal timescales and appropriate testing and commissioning of all building services systems and building fabric in line with best practice.

  SINTEF: The approval includes documentation of all the relevant characteristics of the product, as well as assembly instructions, usage condition and information about environmental characteristics.

- Commissioning building services (1 credit)

  BREEAM: Inspecting, testing, identifying and rectifying defects via an appropriate method.

  SINTEF: Tolerance requirements in NS 3420 is linked to performance and applies at the time of handover. Differences at a later date as a result of such lack of capacity, drying, shrinkage, phrases and unforeseen use of the building, is not meant to handle by tolerance requirements.

- Testing and inspecting building fabric (1 credit)

- Handover (1 credit).

  BREEAM: Provision of a non-technical Building User Guide and user/operator training timed appropriately around handover and proposed occupation.

Aftercare

- Aftercare support (1 credit)

  BRREAM: Provision of the necessary infrastructure and resources to provide aftercare support to the building occupier(s).

- Seasonal commissioning (1 credit)

  BREEAM: Seasonal commissioning activities will be completed over a minimum 12 month period, once the building becomes substantially occupied.

  SINTEF: BRS 740.320 provides an overview of the expected intervals for maintenance and replacement of materials, components and building elements. This specifies relevant measures and refers to more detailed sources in Building.

- Post occupancy evaluation (1 credit).

  BREEAM: The client or building occupier commit to carrying out a post occupancy evaluation (POE) exercise one year after initial building occupation and to disseminate the findings in terms of the building's post occupancy performance.

  SINTEF: Data on maintenance and lifetimes can be used as a basis for maintenance planning, calculation of annual and life-cycle costs and as a reference for condition analysis, technical reports, building certification or equivalent structural engineering documentation.

3.2. Health and well being

Visual comfort

- Glare control (1 credit)

  BREEAM: Potential for disabling glare has been designed out of all relevant building areas.

SINTEF: BRS 554.215 includes installation of shielding (Avskjermingen) provides no light beams in affected area, and the light source is therefore properly shielded.

- Daylighting (up to 3 credits)

  BREEAM: Good practice daylighting levels have been met.

  SINTEF: BRS 421.626 describes accepted methods for documenting daylight conditions in buildings. Requirements for Outlook is not treated.

- View out (up to 2 credits)

  BREEAM: Floor space in relevant building areas has an adequate view out to reduce eye-strain and provide a link to the outside.

  SINTEF: Door and windows should be placed in good order to get satisfactory out viewing. TEK

- Internal and external lighting (1 credit)

  BREEAM: Internal and external lighting systems are designed to avoid flicker and provide appropriate illuminance (lux) levels. Internal lighting is zoned to allow for occupant control.

  SINTEF: BRS 421.610 describes requirements for internal and external lighting.

Indoor Air Quality

- Minimizing sources of air pollution (4 credits)

  BREEAM: Minimizing sources of air pollution through careful design specification and planning.

  SINTEF: BRS 552.360 includes placing fresh air intake and exhaust so that the transfer of pollutants into the ventilation system is minimized.421.505 requirement for indoor climate. 421.502 requirement for air quality.

- Adaptability - potential for natural ventilation (1 credit)

  BREEAM: Building ventilation strategy is designed to be flexible and adaptable to potential future building occupant needs and climatic scenarios.

  SINTEF: BRS 552.302 shows sizing and design of ventilation based on natural and mechanical ventilation. Ventilation systems are designed for small houses (detached, semi-detached, and terraced).

Safe containment in laboratories

- Laboratory containment devices and containment areas (1 credit)

  BREEAM: Production of an objective risk assessment of the proposed laboratory facilities.

  SINTEF: BRS 421,523 describes the issues of chemical compounds from building materials and emission properties of different material groups. It also describes how the emissions measured.

- Buildings with containment level 2 and level 3 laboratory facilities

  BREEAM: Containment devices such as fume cupboards meet best practice safety and performance requirements and objectives.

  SINTEF: Requirements for emissions, limits and labeling schemes described in BRS 421,522 Emissions from building materials. Recommended limits.

  BREEAM: Containment level 2 and 3 laboratory facilities to meet best practice safety and performance criteria where specified.

  SINTEF: Issues of furnishings and furniture can also have a significant impact on indoor air.

Thermal comfort

- Thermal modelling (1 credit)

  BREEAM: Thermal modelling carried out to appropriate standards.

  SINTEF: BRS 421.501 describes measurement principles and recommended guidelines for thermal indoor climate. It explains the key concepts related to temperature and air velocity and shows the conditions that must be met for the users of a building to experience thermal comfort.

- Adaptability - for a projected climate change scenario (1 credit)

  BREEAM: Projected climate change scenario(s) considered as part of the thermal model.

  SINTEF: Climate data provides a basis for thermal sizing and frost protection of structures against the ground, as foundations for heated and unheated buildings, pipes and roads. BRS 451.021

- Thermal zoning and controls (1 credit)

  BREEAM: The thermal modelling analysis has informed the temperature control strategy for the building and its users.

  SINTEF: BRS 421.501 also explains the Control and management of thermal indoor climate.

Acoustic performance

- Multi-residential and Other, Residential institutions building types (4 credit)

  BREEAM: The building meets appropriate acoustic performance standards and testing requirements in terms of: Sound insulation, Indoor ambient noise level and Reverberation times.

  SINTEF: BRS 527.300 provides a general basis for treating acoustic conditions when designing or audio controls of space. The guidelines apply particular room designed for voice, music or other sound. This is also relevant for rooms where noise should be limited, for example in staircases, kindergartens or industrial premises.

Safety and security

- Security of site and building (1 credit)

  BREEAM: Provision of effective measures which support safe access to and from the building. Security needs are understood and taken into account in the design and specification.

  SINTEF: Byggeplanlegging 220,210 discusses various types of accidents in and around the home and the reasons for them. Measures to prevent from injury and death is described, and it provides an overview of risk areas with references to laws, regulations and further information.

3.3. Energy

Reduction of energy use and carbon emissions

- Whole building energy model

  BREEAM: Recognize improvements in the energy performance of the refurbished building over existing building performance in relation to heating and cooling energy demand, primary energy consumption and carbon dioxide emissions.

  SINTEF: BRS 471.018 provides an overview of energy requirements for buildings in accordance with the regulations on technical requirements for construction works (TEK10). Furthermore, this gives overview and descriptions of energy efficiency requirements on energy measures.

- Elemental level energy model

  BREEAM: Encouraging steps taken to reduce energy demand through building design and systems specification.

  SINTEF: BRS 471.024 explains and gives examples of how to certify that the requirements for energy efficiency by energy frames (total net energy) are met in accordance with regulations on technical requirements for construction works (TEK10).

Energy monitoring

- Sub-metering of major energy consuming systems (1 credit)

  BREEAM: Energy metering systems are installed to enable energy consumption to be assigned to end uses.

  SINTEF: BRS 700.264 provides an introduction to how to conduct energy monitoring in buildings. It addresses systems for energy monitoring based on energy and temperature curves (E-T curves). The magazine also shows the interpretation of the E-T curves and necessary equipment to monitor energy consumption.

- Sub-metering of high energy load and tenancy areas (1 credit)

  BREEAM: Sub-meters are provided for high energy load and tenancy areas.

SINTEF: Energy monitoring also determines the number of energy meters, type gauges and required accuracy.Electrical energy is easiest to measure because it is here usually have access to electricity plant's main monitor. BRS 700.264

External Lighting

- Operation of a building without the need for external lighting (which includes on the building, signs and at entrances).
  BREEAM: Specification of energy efficient light fittings for external areas of the development and controls to prevent use during daylight hours or when not needed.
  SINTEF: BRS 380.011 an overview of current light sources and luminaires required for outdoor lighting in public spaces in cities and towns. 380,010 treats planning of outdoor lighting.

Low carbon design

- Passive design/ free cooling (2 credits)
  BREEAM: Analysis of the existing building is undertaken to identify opportunities for, and encourage the adoption of, passive design solutions, including free cooling.
  SINTEF: NS 3700 contains criteria for passive and low energy building. The standard is of practical use in the planning, construction and evaluation of homes with low energy and use of renewable energy sources. BRS 473.003 describes energy-efficient buildings.
- Low or zero carbon technologies (1 credit).
  BREEAM: A feasibility study has been carried out to establish the most appropriate on-site/near-site low or zero carbon (LZC) energy source(s) for the building/development and is specified.
  SINTEF: NS 3700 sets minimum requirements for energy for heating, design criteria and minimum requirements for building components and systems. These criteria can be used for the design, certification and documentation for homes that can be classified as passive or low-energy.

Energy efficient cold storage

- Refrigeration energy consumption (1 credit).
  BREEAM: The refrigeration system, its controls and components have been designed, installed and commissioned in accordance with appropriate codes and standards and demonstrates a saving in indirect greenhouse gas emissions (CO2 eq.) over the course of its operational life.
  SINTEF: BRS 701.266 describes the background and planning of energy saving measures in housing and discusses measures related to living habits, build technical solutions, ventilation, temperature control, heating / energy flexibility and lighting / equipment. This manual is applicable to all existing homes, with emphasis on small houses.
- Indirect greenhouse gas emissions (1 credit).
  BREEAM: The installed refrigeration system demonstrates a saving in indirect greenhouse gas emissions (CO2 eq.) over the course of its operational life.

Energy efficient transportation systems

- Energy consumption (1 credit).
  BREEAM: An analysis of the transport demand and usage patterns is undertaken to determine the optimum number and size of lifts, escalators and/or moving walks.

- Energy efficient features (2 credit)
  BREEM: Energy efficient installations are specified

Energy efficient laboratory systems

- Design specification (1 credit).
  BREEAM: Client engagement to determine occupant requirements and define laboratory performance criteria to optimize energy demand of the laboratory facilities.
  SINTEF: 421.523Emisjoner fra byggevarer. Måling i laboratorium og resultater.
- Best practice energy efficient measures (4 credit).

BREEM: Specification of best practice energy efficient equipment and measures as appropriate.

Energy efficient equipment

- Identifying the building's unregulated energy consuming loads (1 credit).
  BREEAM: Identification of the building's unregulated energy consuming loads which have a major impact on the total unregulated energy demand.
- Identifying reduction in the total annual unregulated energy consumption (1 credit).
  BREEAM: Demonstrate a meaningful reduction in the total unregulated energy demand of the building.

Drying space

- An adequate internal or external space with posts and footings, or fixings capable of holding (1 credit).
  BREEAM: Provision of adequate internal or external space and equipment.

3.4. Transport

Sustainable transport solutions

- Accessibility Index
  BREEAM: Recognition for projects where proximity to good public transport networks has been reviewed.
  SINTEF: BRS 312.112 describes the importance and quality of a residential area with the design of the road system. Conditions safeguards traffic safety are important when designing the road system.
- Alternative transport measures.
  BREEAM: Alternative measures have been implemented thereby helping to reduce transport-related pollution and congestion.

Proximity to amenities

- Close proximity of, and accessible to, local amenities which are likely to be frequently required and used by building occupants.

BREEAM: Recognition of projects where proximity of, and accessibility to, local amenities which are likely to be frequently required and used by building occupants has been reviewed.

Cyclist facilities

- Compliant cycle storage spaces.
  BREEAM: Provision of compliant cycle storage spaces and facilities to encourage safe and healthy cycling.
  SINTEF: BRS 312.130 deals with parking, car park and garage facilities for both residential buildings and for other types of buildings and businesses.

Maximum car parking capacity

- The building's car parking capacity.
  BREEAM: To ensure change of use projects review provision of car parking spaces to optimize car parking capacity and encourage alternatives to car travel.
  SINTEF: This manual describes parking requirements and provides guidelines for locating and Designing Park. It also provides directions for design of parking spaces for the disabled.

Travel plan

- A travel plan has been developed as part of the feasibility and design stages
  BREEAM: To promote sustainable reductions in transport burdens by undertaking a site specific travel assessment/statement and developing a travel plan based on the needs of the particular site.

3.5. Water

Water consumption

- An assessment of the efficiency of newly specified domestic water-consuming components and measures for reducion in water consumption.
  BREEAM: Reducing the demand for potable water through the provision of efficient sanitary fitting, rainwater collection and water recycling systems
  SINTEF: BRS 515.165 treats simple treatment plants for drinking water. It is intended as an aid to selecting cleaning system for households with own water supply or water from small waterworks. The manual informs about regulations and Norwegian drinking water quality, and provide an overview of current cleaning systems.

