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Eracobuild

INTEGRATED STRATEGIES AND POLICY INSTRUMENTS FOR RETROFITTING BUILDINGS TO REDUCE PRIMARY ENERGY USE AND GHG EMISSIONS (INSPIRE)

Final report

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Summary

Background, objectives and research questions

The geographic scope of the project "Integrated strategies and policy instruments for retrofitting buildings to reduce primary energy use and GHG emissions" (INSPIRE) is on four European countries: Denmark, Romania, Sweden and Switzerland. The building sector accounts for 40% to 50% of the final energy consumption in these countries. While in the European Union (EU) energy-related requirements for new buildings are constantly increasing (e.g. EPBD; nearly zero energy buildings up to 2020), the improvement of energy performance of the existing building stock constitutes a major challenge for the future, especially with relation to the greenhouse gas emissions reduction goals of 2050. The mastering of this challenge requires the identification of cost optimal retrofit strategies to achieve maximal reduction of energy consumption and carbon emissions through and within building renovation.

Accordingly, within INSPIRE specific research questions in the three following fields were addressed.

a) Techno-economic assessment of energy efficient building retrofit strategies

b) Assessment of actors and policy instruments for energy efficient renovations

c) Case studies of sustainable renovation

Research questions in these fields are formulated in a generic way and presented in Chapter 1. The goal of the project was to systematically address these research questions for different building types in different institutional and/or country contexts. The research produced

a) guidelines and inputs for retrofit strategies for different building types, aiming at low primary energy consumption and greenhouse gas emissions while being technically and economically favorable, as well as a tool to evaluate and compare packages of renovation measures taking into account the characteristics of any given building (Chapter 2).

b) intervention points for policy approaches as well as institutional settings and design guidelines for policy measures to foster energy efficient retrofitting (Chapter 3).

c) case-specific insights, exemplifying constraints and how they can be faced. The case studies are thought to be relevant for the building stock of the countries where they are located (Chapter 4).

Techno-economic assessment of energy efficient building retrofit strategies

This chapter systematically addresses research questions related to the environmental impact and cost-effectiveness (over lifetime) of renovation measures for different building types and in different institutional and/or country contexts. For this purpose, a tool was developed to evaluate and compare packages of renovation measures taking into account the specific characteristics of any given building in terms of building dimensions, energy performance of building before renovation and available retrofit measures. The calculation tool allows for assessing trade-offs and synergies between different types of measures and to calculate primary energy use and greenhouse gas emissions reductions and associated costs resulting from several retrofit strategies.

The methodology for carrying out the techno-economic assessment involves the following steps:

- Characterization of the building stock and selection of reference buildings for generic calculations or buildings for case studies
- Definition of basic framework parameters
- Gathering of techno-economic data regarding primary energy and GHG mitigation measures
- Definition of the reference case and of potential measures to reduce primary energy use or GHG emissions
- Calculation of energy related impacts of packages of renovation measures
- Calculation of cost-effectiveness of different renovation packages
- Comparison of different options concerning cost efficient and sustainable mixes of measures on the building envelope, the heating system, and energy related building equipment.

Based on the calculation tool and techno-economic data gathered on renovation measures and framework parameters, an assessment was carried out for five reference buildings in the countries Denmark, Sweden, Switzerland, and Romania. Three generic single-family buildings and two generic multi-family buildings were investigated.

The calculation tool is made available to allow energy actors carry out their own calculations to evaluate environmental impacts and cost-effectiveness of different renovation strategies for buildings on a case by case basis. It is published with frame-work parameters from Switzerland. The tool includes a database of empirical techno-economic characteristics of several types of measures from the following categories: (i) building envelope insulation, (ii) heating systems, (iii) ventilation system with heat recovery, (iv) electricity based services (lighting, cooling, and appliances), (v) energy supply mix, (vi) building automation control and regulation, and (vii) on-site energy production. Further comprehensive calculations have been carried out with the tool for different renovation strategies involving measures from all of these categories for the case of Switzerland. The related results are presented in a separate report (Jakob et al. 2014). Underlying boundary conditions (e.g. life cycle cost methodology, future energy price increases are assumed) need to be taken into account when assessing the results.

