Sustainable Refurbishment - Nordic Case Studies

Almås, Anders-Johan; Huovila, Pekka; Vogelius, Peter; Marteinsson, Björn; Bjørberg, Svein; Haugbølle, Kim; Nieminen, Jyri

Published in:
CIP Proceedings

Publication date:
2011

Document Version
Accepted author manuscript, peer reviewed version

Sustainable Refurbishment – Nordic Case Studies

Anders-Johan Almås
PhD-student
NTNU,
SINTEF Buildings and Infrastructure
& Multiconsult
Norway
aja@multiconsult.no

Chief Research Scientist Pekka Huovila, VTT, Finland, pekka.huovila@vtt.fi
Senior Researcher PhD Peter Vogelius, Danish Building Research Institute, Denmark, pev@sbi.dk
Ass Prof Björn Marteinsson, University of Iceland & Innovation Centre of Iceland, bjorn.m@nmi.is
Prof Svein Bjørberg, Norwegian University of Science and Technology, sb@multiconsult.no
Senior Researcher PhD Kim Haugbølle, Danish Building Research Institute, Denmark, khh@sbi.dk
Customer Manager Jyri Nieminen, VTT, Finland, jyri.nieminen@vtt.fi

Summary

To develop a Nordic guideline on sustainable refurbishment, the SURE (sustainable refurbishment) research project has investigated 10 different cases, aiming to find out how the refurbishment is done and which possibilities and barriers there are to achieve a sustainable refurbishment. The similarities and differences between the cases and country specific parameters, together with the client discussions and internal workshops, have crystallized some important topics for a Nordic guideline on sustainable refurbishment of buildings.

Keywords:Sustainable refurbishment, existing buildings, Nordic guideline, building owner

1. Introduction

The overall objectives of the Nordic SURE research project have been to build a Nordic network among industry, authorities and researchers to improve knowledge exchange on sustainable procurement, summarize state-of-the-art on the interplay between life-cycle costing, environmental assessment of buildings and sustainable procurement, assess and classify various sustainable procurement strategies already being deployed by public clients on refurbishment of existing public buildings, analyse the experiences of public clients acting as sustainable change agents on the implementation of sustainable refurbishment in construction and real estate and finally develop a Nordic guideline on sustainable refurbishment of buildings based on the case studies and different client-specific and internal workshops/discussions. The 10 case studies focus on the different interactions shown on the figure to the left. Both the framework conditions for the client, the client organisation, development projects and the refurbishment project itself (case buildings) have been investigated in order to make a good basis for a Nordic guideline for sustainable refurbishment (figure 1).

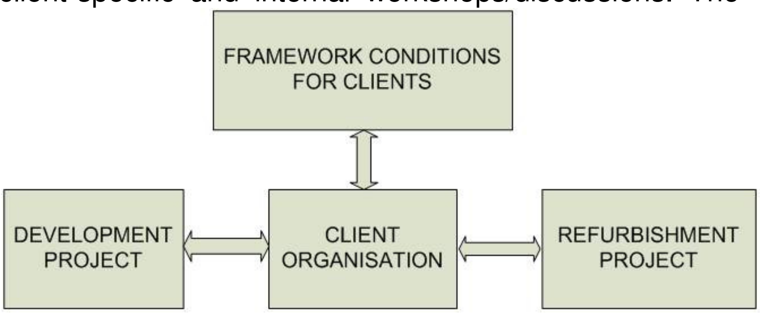

Figure 1: The different interactions studied in the SURE Project.

2. State of the art

The built environment in Norway comprises approximately 3.8 million buildings and 380 million square metres. Among the 3.8 million buildings there are approximately 1.4 million residential buildings, 1.2 million garages and other small annexes, 460 000 cabins and 40 000 office buildings. The population of Norway is 4.9 million and is expected to reach 6.5 million in the year 2050.
In Denmark, buildings built in the period 1950-1979 dominate the building stock, followed by 1980-2009 and 1900-1949. The public building stock (year 2007) counts to a total of 50 200 buildings (43.5 million m^2), and is heavily dominated by institutions owned by the municipalities. The population in Denmark is 5.56 million. The total number of buildings in Finland is approximately 1.4 million (free time residencies and agricultural buildings not included). The gross floor area is about 429 million m^2. The building stock is young; most of the buildings are built after 1970s. Residential buildings account for about 63% of the total building stock. Of these, 35% are built in the 80s or later, 25% in the 70s and 30% between 1946 and 1970. The total value of the building stock is 320 billion EUR, and the population in Finland is 5.26 million. The building mass in Iceland is relatively young, approximately 30 years on average. The energy situation in major parts of Iceland is somewhat special. The energy is both cheap and sustainable. Energy for heating in buildings is supplied by geothermal hot water from a distribution net, and electricity for household appliances and lighting electricity from hydro power stations. The energy is therefore considered as environmentally-friendly. The energy consumption for buildings is typically around 40% of total energy consumption in the Nordic countries, as in most other Western countries. The population in Iceland is 0.3 million.