Water monitoring

- Installation of a water meter on the mains water supply to each building
  BREEAM: Specification of a water meter/s on the mains water supply to encourage water consumption management and monitoring to reduce the impacts of inefficiencies and leakage.
  SINTEF: BRS 523.163 describes different measures to reduce water and energy consumption for sanitary installations.

Water leak detection

- Leak detection system (1 credit).
  BREEAM: Recognition of leak detection systems capable of detecting a major water leak on the mains water supply
  SINTEF: BRS 553.135 describes the leak protection for water systems in buildings. Leak Stoppers installed in or around water-bearing systems to stop unwanted water discharged. For example leakage can stops with humidity sensor.
- Flow control devices (1 credit).
  BREEAM: Flow control devices that regulate the supply of water to each WC area/facility to reduce water wastage.

SINTEF: BRS 553.163 describes the equipment and measures to reduce water and energy consumption for sanitary installations. Manual mainly concerns measures relating to production, distribution and consumption of hot water and heat recovery from hot waste water.

Water efficient equipment

- Identification of all unregulated water demands that could be realistically mitigated or reduced.
  BREEAM: Identifying a building's total unregulated water demand and mitigating or reducing consumption through systems and/or processes.
  SINTEF: BRS 523.163 describes the equipment and measures to reduce water and energy consumption for sanitary installations.

3.6. Materials

Life cycle impacts

- Project life cycle assessment study (6 credits)
  BREEAM: Reductions in the building’s environmental life cycle impacts through the reuse of materials and the use of tools to analyze the life cycle impact of any new materials using robust environmental information assessment of the main building elements.
  SINTEF: BRS 470.101 describes the life cycle assessment (Life Cycle Assessment, LCA), which provides an introduction to the method and describes key concepts and looks specifically at the use of the method to assess the environmental impact of building materials and buildings.

Responsible sourcing of materials

- Sustainable procurement plan (1 credits)
  BREEAM: Materials sourced in accordance with a sustainable procurement plan.
  SINTEF: According to BRS 470.112, one can make a life cycle assessment (LCA) at the construction stage, instruction stage or different material options. The results will be dependent on the methodological choices one makes in the analysis.

- Responsible sourcing of materials (RSM) (3 credits)

  BREEAM: Key building materials are responsibly sourced to reduce environmental and socio-economic impacts.

  SINTEF: ECO product is a method designed to make environmentally friendly product choices in a construction project. This manual describes how to use the method. Information from environmental declaration (Environmental Product Declarations - EPD) for a product must be based to utilize the method. BRS 470.112

Insulation

- Embodied impact of insulation in ground floor, roof, external wall and building service

  BREEAM: Recognition of the use of thermal insulation which has a low embodied environmental impact relative to its thermal properties.

  SINTEF: BRS 470.104 provides instructions to show how to use the results of a life cycle assessment to compare the environmental impact of various building systems and to identify environmental problem areas.

Designing for durability and resilience

- Protecting vulnerable parts of the building from damage

  BREEAM: The building incorporates measures to reduce impacts associated with damage and wear-and-tear.

  SINTEF: BRS 700.110 provides an overview of the most common injuries that can occur in building refurbishment process.

- Protecting exposed parts of the building from material degradation

  BREEAM: Relevant building elements incorporate appropriate design and specification measures to limit material degradation due to environmental factors.

  SINTEF: BRS 520.067 gives information on protection of frost degradation of concrete and other porous construction materials. BRS 720.415 treats the most common causes of injuries in connection with the precipitation. It shows examples of typical injuries, why they occurred and how to rectify them.

Material efficiency

- Measures to optimize material efficiency in order to minimize environmental impact of material use and waste.
  BREEAM: Opportunities and measures have been identified and taken to optimize the use of materials.
  SINTEF: BRS 570.111 provides instructions for actions related to health, safety and environment (HSE) in the handling and use of building materials and substances during the construction period.

3.7. Waste

Project waste management

- Pre-refurbishment audit (1 credit)
  BREEAM: Development of a pre-refurbishment audit to identify options for reuse and recycling.
  SINTEF: BRS 700.804 describes how to plan effective and economical demolition of buildings with minimal environmental impact. These principles can be used on both the demolition and the rehabilitation / reconstruction of buildings, and will be helpful when planning such works.
- Reuse and direct recycling of materials (2 credits)
  BREEAM: Actions to reuse or directly recycle materials. Reducing project waste related to on-site construction and off-site manufacture/fabrication.
  SINTEF: BRS 501.101 describes factors that reduce waste by new construction and remodeling / rehabilitation, and that one should take into consideration when planning buildings.
- Resource efficiency (3 credits)
  BREEAM: Development of a refurbishment resource management plan.
  SINTEF: Waste should be identified and sorted so that it can be reused, recycled or sent to landfills. BRS 501.101.
- Diversion of resources from landfill (1 credit)

BREEAM: Diverting non-hazardous construction (on-site and dedicated off-site manufacture/fabrication), demolition and excavation waste (where applicable) generated by the project from landfill.

SINTEF: BRS 700.806 focuses on different methods for the demolition of different types of buildings. It also discusses the preparatory works, different equipment, as well as handling and delivery of demolition waste.

Recycled aggregates

- Increase in material efficiency in major refurbishment works.

  BREEAM: Percentage levels of recycled or secondary aggregate specified against set targets.

  SINTEF: BRS 572.111 describes the features and important uses of recycled aggregate of bricks and concrete. Typical sorts, standards and recommendations are also discussed.

Operational waste

- Building's operational-related recyclable waste streams, so that this waste is diverted from landfill or incineration.

  BREEAM: Provision of suitable space and facilities to allow for segregation and storage of operational recyclable waste volumes generated by the assessed building/unit, its occupant(s) and activities.

  SINTEF: BRS 700.804 describes how to plan effective and economical demolition of buildings with minimal environmental impact. These principles can be used on both the demolition and the rehabilitation / reconstruction of buildings, and will be helpful when planning such works.

Speculative floor and ceiling finishes

- Speculative floor and ceiling finishes (1 credit)

  BREEAM: Specification of floor and ceiling finishes is done only after agreed with the occupant or for tenanted areas where the future occupant is not known, carpets, other floor finishes and ceiling finishes are installed in a show area only to reduce wastage.

Adaptation to climate change

- Conduction of climate change adaptation strategy appraisal for structural and fabric resilience.

  BREEAM: Encourage consideration and implementation of measures to mitigate the impact of more extreme weather conditions arising from climate change over the lifespan of the building.

  SINTEF: BRS 451.031 climate data provides a basis for design of exterior cladding and roof drainage pipes from rain stress and basis for storm water management. Climate data giving rise to thermal design and frost protection are shown in BRS 451.021 climate data for thermal sizing and frost.

Functional adaptability

- Measures taken to accommodate future changes of use of the building over its lifespan.

  BREEAM: Encourage consideration and implementation of measures to accommodate future changes to the use of the building and its systems over its lifespan.

  SINTEF: SINTEF has described the provision in functional adaptability of buildings. New regulation for functional adaptability can find in Direktoratet for Bygningskvatitet (DIBK).

3.8. Land use and ecology

Protection of ecological features

- Protection of ecological features (1 credit)

  BREEAM: Recognition of where existing features have been protected prior to and during site operations.

  SINTEF: BRS 312.304 refers, development of large residential areas, there must be municipal and zoning / building plan. In connection with a land-use plan may contain provisions regarding the design and use of buildings and spaces, including play and living areas, cf. PBLs § 20-4. According PBLs § 26 should regulatory provisions specify the smallest play area per. unit and establishing procedures for the design and use of such areas. Area provisions should also require the grounds plan must be approved by the building council before building work commences.

Minimizing impact on existing site ecology

- Minimizing impact on existing site ecology (Credit 0)

Enhancing site ecology

- Ecologist's report and recommendations (1 credit)
  BREEAM: Recognition of steps taken to enhance site ecology through the advice of a suitably qualified ecologist.
- Simple buildings specific (1 credit)

Long term impact on biodiversity

- To encourage long term protection and enhancement of biodiversity on the site and surrounding area.
  BREEAM: The production of a long term landscape and habitat management plan to encourage measures that improve the site's long term biodiversity.

3.9 Pollution

Impact of refrigerants

- Buildings that use no refrigerants (3 credits) for buildings that use refrigerants Pre-requisite Impact of refrigerant (1 to 2 credits).Leak detection (1 credit).
  BREEAM: Avoidance or reduction of the impact of refrigerants through specification and leak prevention/detection.

NOx emissions

- All building types except Industrial (3 credits). All Building types with industrial (2 credits)

BREEAM: Reduction in emissions of nitrous-oxides (NOx) arising from the building's space and water heating systems.

Flood risk management and reducing surface water run-off

- Flood risk management - (2 credits)

  BREEAM: Identifying the buildings flood risk and adopting flood resilience or resistance measures through refurbishment or fit-out works.

  SINTEF: Describes the requirements for assessment and prevention of damage due to flooding and landslides in the various parts of the planning and building proceedings.

- Surface water run-off - (2 credits)

  BREEAM: Surface water run-off is managed to be no worse as a result of refurbishment works.

  SINTEF: BRS 311.200 also describes tools that RAV analyzes and considerations zones. Much of this is relevant also for other risks and causes of damage, as surface water and sea level rise.

- Minimizing water course pollution - (1 credit)

  BREEAM: Watercourse pollution prevention systems are in place.

  SINTEF: BRS 515.165 is intended as an aid to selecting cleaning system for households with own water supply or water from small waterworks. This manual also informs about regulations and Norwegian drinking water quality, and provide an overview of current cleaning systems.

Reduction of night time light pollution

- Reducing unnecessary light pollution, energy consumption

  BREEAM: External light pollution is eliminated through effective design or the removal of the need for unnecessary external lighting.

  SINTEF: BRS 380.010 describes the light pollution created by unwanted streetlights above normal requirements.

Reduction of noise pollution

- Where there are, or will be, no noise-sensitive areas or buildings within 800m radius of the assessed site (1 credit)

  BREEAM: Measures to reduce the likelihood of disturbance arising as a result of noise from fixed installations on the development.

  SINTEF: BRS 527.302 treats audio controls and reduction of noise levels by using sound absorbing materials and structures. This manual provides guidance for architects, engineers and consultants who plan and design new industrial premises or remodeling and renovation of existing premises.

3.10. Innovation

- Where the building demonstrates exemplary performance by meeting defined exemplary level performance criteria in one or more of following BREEAM assessment issues.
  BREEAM: Responsible construction practices, Aftercare, Visual comfort, Indoor air quality, Reduction of energy use and carbon emissions, Water consumption, Environmental impact of materials, Responsible sourcing of materials, Project waste management, Recycled aggregates, Adaptation to climate change, Flood risk management and reducing surface water run-off.
  SINTEF: Responsible construction practices, Aftercare, Visual comfort, Indoor air quality, Reduction of energy use and carbon emissions, Water consumption, Environmental impact of materials, Responsible sourcing of materials, Project waste management, Recycled aggregates, Adaptation to climate change, Flood risk management and reducing surface water run-off.

4. Evaluation of quality parameters

In evaluation of quality parameters, only a primary competent factors are selected for study and the comparative study is made with different renovation methods and process. The similarities and dissimilarities in the evaluation method in BREEAM and SINTEF is performed.

4.1 Energy Rating:

BREEAM

In case of whole building energy model (WBEM) (up to 15 credits), calculation are made by National Calculation methodology (NCM) compliment software. Whole building energy model the Energy Performance Ratio for Non Domestic Refurbishment (EPR_{NDR}) is compared with the benchmark value (table 1) to determine the corresponding number of bream credits. The calculation of WBEM value is done in three stages

Step 1: Model the existing building energy performance

Step 2: Model the refurbished building performance

Step 3: Enter the reference, existing and proposed/refurbished building performance into the BREEAM Non Domestic Refurbishment Scoring and Reporting tool.

BREEAM Credits	EPR_{NDR}	Rating	Minimum requirements
1	≥ 0.06	Pass	None
2	≥ 0.12	Good	
3	≥ 0.18	Very Good	
4	≥ 0.24		
5	≥ 0.30		
6	≥ 0.36	Excellent	Requires a minimum of 6 credits to be achieved (equivalent to an EPR_{NDR} of ≥0.36).
7	≥ 0.42		
8	≥ 0.48		
9	≥ 0.54		
10	≥ 0.60	Outstanding	Requires a minimum of 10 credits to be achieved (equivalent to an EPR_{NDR} of ≥0.60).