When comparing results of the calculations the following conclusions can be drawn for the assessments of the generic buildings investigated:

- Energy efficiency measures on the building envelope reduce particularly primary energy use.
- Renewable energy systems reduce particularly GHG emissions.
- It is difficult to reduce significantly GHG emissions only with efficiency measures.
- The importance of using renewable energies within building renovation also arises from the fact that with increasing energy-efficiency performance of the building envelope the share of energy needs for domestic hot water and for electricity is increasing. The related energy need is difficult to reduce with efficiency measures. Renewable energy sources can lower its environmental impact significantly, though.
- The choice of the heating system dominates the results regarding costs and greenhouse gas emissions.
- To some extent retrofit measures on the building envelope are cost effective, for most reference buildings investigated regardless of the choice of the heating system.
- The effect on costs or environmental impact of increasing the ambition level of the energy performance of a single building element is small compared to the effect of involving more building elements in an energy-efficiency renovation.
- In the case of the multi-family reference examples investigated from Romania and Switzerland, the energy-efficiency retrofit of the wall is the most cost effective renovation measure of the building envelope.
- For the single-family reference buildings investigated in Denmark, Sweden and Switzerland, energy-efficiency retrofit measures on the wall and the roof are most cost effective.
- For the single-family buildings from Denmark and Switzerland, and the multi-family buildings from Romania and Switzerland, the trade-offs between renewable energy measures and energy efficiency measures are rather small, in the sense that a renovation package, which is most cost effective with one heating system, is also close to the cost optimum with other heating systems.
- Implementing both envelope insulation measures and a switch to a renewable energy system to reduce primary energy use and GHG emissions effectively is economically attractive.

- Synergies are created between envelope insulation measures and switching to a renewable energy system, as the former reduces the required peak capacity of the renewable energy system. The reduction of the required peak capacity of the renewable energy system is a key driver for making many renovation measures of the building envelope cost effective also when renewable energies are used as the main source for heating.

- The moment of replacement of the heating system is a good opportunity to combine a switch to renewable energies with energy efficiency measures on the building envelope: As the energy need of the building is reduced, peak capacity of the heating system can be reduced as well, which is a key driver for making many renovation measures of the building envelope cost effective also when a new heating system using renewable energies is installed as the main source for heating. If this opportunity is missed, and the dimensions of the heating system are determined without taking into account renovations on the building envelope, subsequent energy-efficiency renovation of the building envelope will be less cost effective.

Policy instruments for energy efficient renovations

A summary of policy instruments for energy retrofits at the national level and case studies focused on programs to stimulate energy efficiency at the local level are presented in Chapter 3. National policies are reviewed in order to:

- provide a “smorgasbord” of the most relevant policy initiatives addressing energy retrofits

- provide an overview of the general level of ambition of national energy efficiency policies

- describe the level of governance and briefly describe the role of relevant national actors in energy retrofits

- bring to attention some relevant policy evaluations and the continuous need for them

The results of this study show that while all countries that have been subject to this report developed and applied policy instruments at the national level to support energy efficiency and energy renovations, there is a more limited tradition of influencing energy efficiency in the building stock at the local level. Motivations and reasons for the local governments to be involved in programs for energy retrofits vary and include the creation of new jobs, the showcase of ambitious program to “get on the map” and the promotion of local investments. How municipalities can involve other actors in order to create market capacity for energy retrofits is also often on the local agenda. The involvement of supply chain actors in programs for energy retrofits, and the consideration of users’ needs, practices, and requirements are increasingly becoming a focus point in the action plan of municipalities and seem to go hand-in-hand with innovative approaches

Policy intervention has got an increasingly important role in energy efficient renovations. Recent building codes are gradually including binding requirements for renovations and besides the traditional grant and tax incentive schemes, additional economic instruments appear in the policy landscape, such as energy utility obligations, to further support energy renovations. Information tools and voluntary agreements, although with varying results, seem to be commonly used instruments.

The *role of municipalities* regarding sustainable development and climate mitigation as well as energy efficiency and sustainable buildings is gradually increasing; the selected best practices show various municipal commitments and ambitious targets towards “a better future”. The main drivers are highly context-dependent, some drivers, however, common to the selected cases, include climate mitigation, energy and cost saving, energy security, forerunner position, promoting local economies and job creation. These municipal best practices often serve as a source of inspiration and learning among municipalities both on a national and international level, for exploring and expanding the potential roles of local authorities in the field of energy efficient renovations.