3. Case Studies

Focusing on energy efficiency in existing buildings is of high importance in Denmark, Norway and Finland. In Iceland, though, due to the use of geothermal energy the refurbishment projects focus much more on quality standard and maintenance than energy efficiency. This exemplifies one major difference between the Nordic countries when it comes to priorities for sustainability refurbishment of buildings. There are also other differences, mostly related to building codes, building stock, population, culture and market changes.
Three of the four Norwegian cases have been set on hold due to finance barriers or conflicts between energy reduction and building conservation. The last Norwegian case study has improved the energy consumption dramatically, but the energy source is still non-sustainable (oil boiler). One of the two Danish cases is very ambitious when it comes to energy reduction, and valuable inputs on the processes and management is collected. The second Danish case study has improved the roof construction and installed an energy control system, and managed to reduce the energy consumption dramatically. The first of the three Finnish case studies has halved the heating energy consumption. The second case study is stopped due to financial barriers, and the last Finish case study is still in planning phase. The Icelandic case study has almost no focus on energy reduction, but high focus on building quality standard and maintenance.

4. Discussions and inputs to guideline

The similarities and differences between the cases and country specific parameters, together with the client discussions and internal workshops, have crystallized some important topics for a Nordic guideline on sustainable refurbishment of buildings. One of the most important actions is to help the clients (building owners) to think sustainable. First, the finance model must be set and the process of defining sustainability has to be done. Then, a strategy and ambition level for the project is needed. The strategy and ambition level cannot be set before the client has a performance profile of the building, and therefore a condition survey is of high importance in a very early stage of the project. One of the questions which often arise is weather to refurbish or tear down the building. A guideline on sustainable refurbishment of buildings should give a helpful tool to make the client conclude on this question. Also, a list of sustainable indicators should be presented. The indicators should be mostly quantitative so that they can be measured and benchmarked. Further, the guideline should help the client to plan how to implement these indicators into the project, but also give guidance on how to check the indicators both during planning, building and operation.

Sustainable Refurbishment – Nordic Case Studies

Anders-Johan Almås
PhD-student
NTNU,
SINTEF Buildings and Infrastructure
& Multiconsult
Norway
aja@multiconsult.no

Chief Research Scientist Pekka Huovila, VTT, Finland, pekka.huovila@vtt.fi
Senior Researcher PhD Peter Vogelius, Danish Building Research Institute, Denmark, pev@sbi.dk
Ass Prof Björn Marteinsson, University of Iceland & Innovation Centre of Iceland, bjorn.m@nmi.is
Prof Svein Bjørberg, Norwegian University of Science and Technology, sb@multiconsult.no
Senior Researcher PhD Kim Haugbølle, Danish Building Research Institute, Denmark, khh@sbi.dk
Customer Manager Jyri Nieminen, VTT, Finland, jyri.nieminen@vtt.fi