Table 4 Energy rating system in BREEAM.

Elemental level energy model (ELEM) (up to 12 credits) includes partial and minor refurbishment projects and fit out projects. There are four steps involved in the calculation methodology:

Step 1: Evaluate existing building performance and the potential for improvement

Step 2: Assign end use sub-component weightings which are a function of:
- The outcomes of Step 1
- The building type
- The building servicing strategy
- The level of certification being undertaken

Step 3: Calculate performance against relevant sub-components for the refurbished building

Step 4: Calculate the energy score by multiplying the sub-component scores by the relevant sub-component weightings

The sub-components that are applicable for assessment vary depending on the level of certification being sought, and the building servicing strategy. Table 2 confirms the various sub-components that are applicable for the different levels of assessment/certification.

Rating	**Minimum requirements**
Pass, Good, Very Good	Evidence that the project has complied with the minimum requirements of Building Regulations Approved Document Part L2B
Excellent	Requires a minimum of 36% of available credits to be achieved.
Outstanding	Requires a minimum of 60% of available credits to be achieved.

Table 5 Buildings performance rating w.r.t minimum requirements.

Assessment part	Applicable components	Applicable sub-components
Part 1: Fabric and Structure	Thermal conductance and infiltration	Fabric (U-value)
		Infiltration rate (against heating and cooling)
		Glazing area
Part 2: Core Services	Heating	% heat recovery
		Efficiency of heat generation
		Heating control factor
		Efficiency of heating distribution
		Heating pipework insulation
	cooling	Efficiency of cooling generation
		Cooling control factor
		Efficiency of cooling distribution
		Cooling pipework insulation
	Ventilation	Fan efficiency
		Duct and AHU leakage
		Ventilation control factor
	Hot water	Efficiency of hot water generation
		Hot water control factor
Part 3: Local Services	Lighting	Lighting efficiency
		Lighting control factor
	Local heating, cooling, ventilation and hot water	As above for core services, depending on scope of local provision for local cooling, heating, ventilation and hot water

Table 6 Assessment parts and applicable performance components and sub-components.

SINTEF

In following SINTEF, BRS 472.212 provides an introduction to the use of energy calculation program TEK-Check Energy. Manual is a supplement to help located in TEK-check energy in the form of excel worksheet where all the factors which has effect on energy efficiency is taken into account. SINTEF is using energy labeling system that will help to ensure information on the energy state of the buildings and whether it is possible to improve it, or not. From 1 July 2010, all residential and professional buildings being sold or rented, have an energy certificate. Energy certificate is composed of an energy character certificate scale which range from A to G, which shows energy delivered to the building. Heating character is marked with a color scale which range from green-red, which explains to what extent it will be possible to cover the heat demand by energy sources other than electricity, oil and gas. The list of measures will provide an overview of possible energy efficiency measures.

Key input for energy calculation according to NS 3031: 2014

Calculation conditions

- Proper building category is selected.
- Type of energy is as planned. Efficiencies are in accordance with NS 3031 or documented.
- All areas are in accordance with applicable drawings (BRA, door, window, siding, roofs, floors, separating the unheated zone, etc.).
- Any zoning is in accordance with NS 3031.
- Any unheated areas are excluded from the BRA.
- Shielding of surroundings is taken into account.
- U-values for all parts of the building envelope is as planned (windows, doors, gates, exterior wall, ceiling, floor, partition wall and floors to unheated rooms).
- Input for ventilation according to the current projected values, assumptions in accordance with NS 3701 for commercial buildings.
- Heat capacity is as planned (type surfaces).
- Indoor climate simulations with real conditions are conducted, and input for any mechanical cooling is accordingly.
- Type and eventual management of solar shading is in accordance with the conditions in indoor climate simulations (except housing in heating season according to EN 3700).
- Normalized thermal bridge is under thermal bridge calculation.
- Leakage figures are according to the measured value.
- Sufficient power for heating and cooling is provided.

Results

- Minimum requirements are within the maximum allowable values.
- Airflow is within minimum.
- Heating requirement is within the maximum allowed value.
- Cooling required is within the maximum allowed value.

- Energy is in accordance with requirements.

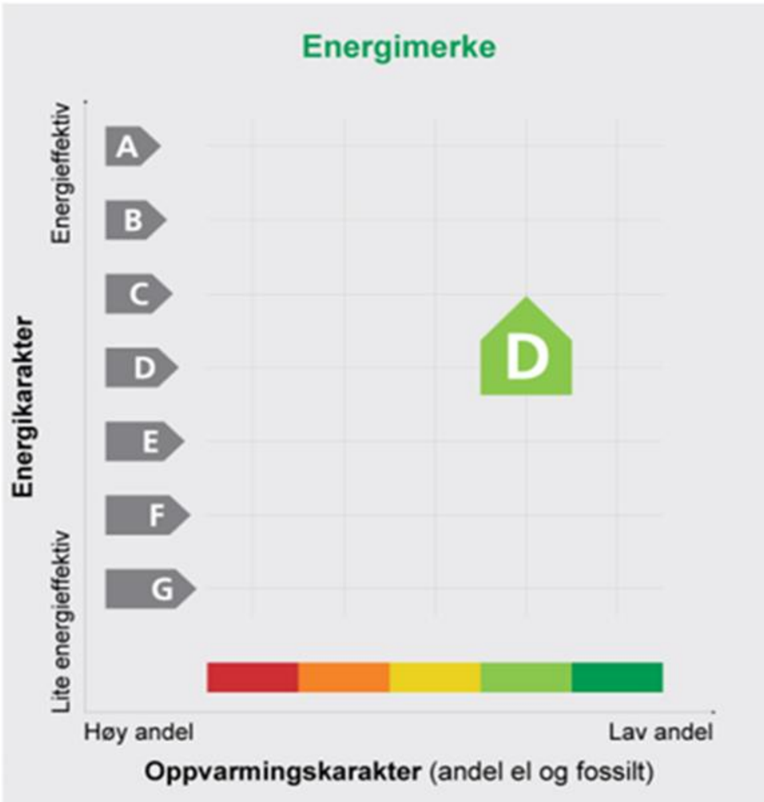

Figure 7 Example of grading scale for energy labeling of homes with energy certificate.

4.2 Energy Monitoring:

BREEAM

BREEAM demands provision of sub metering to both major and minor energy consuming areas. Energy metering systems are installed to enable energy consumption to be assigned to end uses. Energy metering systems should enable at least 90% of the estimated annual energy consumption of each fuel to be assigned from consuming system such as floor heating, domestic hot water heating, ventilation and fans, refrigerants, pumps, lighting etc. Where it is unclear whether an end use(s) would account for 10% of the annual energy consumption for a given fuel type or not, more detailed calculations should be provided.

SINTEF

In following BRS 700.264, Energy Monitoring involves, recording the total usage of energy to a building over shorter periods for example one hour, one day or one week and the energy consumption is analyzed in relation to a characteristic parameter of the measurement period (usually the outside temperature). After this comparison of energy consumption is made in relation expected energy consumption value and client's ambitions and type building determines what level you want to lie on the energy monitoring.

4.3 Visual Comfort:

BREEAM

BREEAM has sub-divided the visual comfort in four assessment criteria which are glare control, daylighting, View out, Internal and external lighting.

Building integrated measures (e.g. low eaves), occupant controlled devices such as blinds (where transmittance value is < 0.1 (10%), bioclimatic design and external shading are the compliment shading measures to meet glare control. The glare control system should be designed to provide the efficient results in both summer and winter days and when using fixed system the design studies can be used to demonstrate that sunlight is prevented from reaching building occupants during occupied hours. The use or location of shading must not conflict with the operation of lighting control systems.

In case of daylighting, the performance of building depends on percentage of relevant building areas that meets either good practice daylight factor or meet good practice average and minimum point daylight illuminance criteria. The minimum requirement of daylight factor for multifamily building is 2% and the minimum average point daylight illuminance for living rooms, dining rooms, study room etc. should be at least 100 lux for 3450 hours per year or more. Credits is distributed with respect to percent of floor area (m^2) complied by daylight. For example, two credits where daylighting provision, averaged over all relevant spaces, has improved after refurbishment or fit-out by 30% or more and there is a minimum glazing to floor area ratio of either 5% glass to floor area ratio for side windows or 2.5% glass to floor area ratio for roof lights. One credit where daylighting provision, averaged over all relevant spaces, has improved after refurbishment or fit-out by 15% or more and there is a minimum glazing to floor area ratio of either 5% glass to floor area ratio for side windows or 2.5% glass to floor area ratio for roof lights.

The minimum requirement of view out in multi-residential building in BREEAM is obtained while the living rooms and bed room's positions within relevant areas are within 5m of a wall which has a window or permanent opening providing an adequate view out. The window/opening must be ≥ 20% of the surrounding wall area.

According to BREEAM all internal lighting should be designed to provide an illuminance (lux) level appropriate to the tasks undertaken, accounting for building user concentration and comfort levels and all external should be designed to provide illuminance levels that enable users to perform outdoor visual tasks efficiently and accurately, especially during the night.

SINTEF

In following BRS 554.215, when the light source for example sun is in the lower angle mostly 0 to 45º with the horizontal axis, there is highest risk of glare which can be controlled by proper shading. An optical reflector can help the occupants to divert the light source according to need and them to control unwanted glare. Figure below how the optical reflector provides no light beams in the required area and the light source is therefore properly shielded.

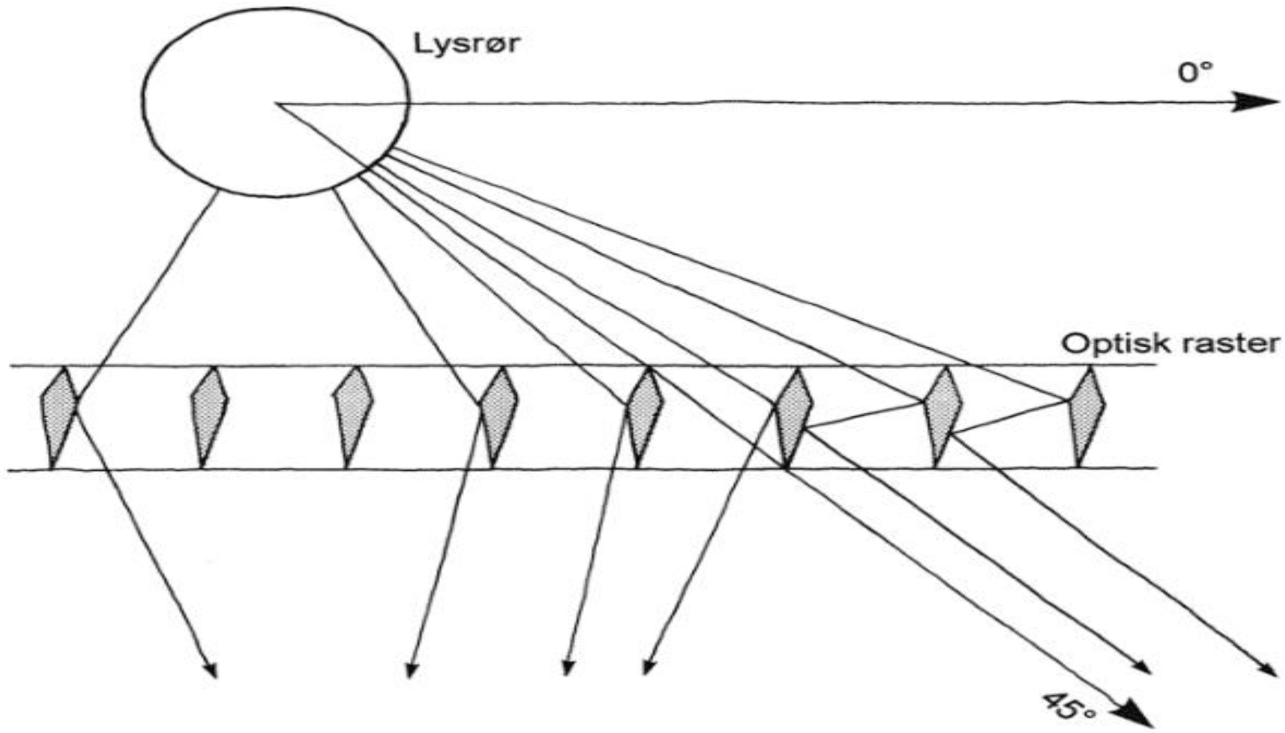

Figure 8 Example showing how optical reflector helps in deviating the light rays.