Summary

The overall objectives of the Nordic SURE research project (Sustainable Refurbishment) have been to build a Nordic network among industry, authorities and researchers to improve knowledge exchange on sustainable procurement. Further, to summarize state-of-the-art on the interplay between life-cycle costing, environmental assessment of buildings and sustainable procurement, assess and classify various sustainable procurement strategies already being deployed by public clients on refurbishment of existing public buildings and analyse the experiences of public clients acting as sustainable change agents on the implementation of sustainable refurbishment in construction and real estate. And finally, to develop a Nordic guideline on sustainable refurbishment of buildings based on case studies and different client-specific and internal workshops/discussions. Focusing on energy efficiency in existing buildings is of high importance in Denmark, Norway and Finland. In Iceland, though, due to the use of geothermal energy the refurbishment projects focus much more on quality standard and maintenance than energy efficiency. This exemplifies one major difference between the Nordic countries when it comes to priorities for sustainability refurbishment of buildings. There are also other differences, mostly related to building codes, building stock, population, culture and market changes. To develop a Nordic guideline on sustainable refurbishment, the SURE research project has investigated 10 different cases in the four countries, aiming to find out how the refurbishment is done and which possibilities and barriers there are to achieve a sustainable refurbishment. The similarities and differences between the cases and country specific parameters, together with the client discussions and internal workshops, have crystallized some important topics for a Nordic guideline on sustainable refurbishment of buildings. One of the most important actions is to help the clients (building owners) to think sustainable. First, the finance model must be set and the process of defining sustainability has to be done. Then, a strategy and ambition level for the project is needed. The strategy and ambition level cannot be set before the client has a performance profile of the building, and therefore a condition survey is of high importance in a very early stage of the project. One of the questions which often arise is weather to refurbish or tear down the building. A guideline on sustainable refurbishment of buildings should give a helpful tool to make the client conclude on this question. Also, a list of sustainable indicators should be presented. The indicators should be mostly quantitative so that they can be measured and benchmarked. Further, the guideline should help the client to plan how to implement these indicators into the project, but also give guidance on how to check the indicators both during planning, building and operation.

Keywords:Sustainable refurbishment, existing buildings, Nordic guideline, building owner

1. Introduction

This paper is written in the ongoing Nordic research project “SURE - Sustainable Refurbishment – life-cycle procurement and management by public clients”. The overall objectives of the SURE project have been to build a Nordic network among industry, authorities and researchers to improve knowledge exchange on sustainable procurement, summarize state-of-the-art on the interplay between life-cycle costing, environmental assessment of buildings and sustainable procurement, assess and classify various sustainable procurement strategies already being deployed by public clients on refurbishment of existing public buildings, analyse the experiences of public clients acting as sustainable change agents on the implementation of sustainable refurbishment in construction and real estate and finally develop a Nordic guideline on sustainable refurbishment of buildings based on the case studies and different client-specific and internal workshops/discussions [1]. The structure and contents in the guideline are described in [2], while this paper focuses on the case studies, describing both differences and similarities between Norway, Denmark, Finland and Iceland when it comes to challenges for sustainable refurbishment, priorities, requirements and client models.

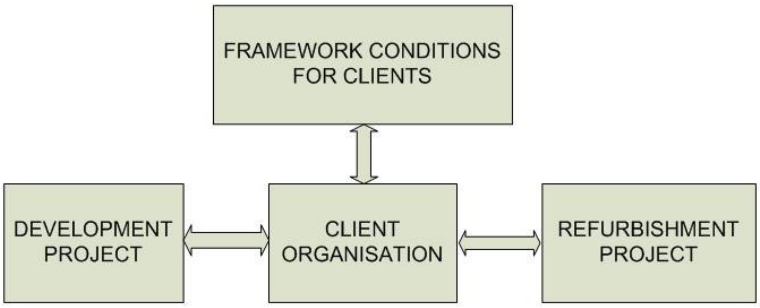

Figure 1 shows the main issues and interactions investigated in the SURE project. The client is here referred to as the building owner. Both the framework conditions for the client, the client organisation, development projects and the refurbishment project itself (case buildings) have been investigated in order to make a good basis for a Nordic guideline for sustainable refurbishment.

Figure 1: The different interactions studied in the SURE Project.

2. State of the art

The energy consumption for the three sectors; industry, transport and services and households for the four Nordic countries participating in the SURE project are shown in figure 2. The distribution varies quite a lot between the countries. The energy consumption for the service and household sector, though, gives relatively similar figures: 32.3% of total demand (Finland) to 46.3% (Denmark). The demand by the service and household sector is primarily due to energy use in buildings and it is evident that this demand for energy is typically around 40% of total energy demand in the Nordic countries, as in most other Western countries [3].

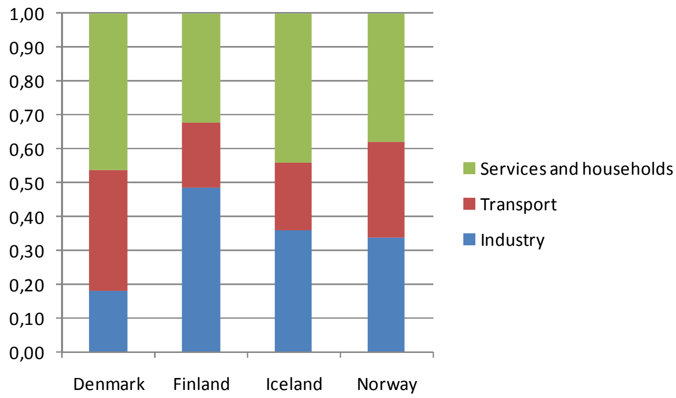

Figure 2: The distribution of energy consumption [3].

The built environment in Norway comprises approximately 3.8 million buildings [4] and 380 million square metres [5]. Among the 3.8 million buildings there are approximately 1.4 million residential buildings, 1.2 million garages and other small annexes, 460 000 cabins and 40 000 office buildings. The energy use in buildings in Norway is highly based on electricity and district heating. There is a high use of floating fossils (i.e. oil) in industry buildings, while gas is mainly used in some hospitals and institutional buildings. The last years, the requirements have become stricter for energy use in buildings in Norway. A Norwegian passive house and low energy standard is established, and there is a governmental goal that in 2020 all new buildings should have a passive house standard. But, for existing buildings the measures and future requirements are still unclear. Case studies are therefore of high importance to find out what to do with the existing buildings and which barriers there are for sustainable refurbishment.

The building stock in Denmark comprises about 470 million square metres (2009). The period 1950-1979 has the highest number of square metres followed by 1980-2009 and 1900-1949 [6]. The *public* Danish Building stock is heavily dominated by institutions owned by the municipalities.
The Danish building regulation does not define sustainability, but includes detailed requirements on allowed energy consumption. Sustainability is included in some town plans, but more as declaration of intent rather than specific standards or guidelines. There is an ongoing effort to establish a Danish Green Building Council, and various international guidelines for sustainability are being studied. Denmark has already taken measure to diminish greenhouse gas emissions through heightened building regulation requirements and this will continue in steps towards 2020.
Municipalities raise finances through taxes but have to negotiate to total level of expenses for all municipalities together. Regions, which primarily are dealing with hospitals and health care, receive a financial frame from the state but make their own budgets. The state has now for 10 years run a renting scheme for its institutions. Some IT tools for systematic planning of maintenance and energy renovation are offered in a joint initiative of landowners and a semiprivate foundation.

The built environment in Finland comprises approximately 1.4 million buildings and 429 million square metres (excluding free-time residences and agricultural buildings). Residential buildings account for 63 per cent of the total gross floor area. Buildings constitute more than 50% and the whole built environment almost 75% (320 billion Euros) of Finnish national wealth. Since the renewal of the building stock is very slow, refurbishment activities are an essential way to improve the quality of the building stock. The Finnish building stock is quite young. The age distribution of residential buildings was in 2005 approximately as follows; 35% have been built in the 80s or later, 25% in the 70s, 30% between 1946 and 1970, less than 10% between 1919 and 1945 and less than 2% before 1919. Compared to other European countries the main difference is the small proportion of old buildings (built before 1945) [7, 8, 9].

The building mass in Iceland is also relatively young, approximately 30 years on average. The energy situation in major parts of Iceland is somewhat special. The energy is both cheap and sustainable. Energy for heating in buildings is supplied by geothermal hot water from a distribution net, and electricity for household appliances and lighting electricity from hydro power stations. The energy is therefore considered as environmentally-friendly. There are few incentives for minimizing energy use in buildings, either based on economical or environmental reasons. Reducing the energy consumption in buildings is therefore of relatively low priority compared to the other Nordic countries. Energy requirements for new and existing buildings are often in the interval 100-400 kWh/m2, and even higher, the new buildings at the lower figure and buildings from the period 1960-1980 at the higher figure. Maintenance needs are primarily (in order of importance); building envelope, technical systems and then interiors. The main incitement for refurbishment of buildings is adaptation to changed needs, better accessibility and comfort [10].

3. Methodology

The SURE research project has been a close cooperation between building researchers from Denmark, Norway, Finland and Iceland. To gain insight into what type of needs to address and what kind of problems the market is struggling with, case studies are of great importance as a basis for developing a guideline for sustainable refurbishment. Each of the countries has investigated 1-4 cases. The building or project owner is here defined as the client, and the main objectives in the SURE project have been to investigate both technical challenges for a sustainable refurbishment and processes/barriers in the client organization and surroundings to find out how a successful sustainable refurbishment can be fulfilled. The results of the analysis, combined with the researcher`s former experiences and knowledge in this field, have given a solid basis for developing a Nordic guideline on Sustainable Refurbishment.