According to TEK, a room for permanent residence should have out view from windows and satisfactory access to daylight. TEK allows one room can get satisfactory daylight access and windows views from the openings to other rooms or from roof windows. The guide to TEK indicates that the regulation requirement in a residential building is satisfied if the average daylight factor is at least 2.0% and minimum 10% of the room's floor space can covered by daylight. The daylight factor, DF is defined as the ratio of horizontal illuminance indoor and horizontal illuminance outdoors. Illuminance indoors measured 0.8 m above the floor.

BRS 421.610 includes the quality of the artificial lighting (strength, color, direction and variation) is an important part of the indoor environment. The different minimum requirements of lighting illuminance are set up based on different types of work which is shown in table below.

Illuminance in lux			Tasks
Low Level	Normal level	High level	
1	3	5	Outdoor lighting, pedestrian traffic, emergency
15	20	30	Storage compartments, entrance, outdoor work
30	50	75	Living without special operations, general lighting
50	75	100	Areas for brief random visits and recreation, open-access areas
75	100	150	Traffic Zones with respect to buildings
100	150	200	Areas that only used for short periods used for work purposes (warehouses, lobbies)
150	200	300	General lighting and spaces for rough work
200	300	500	Areas of work or with simple visual tasks (coarser yard work, auditoriums)
300	500	750	Areas or fields of work with normal requirements for visual conditions (common yard work, office work easier control work)
500	750	1000	Fields with significant demands to visual conditions (sewing, inspection, testing, intensive control efforts, drawing office)
750	1000	1500	Fields with difficult visual tasks (finer yard work, assembly work)
1000	1500	2000	Fields with special requirements for visual conditions (engraving, inspection of very fine work)
	2000		Fields for highly accurate visual tasks (assembly of electronics components, watchmaker work,surgeries)

Table 7 Different minimum requirements of lighting illuminance

4.4 Low Carbon Design:

BREEAM

BREEAM has divided the low carbon design into two analysis method, one is Passive design analysis and the other is low and zero carbon (LZC) feasibility study. In the passive design the reduction in energy use is demonstrated by comparing the heating and cooling energy demand and the total heating, cooling, mechanical ventilation and lighting energy consumption for a standard building specification with passive design measures. Analysis of thermal comfort in different level is done to demonstrate the building is suitable for passive design analysis and the passive design analysis demonstrates a meaningful reduction in the total energy demand as a result. While the low and zero carbon feasibility (LZC) study is carried out with the help of energy experts/specialist in the concept design stage.

Usually the term zero-energy building on a building that generates enough renewable energy to offset or exceed the building's annual net energy. That is, the sum of delivered and exported energy over a year shall be zero. In Norway, it established a definition of net zero energy building attached to the delivered energy, ie the building has so low energy that the building's need for energy supplied seen over the year can be covered by self-generated renewable energy. ZEB levels of zero-emission buildings in Norway

ZEB Research have defined different stages of zero-emission buildings and the levels depend on how many phases of a building's life included in the calculation[1]. Where,

ZEB-O-EQ: The building's renewable energy production to compensate for greenhouse gas emissions from the operation of the building with the exception of "plug loads."

ZEB-O: The building's renewable energy production to compensate for greenhouse gas emissions from the operation of the building. (This corresponds to a zero energy building.)

ZEB-OM: The building's renewable energy production to compensate for greenhouse gas emissions from operations and production of building materials.

ZEB-COM: building renewable energy production to compensate for greenhouse gas emissions from the construction, operation and production of building materials.

ZEB research has defined that zero-emission buildings must also meet criteria other than CO2 emissions. These criteria include indoor environment, comfort, and energy in the production phase, and that the building should have an energy production at any given time are adapted to the need to keep import / export of energy as low as possible.

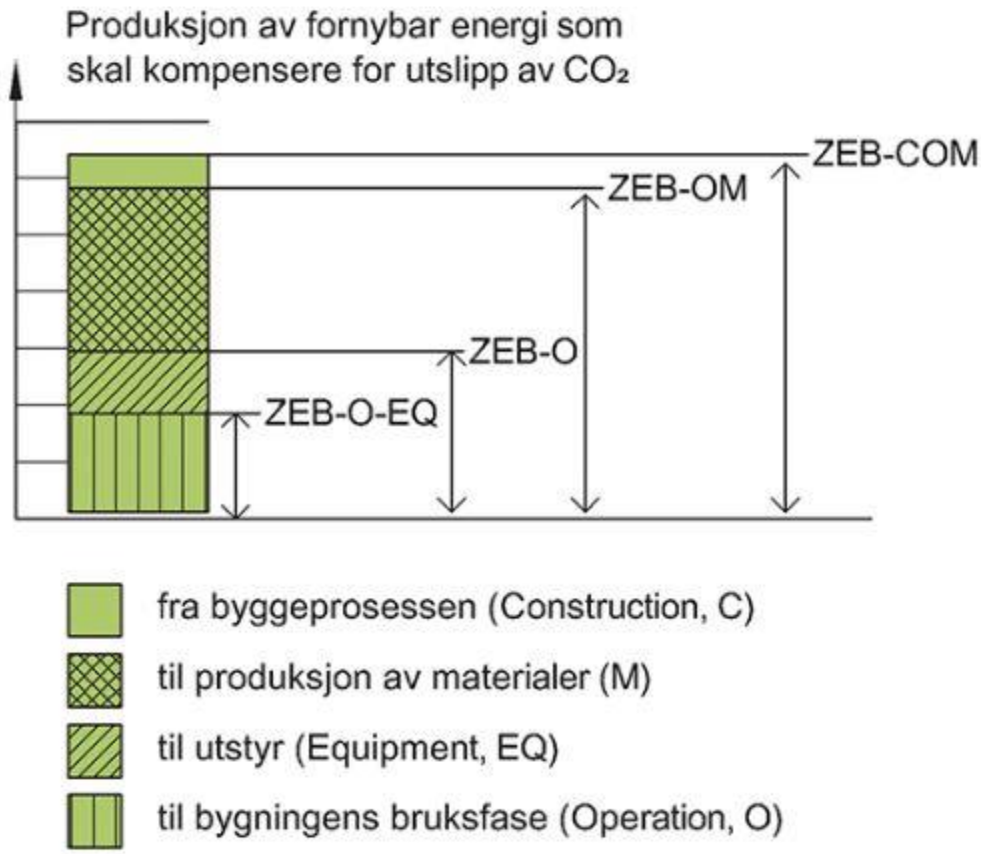

Figure 9 Four important ZEB terms.

4.5 Indoor Air Quality:

BREEAM

In BREEAM the indoor air quality has been analyzed by minimizing sources of air pollution and the potential of natural ventilation. Reducing the air pollution inside a building depends on indoor air quality (IAQ) plan, provision of ventilation and volatile organic compound (VOC) emission levels of materials products as well as post construction.

The indoor air quality plan must consider the following:

- Protection of Heating Ventilation and Air Conditioning (HVAC) systems from sources of pollution during refurbishment/fit-out works for example dust
- Elimination of contaminant sources
- Control of contaminant sources
- Plan of action for pre-occupancy cleaning.
- Action plan for protecting the indoor air quality in the areas zone that may be affected by the refurbishment/fit-out works.
- Plan for identifying and implementing third party testing and analysis required to ensure that the contaminant sources have been removed effectively before occupancy
- Dedication for maintaining indoor air quality in-use, e.g. maintenance and cleaning of the HVAC system, ductwork and filters.

To minimize the concentration and recirculation of pollutants in the building, ventilation with relevant standard should be installed to provide fresh air inside a building. The design of ventilation should satisfy either the building intakes or exhausts are over 10m apart and intakes are over 20m from sources of external pollution or the location of the building's air intakes and exhausts, in relation to each other and external sources of pollution, is designed in accordance with BS EN 13779:2007. In case of naturally ventilated space, openable windows/ventilators are over 10m from sources of external pollution.

Volatile organic compound (VOC) emission levels of materials products must follow the criteria in table 111. In case of volatile organic compound (VOC) emission levels (post construction) should follow the following criteria, The formaldehyde concentration level measured after construction should be less than or equal to 100µg/m3 averaged over 30 minutes (WHO guidelines for indoor air quality: Selected pollutants, 20102).

The total volatile organic compound (TVOC) concentration level is measured after construction should be less than 300µg/m3 over 8 hours, (Building Regulation requirements).

Where VOC and formaldehyde levels are found to exceed the limits defined above, the project team confirms the measures that have, or will be taken, in accordance with the IAQ plan, to reduce the levels to within these limits, including re-measurement.

The testing and measurement of the above pollutants are in accordance with the following standards where relevant:

BS ISO 16000-4: 2011 Diffusive sampling of formaldehyde in air

BS ISO 16000-6: 2011 VOCs in air by active sampling

BS EN ISO 16017-2: 2003 VOCs - Indoor, ambient and workplace air by diffusive sampling

BS ISO 16000-3: 20116 Formaldehyde and other carbonyls in air by active sampling.

The measured concentration levels of formaldehyde (µg/m^3) and TVOC (µg/m^3) are reported, via the BREEAM Assessment Scoring and Reporting Tool.

The level of pollution is tested and measured with respect to relevant standards. The sample measurements is taken from a room where human activities are habitable. And with the help of laboratory measurement and results the further measure to ensure good indoor air quality is done.

The table below shows the standards that should be meet to ensure good quality air.

Ref	Product	Requirements
A	**Paints and varnishes**	
	Performance requirements	VOC content limit
	Compliant performance standard	EU Directive 2004/42/CE ('Paints Directive')
	Compliant testing standard	BS EN ISO 11890-2:2013 – Paints and varnishes – Determination of VOC content, Part 2 – Gas Chromatographic method
	Manufacturer also to confirm	Paint to be fungal and algal resistant in wet areas e.g. bathrooms, kitchens, utility rooms
B	**Wood panels (including particle board, fiberboard including MDF, OSB, cement bonded particle board, plywood, solid wood panel and acoustic board)**	
	Option 1	
	Performance requirements	Formaldehyde E1 class
	Compliant performance standard	BS EN 13986:2004 Wood-based panels for use in construction - Characteristics evaluation of conformity and marking
	Compliant testing standard(s)	In accordance with Annex B of BS EN 13986:2004
	Manufacturer also to confirm	The absence of prohibited wood preservatives/biocides.
	Option 2	
	Performance requirements	Formaldehyde level of 0.1mg/m³
	Compliant testing standard(s)	1. BS EN ISO 16000-9:2006 Indoor air - Part 9: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test chamber method. OR
		2. Standard method for the testing and evaluation of volatile organic chemical emissions from indoor sources using environmental chambers, version 1.1 - Emission testing method for California Specification 01350, Californian Department for Public Health, 2010.
		Note: For either method the resultant emission/surface area obtained from the chamber test method must be extrapolated to predict what the emissions would be in a theoretical model room (as detailed in the standard) and this extrapolated emission rate compared with the required formaldehyde level of 0.1mg/m³.
	Manufacturer also to confirm	The absence of prohibited wood preservatives/biocides.

C	**Timber structures (e.g. glue laminated timber)**	
	Option 1	
	Performance requirements	Formaldehyde E1 Class
	Compliant performance standards	BS EN 14080:2005 Timber structures - Glues laminated timber - Requirements
	Compliant testing standards	In accordance with Annex B of BS EN 13986:2004
	Option 2	
	Performance requirements	As category B Option 2.
	Compliant testing standards	As category B Option 2.
D	**Wood flooring (e.g. parquet)**	
	Option 1	
	Performance requirements	Formaldehyde E1 Class
	Compliant performance standard	BS EN 14342:2005+A1:2008 Wood flooring - Characteristics, evaluation of conformity and marking
	Compliant testing standards	In accordance with Annex B of BS EN 13986:2004
	Option 2	
	Performance requirements	As category B Option 2.
	Compliant testing standards	As category B Option 2.
E	**Resilient textile and laminated floor coverings (e.g. vinyl, linoleum, cork, rubber, carpet, laminated wood flooring)**	
	Option 1	
	Performance requirements	Option 1 - Formaldehyde E1 Class
	Compliant performance standard	BS EN 14041:2006 Resilient, textile and laminate floor coverings - Essential characteristics
	Compliant testing standards	In accordance with Annex B of BS EN 13986:2004
	Option 2	
	Performance requirements	As category B Option 2.
	Compliant testing standards	As category B Option 2.
F	**Suspended ceiling tiles**	
	Option 1	
	Performance requirements	Formaldehyde E1 Class
	Compliant performance standard	BS EN 13964:2004+A1:2006 Suspended ceilings - Requirements and test methods
	Compliant testing standards	In accordance with Annex B of BS EN 13986:2004
	Option 2	
	Performance requirements	As category B Option 2.
	Compliant testing standards	As category B Option 2.
G	**Flooring adhesives**	
	Performance requirements	Carcinogenic or sensitizing volatile substances are substantially absent

	Compliant performance standard	BS EN 13999-1:2013 Adhesives - Short term method for measuring the emission properties of low-solvent or solvent-free adhesives after application - Part 1: General procedure
	Compliant testing standard	1. BS EN 13999-1:2013 Adhesives - Short term method for measuring the emission properties of low-solvent or solvent-free adhesives after application - Part 1: General procedure
		2. BS EN 13999-2:2013 Adhesives - Short term method for measuring the emission properties of low-solvent or solvent-free adhesives after application - Part 2: Determination of volatile organic compounds
		3. BS EN 13999-3:2007+A1:2009 Adhesives - Short term method for measuring the emission properties of low-solvent or solvent-free adhesives after application - Part 3: Determination of volatile aldehydes
		4. BS EN 13999-4:2007+A1:2009 Adhesives - Short term method for measuring the emission properties of low-solvent or solvent-free adhesives after application - Part 4: Determination of volatile diisocyanates
H	**Wall coverings**	
	Performance requirements	Vinyl chloride monomer (VCM) content
		Formaldehyde level
		Migration of heavy metals
	Compliant performance standard	1. BS EN 233:1999 Wallcoverings in roll form - Specification for finished wallpapers, wall vinyls and plastic wall coverings
		2. BS EN 234:1997 Wallcoverings in roll form - Specification for wallcoverings for subsequent decoration
		3. BS EN 259-1:2001 Wallcoverings in roll form - Heavy duty wallcoverings - Part 1: Specifications
	Compliant testing standard	BS EN 12149:1998 – Wall coverings in roll form. Determination of migration of heavy metals and certain other elements, of vinyl chloride monomer and of formaldehyde release

Table 8 Standards that should be meet to ensure good quality air.

The natural ventilation design strategy is a capability of ventilation to provide at least two levels of user-control on the supply of fresh air to the occupied space which are,

Higher level: higher rates of ventilation achievable to remove short term odors and/or prevent summertime overheating
Lower level: adequate levels of draught-free fresh air to meet the need for good indoor air quality throughout the year, sufficient for the occupancy load and the internal pollution loads of the space.

SINTEF

According to TEK § 8-32 concerning air quality, indoor air shall not contain harmful concentration of contaminants known that can cause health hazards and irritation. If the outdoor air is not satisfactory clean with regard to health hazards or risk of soiling of ventilation installations must be cleaned before being installed into the building. BRS 421.502 concerns with requirements for air quality and has given the recommended values for indoor air quality.

Contamination	recommended standard	comments
Tobacco smoke		Should not occur indoors
Non-smoking zone	< 1,0 µg/m3	Practical standard norm for Nico tin concentration
Smoking zones	< 10 µg/m3	Practical standard norm for Nico tin concentration. Apply in restaurants.
Moisture		Moisture and rot should not occur
Muggsopp		Visible mold and mildew smell should not occur
House dust mites	< 1 µg allergen/g dust	Dermatophagoides pteronyssinus
Radon		
Measures Limit 1	> 200 Bq/m3	Easy and cheap measures should be implemented
Measures Limit 2	> 400 Bq/m3	Measures should be implemented
Volatile organic compounds (VOC)		Unnecessary exposure should be avoided
Formaldehyde	< 100 µg/m3	30 minute averaging period
Asbestos	< 0,001 fibrer/ml	Free asbestos fibers should not occur
Synthetic Mineral Fibrer	< 0,01 fibrer/ml	
soar Particles	< 20 µg/m3	PM2,5 24 timers averaging period
Carbon dioxide(CO2)	< 1 800 mg/m3 /1000 ppm	General hygienic indicator air change to prevent uncomfortable body ordor
Carbon monoxide (CO)	< 25/10 mg/m3	1/8 timers averaging period
Nitrogen dioxide	< 100 µg/m3	1 times averaging period

Figure 10 Recommneded technical standards for indoor air quality at specified gas concentration.

Outside air ventilation

In § 8-34, the ventilation plant air intake positioned so that the outside air is the best quality, and so that the heat load in the hot season is minimized. By location should be taken into consideration pollution from traffic, chimneys, wastewater aeration and ventilation exhaust air and sun and danger of driving rain and the like.

Outdoor air can be as polluted because of pollution sources outdoors (road traffic, polluting industries, emissions from furnaces and the like) that it must be cleaned before being fed a building. Normally, this means balanced ventilation. In plants with balanced ventilation and heat recovery should be used filters on both supply and exhaust air to keep channels and components r one.

An outdoor air quantity corresponding to the total exhaust enters the dwelling by a private air supply equipment's. Property located in heavily polluted outdoor air should have balanced mechanical ventilation so that outside air can be cleaned before it enters the dwelling.

Increased ventilation

According to § 8-32 requires TEK that airflows by ventilation will help the indoor climate is perceived as satisfactory. The necessary air supply will be determined by use of materials, number of people and activities. TEK with guidance specifies the minimum amount of air in relation to personal and material stresses.

When sedentary work / light activity, personal factor, equals 7 l / s pr. person. This means that 20% of the visitors to the building will perceive air quality as unsatisfactory,

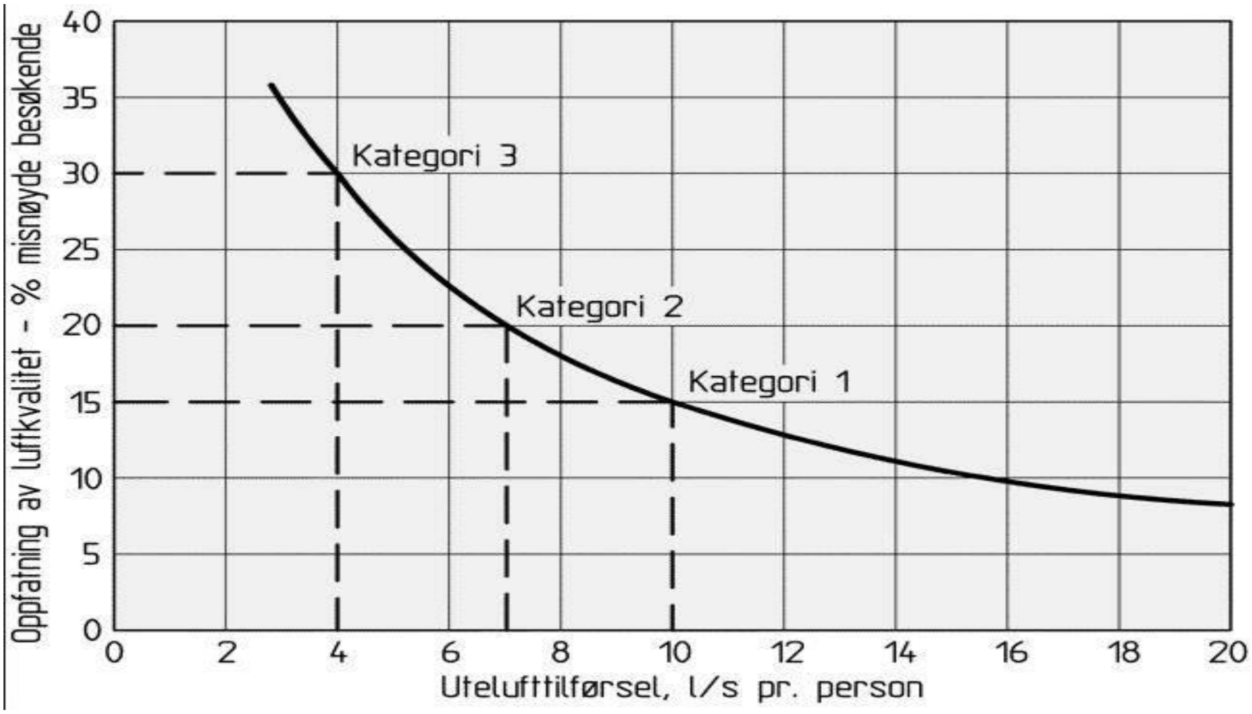

Figure 11 Relationship between the supply of outdoor air per. person and percentage discontented visitors. BRS 421.505.

Management plan for inside climate under construction

The BRS 501,107 describes what can be done during the construction period for a good working under construction and a good indoor environment in the completed building. An important goal is to prevent contaminants and moisture damage from the construction period.

Clean, dry and tidy building process contributes to better track and low volume on the construction site, which improves the work environment and reduces occupational accidents / -Damage and sick leave. Besides contributing such a process to fewer construction defects, less need for working, less time searching for tools, large reductions in landfill waste, and less impurities and moisture damage from the construction period in the finished building.

Management plan for indoor climate before moving

BRS 501,107 in Building deals with clean, dry and tidy building process. Surfaces in rooms, ducts and the like should be cleaned and free of visible dust and grease before building is used. According to the Guide to TEK must establish fixed procedures for cleaning and cleaning throughout the construction period.

It includes:

- establish procedures to prevent dust supplied to the building during the construction period daily cleaning and removing waste, packaging and the like
- periodically vacuuming vulnerable systems, technical rooms, shafts, pipelines and the like
- ensure that the ventilation ducts are sealed by the manufacturer and that the seal is not broken until assembly
- ensure that polluting processes are performed with equipment mounted dust extraction
- ensure that all sawing and cutting takes place outside the building or in a separate kapperom clean surfaces in cavities, walls, etc., before they are closed or sealed
- clean installations ventilation systems before handover conduct thorough main cleaning all surfaces before moving

Low-emission materials

§ 8-33 in technical regulations dealing with pollution. Building and surface materials shall not emit pollutants to the indoor air in the known harmful concentrations with regard to health hazards and irritation. Building and surface materials to be manufactured, handled, stored and used so that issues of pollution and smell to the air being the lowest. The materials must withstand normal use.

VOC values can be used as an indicator of indoor air quality. The following guidelines can be used in Norway under the BRS 421,502 in Building:

- Rooms with VOC concentrations 10- 25 mg / m³ should be used only for short-term stay.
- In rooms for permanent residence should total concentration does not exceed 1 3 mg / m³. Concentrations above 1 mg / m³ suggests that specific pollutants are present.
- As a long term goal should VOC concentration indoor range 0.2 to 0.3 mg / m³.

Indoor chemical pollution control

This is covered in IK required 1. Indoor air shall not contain contaminants known to be harmful concentrations with regard to health hazards and irritation.

4.6 Thermal Comfort

BREEAM

BREEAM has taken thermal modelling, adaptability for a projected climate change scenario and thermal zoning and controls as an assessment criteria to ensure that appropriate thermal comfort levels and thermally comfortable environment for occupants within the building. Thermal modelling has been carried out by help of a software where the simulation at the detailed design stage provides full dynamic thermal analysis in accordance with CIBSE AM111 Building Energy and Environmental Modelling. The thermal modelling of a building demonstrates that the relevant requirements for a projected climate change environment. If the thermal comfort criteria are not met for the projected climate change environment, the project team demonstrates how the building has been adapted, or designed to be easily adapted in the future using passive design solutions In the case for air conditioned buildings, the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices based on the above modelling are reported via the BREEAM assessment scoring and reporting tool.

Control in thermal zoning is based on user's knowledge of building services, occupancy type, and room functions and users expectation. It also depends upon how the user is likely to operate or interact with the system(s), e.g. are they likely to open windows, access thermostatic radiator valves (TRV) on radiators, change air-conditioning settings etc. it is necessary to find out how the proposed systems will interact with each other and how this may affect the thermal comfort of the building occupants.

SINTEF

To evaluate thermal comfort it is introduced two standardized indices, PMV index (Predicted Mean Vote, expected average rating) and PPD index (Predicted Percentage Dissatisfied, waited proportion discontented).

PMV index measures expected average rating of thermal climate on the basis of the following seven point scale:

+ 3 very hot, + 2 hot, + 1 less hot, 0 neutral, -1 less cold, -2 cold, -3 very cold.

PPD index predicts the percentage of a group of people will be dissatisfied with a given thermal indoor climate in a given activity level. When PMV index is calculated, the PPD index calculated or read. The figure below has shown even if the expected average rating is zero the percent dissatisfaction is 5%.