4. Description of the cases

4.1 The Norwegian case studies (4)

The first Norwegian case study is a listed school building (Strømsø School) built in 1891 in the city of Drammen. The school building has high energy consumption and will probably not be used as a school in the future. The SURE main task for this project was to come up with a sustainable concept for the refurbishment mainly focusing on the future use of the building and an energy reduction. Three energy concepts were investigated; refurbishment to fulfil the national technical regulation, passive house standard and zero energy. The analysis [11] shows that the most sustainable way of refurbishing the building is to change the use into offices and aim for "low energy class 2" (45 kWh/m^{2}year for space heating, ventilation included) according to the Norwegian Passive- and Low Energy House Standard, NS 3700 [12]. Recommended measures are: *no* insulation of outer brick walls due to listed status and building physics, new windows, insulation of the roof, new ventilation system, solar heat for hot water, solar shading, low energy equipment, central energy control system, user guiding and adding a new, smaller building annex with toilets and other service functions.

The second Norwegian case study is a multi-dwelling residential brick building built in 1937 (Stiboltsgate 13), now serving as social housing in Drammen. The analysis of three energy concepts [13] shows that the most sustainable way of refurbishing the residential buildings, is aiming at a near Norwegian passive house standard. Improvements of thermal bridges to fulfil the requirements of the standard are considered to be too complex and cost driving, but the other passive house requirements could be fulfilled. The main measures for energy improvements are outer insulation of walls, insulation of roof and floor, new passive house windows, reduction of air leakages, new ventilation system, solar collectors, user guidance and energy monitoring. The energy supply is given two alternatives; district heating or geothermal heat pump. Aiming at zero energy will result in very high cost and a practical problem of installing big areas of solar panels, and is together with wind power not seen as an option.

The third Norwegian case study is a brick building in Ringstabekkveien 105, Bærum, built in 1921. The building has operated as a school, but will be changed into apartments for elderly people with social services in the ground floor. In this case, the building owner (client) has also asked for a sustainable energy concept for the refurbishment. The building facades are protected, a boundary making low energy refurbishment a real challenge. Analysis of the case shows that improvements in air tightness, a new ventilation system, a geothermal heat pump and window improvements combined with low energy technical equipment and lightening would be the main actions for a sustainable refurbishment. An interesting finding is the difficulties to find the right solution for windows combining cultural values, building physics and heat loss. In fact, the whole project is set on hold until the window solution is concluded.

The forth, and last, Norwegian case study is a residential multi-dwelling building housing 54 apartments in the city of Kristiansand, in the south of Norway. Here, the contractor together with the building owner has planned a concept fulfilling the "low energy standard, class 2" (NS 3700) [12]. This is done by outer insulation of the walls and roof, insulation of thermal bridges and installation of a balanced ventilation system. The SURE research project has evaluated the chosen concept to find both good examples and potential improvements. The main conclusion is that the measures for the building envelope and ventilation system is of good character, but the energy supply for heating (oil boiler) should be changed into a more environmental-friendly energy source, e.g. a geothermal heat pump combined with solar collectors and an electrical (or bio) boiler for peak loads.

4.2 The Danish case studies (2)

The Danish case studies deal with a public clients formulated policy for sustainability. Our focus is directed against the part of the policy which deals with the built environment as a subdivision of the target areas for sustainability policy. The analyses at systemic level are confronted with specific studies of recent renovation projects in the municipality. The study operates on two levels; the systematic policy and the specific building project. Two renovation projects are selected; "The Osram House" and "Grøndalscentret".

The Osram House is a former factory for production of electric bulbs raised in 1953. It is a "high profile" project which is also a part of a broader urban renewal initiative based on sustainability. Due to architectural value of the building, several compromises have to be reached in the design measures, this count especially for the façade, including the windows and the entrance.

Before the renovation, the building was practical speaking un-insulated. The walls were made of concrete, approx. 12 cm thick, without any further insulation. The windows were single layer in steel frames. The renovated building is well insulated with walls having a total thickness of 41 cm. The windows are low transmission models with a heat transmission at 1.1 W/m^2K. For architectural reasons there has been a restriction on the possible insulation initiatives at the facade, and the building is now rated "low energy class B".