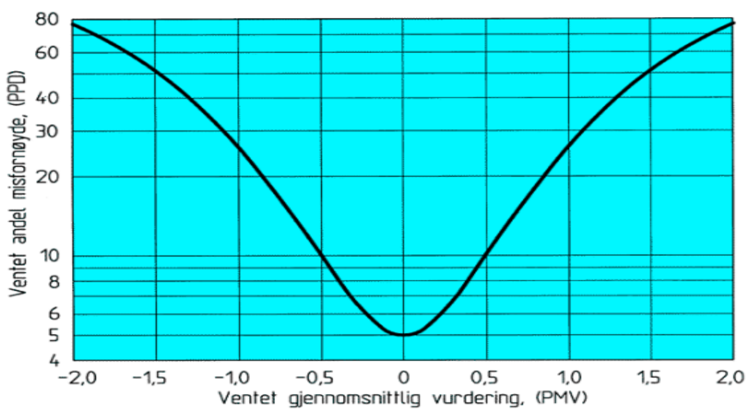

Figure 12 Relationship between expected average rating (PMV) and expected percentage dissatisfied (PPD)

Category	Thermal comfort in the body(Operating temperature)		Local Discomfort			
			Percentage dissatisfied because of			
	Waited and Dissatisfied (PPD) %	Waited Average Rating (PMV)	Pressure %	Temperature Difference %	Varmt or cold floor %	Radiation temperature asymmetry %
Krav	< 10	-0.5 < PMV < +0.5	<15	<5	<10	<5
Refrence	Fig. 12	Fig. 12	Fig. 13	Fig. 14	Fig. 15	Fig. 16

Table 9 Minimum requirement for thermal indoor climate.

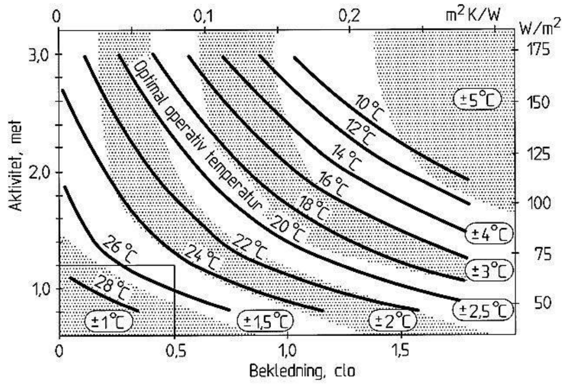

Figure 13 Optimal Operative Temperature depending upon Activity and Clothing.

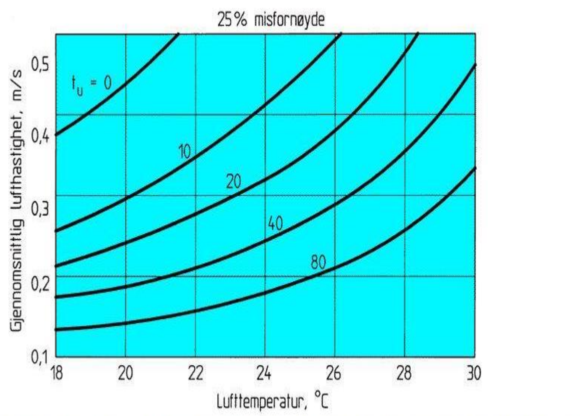

Figure 14 Combination of air temperature, turbulent intensity and average air velocity.

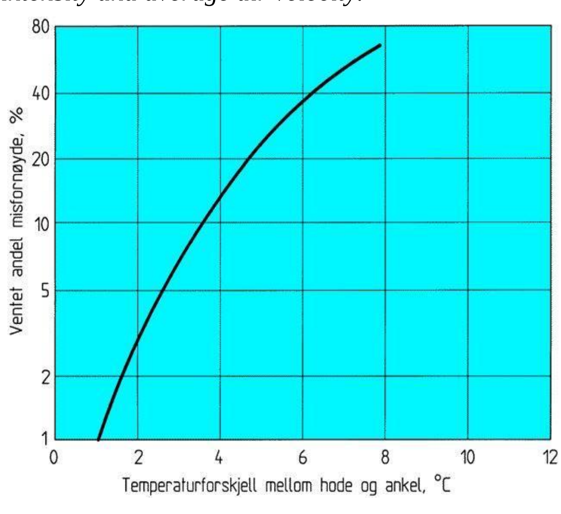

Figure 15 Percentage dissatisfied as a function of difference between air temperature in head and foot.

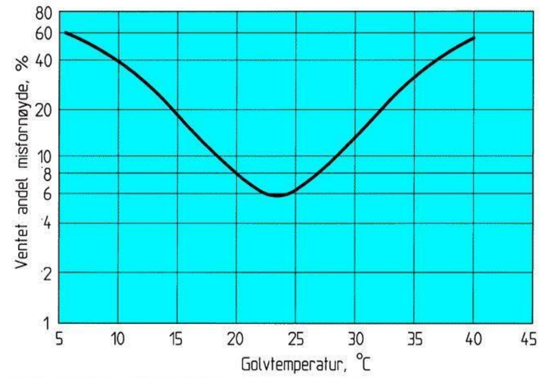

Figure 16 Percentage dissatisfied as function of floor temperature for people.

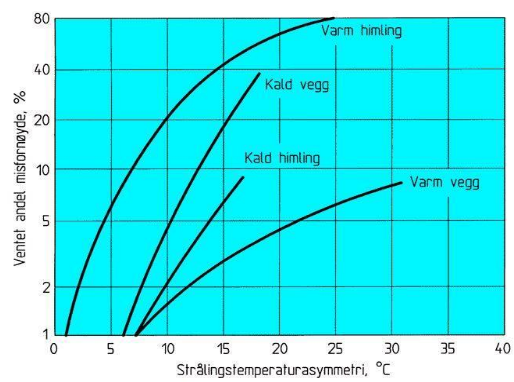

Figure 17 Percentage dissatisfied as a function of radiated temperature asymmetric.

Control of thermal climate

A precise control of thermal indoor climate includes,

- Measurement of air temperature at heights from 0.1 m to 1.6 m.

- Measurement of air velocity at the head and ankle level.

- Measurement of radiation temperature.

- Measurement / calculation of operative temperature at the body's center of gravity.

If the activity level and clothing is known, one can calculate the PMV and PPD on the basis of measurements according to Fig 16.

Measuring points and type of measurements for control of local thermal discomfort and thermal comfort for the body as a whole

Ta = air temperature

V_a = air velocity

T_{op} = operating temperature (measured or calculated, cf. section 23).

P_a = humidity (optional)

D_{tpr} = radiation temperature symmetry

4.7 Acoustic comfort:

In BREEAM acoustic comfort reveals with

- Criteria for sound insulation
- Criteria for indoor ambient noise levels
- Criteria for reverberation control

In case of multi-residential and other residential types of building, one credit is given for where airborne sound insulation values are at least 3dB higher and impact sound insulation values are at least 3dB lower than the performance standards in the relevant Building Regulations or

Standards. Three credits for airborne sound insulation values are at least 5dB higher and impact sound insulation values are at least 5dB lower than the performance standards in the relevant Building Regulations or Standards .And four credits for airborne sound insulation values are at least 8dB higher and impact sound insulation values are at least 8dB lower than the performance standards in the relevant Building Regulations or Standards. The guidance for Building Regulations and Standards depends on country specific guidance and can be different from one country to another. The following Standards or Building Regulations etc. are relevant for the assessment of the issue:

- England referring to Approved Document E 2003 edition, with amendments 2004 and 2010 – Resistance to the passage of sound.
- Northern Ireland referring to - DOE Technical Booklet G - Sound 2012
- Scotland refer to the use of HTM08-01, assessments in Scotland should use SHTM08-017.

SINTEF

In following SINTEF sound insulation is characterized by different building elements such as outer wall, inner wall, slabs, doors windows etc. According to guidance for Planning and Building Act (PBA) Norway follows these standards for acoustic evaluation:

NS 3150 Doors. Sound insulation. Ranking

NS 8175 sound insulation in buildings. Sound classification of different types of buildings

4.8 Project life cycle assessment study

BREEAM

BREEAM has provided the provision to measure the life cycle environmental impact of the refurbishment or fit-out works. The BREEAM project uses a life cycle assessment (LCA) tool or building information model life cycle assessment (BIM LCA) to measure the life cycle environmental impact. The relevant elements that is undertaken for LCA workout are as divided into four parts which are as follows

Part 1 includes elements of the fabric and structure including:	Part 2 and 3 includes elements used for core and local services including:	Part 4 includes interior fit-out elements including:
External walls (envelope, structure and finishes)	Heat source, space heating, air-conditioning and ventilation	Internal floor finishes (including access floors)
External windows and roof lights	Communication, security and control systems	Internal ceiling finishes (including suspended/access ceilings)
Structural frame	Electrical installations	Internal walls and partitions
Basements/retaining walls (including excavations)	Fire and lightning protection	Internal wall finishes
Upper floors (including horizontal structure)	Lift and conveyor installations/systems	Internal windows
Roof (including coverings)	Water and waste installations	Internal doors
Stairs	Sanitary installations	Furniture (desks, chairs, display cabinets, shelving)
External solar shading devices, access structures etc.		Fittings (shop fittings, railings, screens, gutters, vents, air grilles)
Ground/lowest floor		Hard landscaping and boundary protection are included where within scope of work

Table 9: The relevant elements that is undertaken for LCA workout.

The methodology for life cycle assessment study could be described by two options:

Assessing the points awarded for the project life cycle assessment study: This includes Answering the materials assessment tool/method and data questions, assessing the materials assessment scope, calculating the number of points awarded.

Assessing the points awarded for an element: this includes elements present, identify the percentage re-used in situ, calculate the points awarded per element and calculating the percentage of available points achieved.

The points awarded from these method of assessment are used for building performance rating.

SINTEF:

To conducted life cycle assessment an extensive collection of data for the various phases are analyzed. Data can be collected from various sources. Common sources are direct contact with manufacturers, databases, scientific publications and publicly available information. Publicly available environmental information may be obtained from sites managed by Environment Directorate or databases of Statistics Norway. It is recommended to collect data from multiple sources, as far as possible so that one can then compare sources and assess the quality of the sources against each other. Data and data sources must be well documented and transparent. When putting together the life cycle assessment data should be the most product-specific as recommended on BRS 470,103. The procedure for data collection must be carried out in a systematic manner. Good communication with producers is essential.

Where there are no concrete data that can be used and it must be made assumptions regarding expected developments. Assumptions should meet future events related to the construction phase, the use phase and disposal phase. There may be a scenario for how long a transport distance is assumed to be, how often a window replaced, or what kind of waste most likely for a given product. Major methodological differences in choice of scenarios from analysis to analysis could make life cycle methodology lose credibility and usefulness as a basis for sound environmental choice.

5. Comparative summary of quality parameters

The table below shows comparative summary of quality parameters in evaluation of renovation process.

Summary of results based on comparative evaluation:	
Evaluation criteria in BREEAM	**Evaluation criteria in SINTEF/Scandian**
Energy Rating	
Calculation are made by National Calculation methodology (NCM) compliment software	TEK-Sjekk Energy program is used for energy calculation
Whole building energy model the Energy Performance Ratio for Non Domestic Refurbishment (EPR_{NDR}) is compared with the benchmark value	Energy labeling system that will help to ensure information on the energy state of the buildings and whether it is possible to improve it, or not
Major building components are, thermal conductance and infiltration, heating equipment, cooling equipment's ventilation, hot water, lighting	Key input for energy calculation according to NS 3031: 2014
Rating system follow the order Pass, good, very good, excellent, outstanding	Energy certificate is composed of an energy character certificate scale which range from A to G, which shows energy delivered to the building
Energy monitoring:	
Sub-metering to both major and minor energy consuming areas	Energy Monitoring involves, recording the total usage of energy to a building over shorter periods for example one hour, one day or one week
Detailed calculations is provided. It is unclear whether an end use(s) would account for 10% of	Comparison of energy consumption is made in relation to expected energy consumption value.

the annual energy consumption for a given fuel type or not.	
Low carbon design	
two analysis method, one is Passive design analysis and the other is low and zero carbon (LZC) feasibility study.	zero-energy building on a building that generates enough renewable energy to offset or exceed the building's annual net energy
analysis of thermal comfort in different level is done to demonstrate the building is suitable for passive design analysis	considerable amount of thermal comfort
Low and zero carbon feasibility (LZC) study is carried out with the help of energy experts/specialist in the concept design stage.	different ZEB levels are developed depending on how many phases of a building's life included in the calculation
Visual comfort	
External shading are the compliment shading measures to meet glare control.	proper shading is used to control glare, An optical reflector can help the occupants to divert the light source according to need
good practice daylight factor or good practice in average and minimum point daylight illuminance criteria	daylight factor should be at least 2.0%
view out is obtained while the room's positions within relevant areas are within 5m of a wall which has a window or permanent opening providing an adequate view out.	Building should have satisfactory view out from windows and satisfactory access to daylight.
The window/opening must be ≥ 20% of the surrounding wall area.	
internal lighting designed to provide an illuminance (lux) level appropriate to the tasks undertaken, accounting for building user	The different minimum requirements of lighting illuminance are set, based on different types of tasks undertaken inside room.

concentration and comfort levels and all external should be designed to provide	
Indoor air quality	
concerns with minimizing sources of air pollution and the potential of natural ventilation	Concerns with requirements for air quality and has given the recommended values for indoor air quality.
ventilation with relevant standard is installed to provide fresh air	the ventilation plant air intake positioned so that the outside air is the best quality, and so that the heat load in the hot season is minimized
BS EN 13779:2007 is used for design of ventilation	BRS 552.301 manual describes the principles for building ventilation and gives examples of how to calculate ventilation requirements in different homes.
In case of naturally ventilated space, openable windows/ventilators are over 10m from sources of external pollution.	Buildings located in heavily polluted outdoor air should have balanced mechanical ventilation so that outside air can be cleaned before it enters the dwelling.
Thermal comfort	
Thermal modelling has been carried out by help of a software where the simulation at the detailed design stage provides full dynamic thermal analysis	To evaluate thermal comfort it is introduced two standardized indices, PMV index (Predicted Mean Vote, expected average rating) and PPD index (Predicted Percentage Dissatisfied, waited proportion discontented).
Control in thermal zoning is based on user's knowledge of building services, occupancy type, and room functions and users expectation	Control of thermal climate includes measurement of air temperature,air velocity

	radiation temperature and calculation of operative temperature
Acoustic comfort	
includes criteria for sound insulation, criteria for indoor ambient noise levels,criteria for reverberation control	sound insulation is characterized by different building elements such as outer wall, inner wall, slabs, doors windows etc.
airborne sound insulation and impact sound insulation values are compared with relevent building regulation and standards	NS 3150 used for doors sound insulation ranking and NS 8175 is used sound insulation in buildings
Project life cycle assesment study	
The BREEAM project uses a life cycle assessment (LCA) tool or building information model life cycle assessment (BIM LCA) to measure the life cycle environmental impact.	Common sources for LCA are obtained from direct contact with manufacturers, databases, scientific publications and publicly available information
The methodology for LCA study is divided in two options: i) assessing the points awarded for the project life cycle assessment study, ii) Assessing the points awarded for an element	Assumptions regarding expected development is made when there are no concrete data.

Table 10 Comparive summary of quality parmeters in evaluation of renovation process.

6. Discussing best practice method

From the study in different inventory methods that is used for identifying quality parameters in evaluation of renovation process, it is well known that these methods has both similarities and dissimilarities. In this paper the major parameters are selected and evaluated for best renovation practice.

Energy rating: In energy rating system, it is found that BREEAM has more organized system than in SINTEF. BREEAM is using a systematic tool for energy rating where calculation are made by National Calculation methodology (NCM) compliment software while SINTEF is using TEK-check Energy– Norway, excel calculation tool featuring. In case of refurbishment project BREEAM has focused on the potential for improvement by comparing the existing building performance to the average performance of the existing building stock. But in control capacity SINTEF has covered more area than in BREEAM. SINTEF has covered control calculation of energy, control climate calculation, control for passive and low-energy standards in energy rating issues. Nevertheless the Nordic inventory system is more reliable and have high grade of accuracy for energy calculation and rating.

Energy Monitoring**:** Both BREEAM and SINTEF has the provision of energy monitoring system but there is significant different in the methodology used. BREEAM follow sub-metering to both major and minor energy consuming areas to find out the total energy consumption in a building while in SINTEF energy monitoring involves, recording the total usage of energy to a building over shorter periods for example one hour, one day or one week. The method for energy monitoring in BREEAM is quite easy and understandable, but installing sub-meters for each energy source can be more costly and demand more space for sub metering equipment. SINTEF basically focus on the building performance in relation with energy use, where energy consumption from different components and equipment is summed up to find out total energy requirement for a defined time period. Therefore, SINTEF has studied more depth in the energy monitoring system because energy monitoring system has direct influence in building performance against outdoor climatic condition.

Low carbon design**:** Existing buildings are a major contributor to global warming, so both BREEAM and SINTEF has provided different measures to identify areas for carbon reductions.

In BREEAM low or Zero Carbon (LZCs) technologies have been specified to help the building not exceed Target Emission Rate (TER) and this issue seeks to motivate the provision of energy from LZC technologies within the standards set by Building Regulations. In case of SINTEF, ZEB research has defined that zero-emission buildings must also meet criteria of CO2 emissions. These criteria include indoor environment, comfort, and energy in the production phase, and that the building should have an energy production at any given time are adapted to the need to keep import / export of energy as low as possible. In fact the carbon reduction measures in both methods should meet certain building regulation. But in SINTEF we could find more measures for low energy house because the methods used in SINTEF is mainly designed for cold climate Nordic countries where the need for energy efficient buildings is more demanded.

***Visual comfort*:** Both BREEAM and SINTEF has provision of shading against direct sunlight by preventing glare and reflection. Shading reduces the inside temperature and can affect energy consumption in several ways. In case of daylighting, the performance of building depends on percentage of relevant building areas that meets either good practice daylight factor or meet good practice average and minimum point daylight illuminance criteria. The minimum requirement of daylight factor in both BREEAM and SINTEF for multifamily building is 2% and the lighting illuminance is set after knowing the task undertaken or the purpose for using room. Both methods has provision for view out and criteria for requirement for minimum window area. So, in case of visual comfort it can be said that both BREEAM and SINTEF uses more or less same assessment criteria and design practice. But in SINTEF it is more common to use of an optical reflector that can help the occupants to divert the light source according to their need.

***Indoor air quality*:** Indoor air quality is the most important parameter because the indoor air quality has direct impact to health and wellbeing of inhabitants. BREEAM mainly concerns with minimizing sources of air pollution and the potential of natural ventilation where ventilation with relevant standard is installed to provide fresh air. While SINTEF focus on passive solution in designing heating and cooling system of a building and the impact of ventilation, heating, cooling, maintenance, automation regulation, building materials, design, planning etc. on the indoor environment is studied in SINTEF. The indoor air quality system in BREEAM is designed for normal average outdoor temperature in EU while the SINTEF is focused on the indoor design for extreme cold weather condition. But in both methods the naturally openable windows/ventilators should not be close to sources of external pollution. In following SINTEF buildings located in heavily polluted outdoor air should have balanced mechanical ventilation so that outside air can be cleaned before it enters the dwelling.

***Thermal comfort*:** Both BREEAM and SINTEF uses PMV and PPD index where PMV indicates human psychophysical scale and PPD the index gives a quantitative prediction of the number of people who will be dissatisfied with the thermal environment. Operative temperature is the most important for thermal comfort, which is the average of the air dry-bulb temperature and of the mean radiant temperature at the given place in a room. In addition variation the in the radiant temperatures from different directions in the room, the humidity has to be in a comfortable range, and the air temperatures in a height of 0.1 m above the floor should not be more than 2°C lower than the temperature at the place of the occupant's head. In addition, there should be low air velocities and no 'drafts', little variation in the radiant temperatures from different directions in the room, the humidity has to be in a comfortable range, and the air temperatures in a height of 0.1 m above the floor should not be more than 2°C lower than the temperature at the place of the Occupant’s head. Furthermore SINTEF consider the environmental conditions where the thermal comfort depends on the clothing and activity level of a person. Thermal comfort in BREEAM and SINTEF, has no significant variation in evaluation process and method.

***Acoustic Comfort*:** BREEAM includes criteria for sound insulation, indoor ambient noise levels, and reverberation control. Testing of each criteria and comparing with standard value is done for the evaluation of acoustic comfort and the standard value can be different from each other depending open the type of building for example (residential, office, industry etc.). Multi-residential and other residential institutions often contain a mixture of ‘non-residential’ areas such as offices, small retail outlets, meeting rooms etc. and residential areas, e.g. self-contained dwellings or rooms for residential purposes. If an acoustic testing of a building do not satisfy the minimum requirements, remedial works must be carried out to all affected and potentially affected areas. The remedial work specified in BREEAM can be sealing of open area or use of sound observation materials. While in SINTEF the procedure for testing and evaluation for acoustic comfort is same as in BREEAM but the standard values measures of remedial works is defined in NS 3150 (used for doors sound insulation ranking) and NS 8175 (used sound insulation in buildings). For evaluation of acoustic comfort both BREEAM and SINTEF has done sufficient study and have developed advanced remedial measures.

Project life cycle assessment study: The BREEAM project uses a life cycle assessment (LCA) tool or building information model life cycle assessment (BIM LCA) to measure the life cycle environmental impact while in SINTEF life cycle assessment of each building component evaluates the potential environmental impacts throughout a product's or a building's life cycle, from extraction of raw materials through production and until disposal. Common sources for LCA in SINTEF are obtained from direct contact with manufacturers, databases, scientific publications and publicly available information. Building Research series 470.102 provides guidance for defining system boundaries, functional unit and life as well as the scope and what tools to use for LCA. The best alternative is the one that the LCA shows to have the least negative impacts on environmental.

7. Conclusion

The purpose of this project was to make a comparative study of different inventory methods between BREEAM and Nordic methods (SINTEF) for the evaluation of quality parameters in renovation project. From the study, it is found that BREEAM is using more advanced and latest technologies for the evaluation of refurbishment projects while SINTEF is using theory and data based research papers and contain huge amount of data and resources.

From this research project it can assume that BREEAM is using consistently best inventory research but this may not be suitable in all condition or in every place over Europe. It is because the refurbishment methods, standards and tools used for example in Norway and UK can vary from large extent due to geographical and climatic variation. Furthermore, the evaluation of quality parameters largely depends on the user's capacity for investment and their desire for comfort level. Every people cannot afford same comfort level as other do.

Although the evaluation performed in this research purposed for alternative solution, but this research do not cover evaluation of all the parameters that can be used for upgradation of a building. The major parameters are carried out for the evaluation of renovation project because of limitation of task to be performed and these parameters are selected on the basis of highest impact in quality evaluation.

Based on the findings, this research will give a clue for all the key personal (engineers, designer, consultants, owner etc.) of the project for implementing the best measure in renovation projects. Although the purpose of different factors for evaluation of quality parameters attempt to find the same thing but the methodology of implementation has significant variation in some cases. For example in case of energy rating, energy calculation in BREEAM are made by National Calculation methodology (NCM) compliment software, while in case of TEK-check energy program is used for energy calculation. But in some cases both methods uses the same procedure in evaluation, for example while evaluating thermal comfort the procedure of finding out PMV and PPD index is same in both BREEAM and SINTEF.

8. Development of suitable questionnaires for evaluation of the renovation process

The suitable question for the evaluation of renovation process can be as follows,

1. How important is it for you to increase the market value of your home after refurbishment?
2. How important is it for you to reduce your home maintenance yearly spending?
3. How much do you spend yearly in the maintenance of your home?
4. How important is it for you to reduce energy consumption?
5. How much amount of energy you spent in one month?
6. How much money you want to spent in refurbishment?
7. How much time you spent inside your home?
8. How satisfactory is the quality of the indoor air quality in your home?
9. Has anyone of the family member experience sickness and fatigue inside home?
10. Has anyone of the family member experienced a feeling discomfort in your home?
11. Has anyone of family member has asthma or other allergic disease in your home?
12. Has anyone in the family been bothered by humid air, traces of humidity or condensation in your home?
13. Has anyone in the family been bothered by bad or stuffy smells in your home?
14. How satisfactory is the quality of the sanitary equipment in your home?
15. Has anyone in your family feels too cold or too warm inside your home?
16. Has any in the family been bothered by fluctuations of temperatures?
17. Has anyone in the family experienced the need of more lighting in your home?
18. Has anyone in the family been bothered by reflects or glare?
19. Do you wish for a better view to the outside?
20. How you control temperature inside your home?
21. Do you feel enough floor area of your home?
22. Are you bothered from unwanted sound inside your home?

References

(u.d.).