Grøndalscentret is a former exhibition building from the mid-sixties, originally meant for temporary use for maximum 10 years. It is situated in the outer part of Copenhagen. Today the complex is one of northern Europe's largest sport- and leisure centres, hosting a lot of diverse activities in all kind of sports. The 35.000 square meter building has approximately 3000 daily users. In the late 90's and early 2000, several building investigations with internal and external experts were conducted. The result showed that the centre had a serious backlog in maintenance. All the technical installations were in a very bad condition (e.g. ventilation, electricity and water). There were damages from leaking water pipes due to frost. Due to a nearly flat roof construction, too few roof drainages and a missing vapour membrane, the roof had been leaking for many years, consequently a comprehensive attack of mould growth had developed widely in the roof construction. The energy prices in the mid-sixties were low and the roof was build with only 50 mm insulation.

As a part of the process with layout and dimensioning of the renovation, there was set up a line of goals for the future use of the building. The goals included definitions of needs for spaces, rooms and functions. This was done mainly to ensure that there was sufficient daylight in the different rooms and to be sure that the design of the new roof should not collide with the functions in the rooms/halls. Also, energy consumption played a major role in the concept, and it was a major priority to minimize the future energy consumption. Finally, some considerations regarding fire risk were included in the design. The new construction was arranged by insulating the upper part of the roof sections adding two layer roofing. It was also of high priority to avoid any cold joints which could cause moister and mould growth. Therefore, a solution with a "warm roof construction" was chosen (e.g. the insulation on the top above the bearing timber). The new insulation was 200 mm which on the other hand gave rise to another design problem. The (load-) bearing was not designed for more weight. To compensate this, a lightweight timber construction in the roof had to be designed.

4.3 The Finnish case studies (3)

The first Finnish case study deals with 42 rental apartments and living area of 2 586 m^2 where the owner (VAV Asunnot Oy) wanted first only to renovate the facades (prefabricated sandwich elements), balconies and roof. After discussions with ARA (The Housing Finance and Development Centre of Finland) more ambitious targets were studied for improved energy efficiency (Nordic Passive House level), improved indoor conditions (new ventilation system with heat recovery), accessibility (adding lifts), replacement housing and financing (construction of an additional floor) by industrial, replicable solutions and no major increase in rents.

During the process air permeability measurements, harmful substances mapping, sewer surveys, roof, pipeline facade and balcony inspections were conducted and discussions held on the use of renewable energy. As an end result heating energy consumption was halved (energy class: F → B) and improved indoor conditions achieved [14]. At present the results are monitored and discussion going on with the client how these experiences can be exploited in the coming renovations.

The second Finnish case study is quite similar to the first one. Domus Arctica Foundation (DAS) is an owner and builder organisation who rents student homes in the City of Rovaniemi, at the polar circle. The case study (DAS III) is a five-floor apartment building with 46 apartments for 84 residents and total living area of 1 923 m^2. The aimed refurbishment included energy-efficiency improvement, new facades, additional spaces for user activities and measures to improve the performance, e.g., new balconies. The average energy consumption for space heating and hot water is 162 kWh/m^2 gross floor area. The present master plan restricts the possibility for an additional floor. DAS III locates just in front of the railway station and close to the university premises. Improvement of the performance and appearance of the building helps for getting new residents.

The planned sustainable refurbishment did not start. Some of the barriers for the suggested refurbishment were identified as follows:

- Master plan renewal is a slow process. The processing of the possible complaints on the new plan may take years even though the city is ready to increase the building rights.
- Apartment based ventilation systems increase maintenance. The filters in the system need to be changed twice a year. However, routing of a centralized ventilation system is very difficult in the building
- The technical quality of the existing windows is actually quite good
- Financial planning: Refurbishment costs will be high, and suggested financing sources may not be enough. Increasing the rent, however, may not be possible.

The third case study is a listed Church (1930) which the Parish Union of Helsinki wants to refurbish after some indoor complaints. They also plan to renew their services by constructing two new buildings for office and other services next to the Church and move some of their functions to the same plot because of merging of two congregations. Sustainable procurement was studied in relation with both energy efficient refurbishment and new construction aiming at Nordic Passive House level. The congregation also plans to do carbon footprint calculation for all their activities in the Töölö Parish. Indoor condition inspection and energy simulations resulted in design guidelines and a proposal for carbon footprint monitoring. Design has been started but the required zoning change for additional construction has not been approved.

4.4 The Icelandic case study (1)

In the 50s and 60s, the housing market was in a great demand for new buildings, and 1960-1980 was a lively building period. In this period houses were built in various places in Reykjavik, and the housing stock from this time is an important part of the environment both socially and culturally.

The Icelandic case study is a multi family dwelling at Meistarabellir 19-23 in Reykjavik built in 1964 and is now (2010/2011) being refurbished. The main measures for the refurbishment are insulation of the building envelope, new sewage pipes, partly new windows and installation of an elevator to remodel the building into a “building for life”. The building is owned by Félagsbústaðir hf. (Reykjavík Social Housing), which is a public limited company, owned by the city of Reykjavík, which owns, runs and maintains rented social apartments for individuals and families under a specific income and property maximum. The client owns all social housing in Reykjavik, and aims to be a front runner in the field of good accessibility and living standard in dwellings. To be successful in this, and at the same time fulfil economical requirements, the client have stated that they will focus on keeping the flats in use with as few changes in users as possible, keeping a good building standard to make the flats desirable for clients with different needs, give the tenants a good service and listen to their wishes regarding what can be done better and to keep maintenance costs low.

The building has three stairwells and four floors with two apartments on each floor. The apartments are rather small (about 55 m^2). The building does not have an elevator, as this was not required at the time of construction. The building is made of in-situ poured concrete (outer walls, floor slabs and inner walls between apartments), the outer walls insulated on the inside with 50mm cork insulation and cement rendering. The roof construction is timber roof on a concrete slab. The use of concrete, insulated on the inside results in a high amount of thermal bridges. The windows are two pane insulation glass with U-value of 2.9 W/m^2K and massive wooden frames. The southern wall and a part of the north facing wall have insulated panels to the height of 85 cm, a window band and then 35 cm panel above windows (panels insulated with 50 mm polystyrene). Air tightness of concrete buildings in Reykjavík is usually rather good (n_{50}<1 airchange pr. hour) if tightness of windows is good. The air tightness of the case building has not been measured.
For some years there had been increasing problems with the sewage pipes, and clearly these needed to be changed out due to age. As this would be a major work, it was considered as appropriate to use this chance to make bigger refurbishments by improvements of insulation in gable walls as tenants complained of cold surfaces, replacement of windows and fill-ins in facades below windows. Part of the building is remodelled, to make it usable as a “dwelling for life” (accessible for handicapped and elderly). The insulation standard is only heightened to a small extent by better insulation of an end wall and parts of the south wall. Improved control devices on heating systems are installed and there has been a high focus on informing the tenants on energy-efficient measures.

The sewage pipe system and the electrical system are totally replaced and each apartment has now its own electricity meter, while the energy meter for the heating system is common for all apartments in each stairwell. An elevator is installed into one of the old stairwells. This is the first action of this kind in Iceland and had to be discussed thoroughly with building authorities. A mock up was built to show what free space would be left in the stairway and this was then tested by ambulance personal. A permit for the elevator was given by the building authority, but the decision is still debated. The refurbishment cost for the building alone (cost for moving tenants temporarily to other dwellings not included) is about 134 000 ISK/m^2 (about 885 €/m^2) which is a little more than half the market price for a dwelling of this type and location. The client has used a “Green bookkeeping” document in this project, but not a specific guideline for refurbishment [10].

5. Results and discussions - input to guideline

In Norway, Finland and Denmark, energy reduction is of very high importance both for new and existing buildings. Stricter requirements in building codes, implementing of passive house standard and a high focus on increasing the amount of renewable energy sources combined with reducing the electricity consumption is of high priority. In Iceland, though, due to the use of renewable geothermal heating, the energy focus is much lower. Here, the standard of the building and low maintenance costs are seen as more important qualities for a sustainable development. The energy issue described is one of the major differences between the Nordic countries when talking about sustainable refurbishment. But there are also other differences in the priorities among the countries, mostly related to building codes, building stock, population, culture and market changes.

The similarities and differences between the countries, together with the client discussions and internal workshops, have crystallized some important topics for a Nordic guideline for sustainable refurbishment of buildings. One of the most important outputs is the great need for a tool to help the clients (building owners) change into thinking sustainability. First, the finance model must be set and the process of defining sustainability has to be done. The content of sustainability could differ for each project. What is sustainable for the specific refurbishment project in the specific location with the given assumptions, limitations and possibilities? Is the client aware of the meaning of sustainability? After answering these questions, a strategy and ambition level for the project is needed. The strategy and ambition level cannot be set before the client has a performance profile of the building, and therefore a condition survey is of high importance in a very early stage of the project. A condition survey must be carried out by highly qualified personnel, and should give alternative concepts for the refurbishment as outputs, highlighting the economical, social and environmental consequences of the different concepts.