(2014, May 18). Hentet fra Slide Share: http://www.slideshare.net/satyakisikdar3/maintenance-and-repair-of-buildings

(2016, June 22). Hentet fra Norsk Kommunalteknisk Forening: http://www.kommunalteknikk.no/

Anders Homb, F. S. (1997, Spring). SINTEF Byggforsk Kunnskapssystemer. *527.302 Lydregulering og støyreduksjon i industrilokaler*, ss. ISSN 2387-6328.

Bjørneboe, J. (1990, Autum). SINTEF Byggforsk Kunnskapssystemer. *312.304 Felles og private utearealer*, ss. ISSN 2387-6328.

Bjørn-Roar Krog, J. C. (2013, June). SINTEF Byggforsk Kunnskapssystemer. *553.135 Lekkasjestoppere*, ss. ISSN 2387-6328.

Bjørn-Roar Krog, J. C. (2015, December). SINTEF Byggforsk Kunnskapssystemer. *553.163 Energieffektive og vannbesparende sanitærinstallasjoner*, ss. ISSN 2387-6328.

Christian J. Engelsen, M. S. (2015, March). SINTEF Byggforsk Kunnskapssystemer. *572.111 Resirkulert tilslag av tegl og betong*, ss. ISSN 2387-6328.

Dawn Danby, A. M. (u.d.). Hentet fra Autodesk Sustainability Workshop: http://sustainabilityworkshop.autodesk.com/buildings/occupant-comfort

DPR Art Rescue, L. O. (2016, March). Hentet fra A Publication of DPR Art Rescue: http://www.conservation-design.com/index.html

Dr. Márton Herczeg, D. M. (2014). *Resource efficiency in the building.* Copenhagen: Copenhagen Resource Institute.

Eivind Junker, A. K. (2013, December). SINTEF Byggforsk Kunnskapssystemer. *311.200 Forebygging av flom- og skredskader. Lovgivning og ansvar*, ss. ISSN 2387-6328.

Erik Selmer, T. G. (1999, Spring). SINTEF Byggforsk Kunnskapssystemer. *380.011 Utendørs belysning. Utstyr*, ss. ISSN 2387-6328.

Erik Selmer, T. G. (1999, Spring). SINTEF Byggforsk Kunnskapssystemer. *380.010 Utendørs belysning. Planlegging*, ss. ISSN 2387-6328.

G.P.A, B. J. (1997). Hentet fra Introduction to paint chemistry and principles of paint technology. Unk. ISBN 0-412-: https://simple.wikipedia.org/wiki/Paint

Gine Støren, K. N. (2003, Autum). SINTEF Byggforsk kunnskapsystemer. *220.210 Sikkerhet mot ulykker i og ved boligen*, ss. ISSN 2387-6328.

Group, B. (2012). *BREEAM Nor Version 1.1 Technmical Manual.* Norway: Norwegian Green Building Council.

Group, B. (2014). *BREEAM UK New Construction Technical Manual.* UK: BRE Global LTD.

Group, B. (2014). *BREEAM UK Refurbishment and Fit-out 2014* . UK: BRE Global LTD 2014.

Gyran, T. (1998, Autum). SINTEF Byggforsk Kunnskapssystemer. *554.215 Belysningsarmaturer*, ss. ISSN 2387-6328.

Gyran, T. S. (1998). SINTEF Byggforsk kunnskapsystemer. *554.215 Belysningsarmaturer*, ss. ISSN 2387-6328.

Ingunn Milford, A. K. (1997, Autumn). SINTEF Byggforsk kunnskapsystemer. *421.610 Krav til lys og belysning*, ss. ISSN 2387-6328.

Institutt, K. R.-L. (2000). SINTEF Byggforsk kunnskapssystemer. *511.211 Planlegging for bygging på forurenset grunn*, ss. ISSN 2387-6328.

James P. Rydock, J. C. (1999, Spring). SINTEF Byggforsk kunnskapsystemer. *552.360 Plassering av friskluftinntak og avkast for å minske forurensning*, ss. ISSN 2387-6328.

Jens Bjørneboe, A. K. (2004, Autum). SINTEF Byggforsk Kunnskapssystemer. *312.112 Trafikksikker utforming av veier i boligområder,* ss. ISSN 2387-6328.

Jens Holger Rindel, B. G. (1998, Autum). SINTEF Byggforsk kunnskapsystemer. *527.300 Romakustikk*, ss. ISSN 2387-6328.

Johan B. Skjønhaug, J. C. (2000, Autum). SINTEF Byggforsk Kunnskapssystemer. *515.165 Enkle renseanlegg for forbruksvann,* ss. ISSN 2387-6328.

Johan B. Skjønhaug, J. C. (2000, Autum). SINTEF Byggforsk Kunnskapssystemer. *515.165 Enkle renseanlegg for forbruksvann*, ss. ISSN 2387-6328.

Jonassen, K. R.-L. (2000). SINTEF Byggforsk kunnskapsystemer. *511.211 Planlegging for bygging på forurenset grunn*, ss. ISSN 2387-6328.

Kirkhus, A. (1997, Autum). SINTEF Byggforsk Kunnskapssystemer. *421.610 Krav til lys og belysning*, ss. ISSN 2387-6328.

Kirkhus, A. (2015, Mars). SINTEF Byggforsk Kunnskapssystemer. *312.130 Parkeringsplasser og garasjeanlegg*, ss. ISSN 2387-6328.

Kirkhus, J. N. (2004, Autumn). SINTEF Byggforsk kunnskapsystemer. *421.626 Beregning av gjennomsnittlig dagslysfaktor og glassareal*, ss. ISSN 2387-6328.

Knut Ivar Edvardsen, E. B. (2012, May). SINTEF Byggforsk Kunnskapssystemer. *451.021 Klimadata for termisk dimensjonering og frostsikring*, ss. ISSN 2387-6328.

Levin, P. (2014). *Energy Renovations of.* Sweden: Projektengagemang AB.

Marit Thyholt, I. S. (2011, June). SINTEF Byggforsk kunnskapsystemer. *471.024 Krav til energieffektivitet ved energirammer (totalt netto energibehov)*, ss. ISSN 2387-6328.

Michele De Carli, V. D. (2008). *Michele De Carli, Valeria De Giuli* and Roberto Zecchin* . Copenhagen, Denmark: Michele De Carli, Valeria De Giuli* and Roberto Zecchin .

Ottesen., N. A. (2009, August). SINTEF Byggforsk kunnskapssystemer. *773.341 Asbestsanering*, ss. ISSN 2387-6328.

Peter Blom, B. R. (2011, June). SINTEF Byggforsk kunnskapsystemer. *471.018 Generelle energikrav til bygninger. Krav til energieffektivitet ved energitiltak*, ss. ISSN 2387-6328.

Peter Blom, I. C. (1999, Spring). SINTEF Byggforsk kunnskapsystemer. *421.501 Temperaturforhold og lufthastighet. Betingelser for termisk komfort*, ss. ISSN 2387-6328.

Peter Blom, I. C. (1999, Spring). SINTEF Byggforsk kunnskapsystemer. *421.501 Temperaturforhold og lufthastighet. Betingelser for termisk komfort*, ss. ISSN 2387-6328.

Peter Blom, K. I. (2000, Autum). SINTEF Byggforsk kunnskapsystemer. *421.505 Krav til innemiljøet i yrkes- og servicebygninger*, ss. ISSN 2387-6328.

Peter Blom, O. M.-J. (1994, Autum). SINTEF Byggforsk kunnskapsystemer. *552.302 Naturlig og mekanisk avtrekksventilasjon i småhus*, ss. ISSN 2387-6328.

Plesser, T. S. (2012, October). SINTEF Byggforsk Kunnskapssystemer. *421.523 Emisjoner fra byggevarer. Måling i laboratorium og resultater*, ss. ISSN 2387-6328.

Rosenberg, E. (2015). *Energy Efficiency trends and policies in Norway.* Norway: Institute for Energy Technology.

Silje Wærp, H. V. (2011, August). SINTEF Byggforsk Kunnskapssystemer. *470.112 Miljøriktig valg av produkter. ECOproductmetoden*, ss. ISSN 2387-6328.

Silje Wærp, T. S. (2012, October). SINTEF Byggforsk kunnskapsystemer. *421.522 Emisjoner fra byggevarer. Anbefalte grenseverdier*, ss. ISSN 2387-6328.

SINTEF Byggforsk Kunnskapssystemer. (1991, Autum). *700.264 Systemer for energioppfølging*, ss. ISSN 2387-6328.

SINTEF Byggforsk Kunnskapssystemer. (1999, Spring). *520.067 Frostnedbrytning av betong og andre porøse byggematerialer*, ss. ISSN 2387-6328.

Staniaszek, D. (2013). *A GUIDE TO DEVELOPING STRATEGIES FOR BUILDING ENERGY RENOVATION.* Berlin: Buildings Performance Institute Europe (BPIE).

Stig Kåre Kanstad, P. B.-J. (1991, Autum). SINTEF Byggforsk kunnskapsystemer. *700.264 Systemer for energioppfølging*, ss. ISSN 2387-6328.

Sverre K. Fossdal, T. K. (2004, Autum). SINTEF Byggforsk Kunnskapssystemer. *501.101 Planlegging og bygging med lite avfall*, ss. ISSN 2387-6328.

Thale Plesser, K. S. (2015, June). SINTEF Byggforsk Kunnskapssystemer. *470.104 Eksempler på livsløpsvurdering (LCA) av trefasader og ytterveggskonstruksjoner*, ss. ISSN 2387-6328.

Thale Sofie Wester Plesser, S. W. (2012, October). SINTEF Byggforsk kunnskapsystemer. *421.523 Emisjoner fra byggevarer. Måling i laboratorium og resultater*, ss. ISSN 2387-6328.

Thyholt, M., Pettersen, T. D., Haavik, T., & Wachenfeldt, B. J. (2009). *Advanced Housing Renovation.* Norway: Solar Heating & Cooling Programe International Energy Agency.

Tollef Eliassen, A. H. (2011, May). SINTEF Byggforsk Kunnskapssystemer. *700.804 Planlegging av rivearbeider*, ss. ISSN 2387-6328.

Tollef Eliassen, A. H. (2011, August). SINTEF Byggforsk Kunnskapssystemer. *700.806 Gjennomføring av rivearbeider*, ss. ISSN 2387-6328.

Tor Kristensen, O. M.-J. (2005, Autum). SINTEF Byggforsk Kunnskapssystemer. *570.111 Helse, miljø og sikkerhet (HMS) ved bruk av bygningsmaterialer*, ss. ISSN 2387-6328.

Tore Kvande, K. R. (2010, September). SINTEF Byggforsk Kunnskapssystemer. *Byggskader. Oversikt*, ss. ISSN 2387-6328.

Tore Kvande, K. R. (2012, May). SINTEF Byggforsk kunnskapsystemer. *451.021 Klimadata for termisk dimensjonering og frostsikring*, ss. ISSN 2387-6328.

Tore Kvande, K. R. (2013, August). SINTEF Byggforsk Kunnskapssystemer. *451.031 Klimadata for dimensjonering mot regnpåkjenning*, ss. ISSN 2387-6328.

Trine Dyrstad Pettersen, T. K. (2044, Spring). SINTEF Byggforsk Kunnskapssystemer. *701.266 Energisparende tiltak i boliger*, ss. ISSN 2387-6328.

Valde, N. A. (2010, January). SINTEF Byggforsk kunnskapssystemer. *773.340 Asbest i bygninger. Forekomst og påvisning*, ss. ISSN 2387-6328.

Valde, N. A. (2011, March). SINTEF Byggforsk kunnkapssystemer. *241.070 Avfallshåndtering i byggesaker. Planlegging og dokumentasjon*, ss. ISSN 2387-6328.

Vik, H. (2014, September). SINTEF Byggforsk Kunnskapssystemer. *470.101 Livsløpsvurdering (LCA) av byggevarer og bygninger. Innføring og begreper*, ss. ISSN 2387-6328.

Webster, M. (2013, October 3). Hentet fra https://en.wikipedia.org/wiki/Renovation

Wærp, S. (2014, September). SINTEF Byggforsk kunnskapsystemer. *Byggforskserien 470.101*, ss. ISSN 2387-6328.

Yrkesbygninger, K. f. (2016, Feburary). SINTEF Byggforsk Kunnskapssystemer. *472.212 Bruksanvisning for energiberegningsprogrammet TEK-sjekk Energi*, ss. ISSN 2387-6328.