One of the questions which often arise is weather to refurbish or tear down the building. In a guideline for sustainable refurbishment of buildings, a helpful tool to make the client conclude on this question should be implemented. Also, a list of sustainable indicators should be presented. The indicators should be sorted in three main groups; social, environmental and economical, and should be mostly quantitative so that they can be measured and benchmarked. The guideline should help the client to plan how to implement these indicators into the project, but also give guidance on how to check the indicators both during planning, building and operational phase. The lack of measuring, monitoring and benchmarking of important sustainable indicators is one of the main barriers against a successful archival of a more sustainable development in building construction.

6. Conclusions

Sustainable refurbishment of buildings is mainly about increasing the quality and value of the building with as low environmental impact as possible. The 10 different case studies in Norway, Denmark, Finland and Iceland give examples on solutions and barriers in the different countries, and thus form a solid base for a framework for a Nordic guideline for Sustainable refurbishment of buildings.

7. Acknowledgements

This paper has been written within the framework of the ongoing Nordic research project SURE – Sustainable Refurbishment (2009-2011) and as a part of the ongoing SINTEF research & development programme "ROBUST – Robust Envelope Construction Details for Buildings of the 21st Century" (2008-2011). The authors gratefully acknowledge the assistance given by NICe (Nordic Innovation Centre), all construction industry ROBUST partners, the Research Council of Norway and RANNIS – Icelandic Centre for Research. The authors would also like to thank all clients for valuable discussions and inputs, and for making specific case buildings available for investigation.

8. References

[1] HAUGBØLLE K., "*SURE - Sustainable Refurbishment – life-cycle procurement and management by public clients – Description*", Research Project Description, Danish Building Research Institute, 2009.

[2] ALMÅS A.J., HUOVILA P, VOGELIUS P, MARTEINSSON B, BJØRBERG S, HAUGBØLLE K, NIEMINEN J, "A Nordic Guideline on Sustainable Refurbishment of Buildings", *World Sustainable Building Conference*, Helsinki, 2011.

[3] European Commission – Statistics, Eurostat, 2010, http://epp.eurostat.ec.europa.eu

[4] Norwegian Mapping Authority (2010): *The Matrix,* http://www.statkart.no/nor/Matrikkel/

[5] ALMÅS AJ, BJØRBERG S, EVJENTH A, SANDVIK P, "*Future requirements for existing buildings in Norway*", Report [In Norwegian], Multiconsult, 2011.

[6] Statistics Denmark, Danmarks Statistik, 2009, http://www.dst.dk

[7] Statistics Finland, 2010, "Tilastokeskus". http://www.stat.fi/

[8] ROTI, 2009. "*Rakennetun Omaisuuden Tila"*. Report about the state of the Finnish built environment [in Finnish].

[9] NEMRY & UIHLEIN, "*Environmental Improvement Potentials of Residential Buildings (IMPRO-Building)"*. Joint Research Centre, Scientific and Technical Reports, Institute for Prospective Technological Studies, European Commission, European Communities, 2008.

[10] MARTEINSSON B, SURE Research Project, "*State of the Art Report"*, Innovation Centre of Iceland, 2011.

[11] TOVMO, S, "*Energy efficient refurbishment of Strømsø school"* [in Norwegian, English summary], Master Thesis, Department of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, 2010.

[12] Norwegian Standard for Passive houses and Low energy house standard (NS 3700), 2010.

[13] PAHR G.D.R, "*Energy efficient refurbishment of a residential brick building"* [in Norwegian, English summary], Master Thesis, Department of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, 2010.

[14] PETÄJISTÖ T, OJANKOSKI T, "*Sustainable Refurbishment - Life Cycle Management and Property Management (SURE), Sahatie 2"*. In: Huovila, P., Karvonen, A. & Raasakka, V. (eds.) SB10 Finland, Sustainable Community - building SMART. Conference Proceedings. Espoo September 22-24, 2010. pp. 154-155. ISBN 978-951-758-506-4. Extended abstracts 317 p. printed in Helsinki 2010. Full papers in a memory stick 978 p.