The main *barriers* to the promotion of energy renovation described in Chapter 3 are related to the economics of the projects. Even though the life cycle cost is often reduced through energy renovations, the short-term costs increase and the longer payback time can be a great barrier to energy renovations. Often shorter payback time initiatives are chosen instead. Another common barrier is the energy renovation of historical buildings, in which the energy renovations can become very expensive, if not impossible, due to the architectural demand of these historical buildings.

The *drivers* to energy renovations are typically indirect or based on strong (individual) commitments. The need for the involvement of “more active and innovative” financial actors and guarantees into energy renovations is under an on-going discussion. In Denmark, the banks begin to act as a coordinating actor pulling together different players of building renovations in order to make it easier and better organized for the client. In Sweden, the strong engagement of individual local actors in energy issues resulted in the implementation of energy efficient renovations.

Due the complexity of energy renovations strategies and policies promoting learning and networking for advanced knowledge are required. Over the long term the different types of policy instruments promoting learning at different stages are required. In addition to this more strategic evaluations are needed to understand how to improve learning and the dissemination of best practices in energy renovations.

Case studies of sustainable renovation

In Chapter 4, case studies for the retrofit of relevant building types from four countries are presented. By using the cases of Hotel Sanden Bjerggaard in North Jutland

(Denmark), the T744R prefabricated concrete building in Timisoara (Romania), the Brogården passive house-oriented renovation in Alingsås (Sweden) and the settlement “Paradies” in Zurich (Switzerland) the intention was to understand how the pure arguments on cost-effectiveness and the very complex interaction of the stakeholders play out in the case of real world retrofit and renovation cases.

While the backgrounds of the case studies are very different, we can observe a clear tendency that cost effective interventions are actively sought out by the investor (Danish case) or recognized by the markets and implemented by owners (Romanian case of changing heating system). On the other hand, quite often co-benefits drive the application of retrofit measures that are shown not to be cost effective (e.g. windows in Denmark and Romania).

In all cases, the cost effectiveness of certain measures strongly depends on the type of the building being renovated. E.g. in the Danish case wall retrofit is cost effective in the general case, but for the particular building, with a certain esthetic value, the implementation would be extremely difficult.

Two tendencies are recognized from the case studies. High-tech control systems are more and more used in energy retrofitting due to their low cost and high impact, especially to limit unnecessary use of energy. These smart sensors will become more sophisticated, and certainly will be used on wider scale in the future. The other tendency is to implement complex interventions, instead of just upgrading a single building element at once. Often the renovation is targeted to improve social sustainability also, not only energy efficiency. These type of complex measures, shown to be more efficient also by calculations (Chapter 2), require more sophisticated planning and coordination, technical, legal, economical, etc.

In the most of the cases the “integrator”, required to do this sophisticated planning, is not well defined. In the Danish case study, the owner, supported by a research group from the local University, played the role of integrator. In Sweden, the municipality, at the same time (part-)owner, investor, and energy supplier, took the role of integrator. However, in the Romanian case this role is missing from the picture. It is important to create or delegate the integrator role to one stakeholder in each (country) context. For instance, in Romania the cities could very well take the integrator role by opening renovation advisory centers to encourage more renovation activity. This would be in line with the tendencies highlighted in Chapter 3, with cities taking more active roles. Certainly, if the intention is to encourage owners to start thinking about complex renovations in large numbers, then expert advice is needed on a much more integrated and organized level.

Furthermore, the following specific conclusions are drawn from the case studies:

- In the Danish case study the most effective saving measures were to stop the needless ventilation and flow of hot water to bathrooms. These are the most common sense measures as well.

- In the case studies there are two main drivers for the choices of retrofit measures (1) typology of the building and the (2) budget targets for investment.
- An interplay of more considerations can be observed in the retrofitting case studies
    - Social sustainability of the neighborhood
    - Shared interest of the district heating supplier and the city/municipality
    - The ability to attract R&D funding to a pilot project
    - The interest of the contractor to participate in a pilot project
- The change from oil heating to ground source heat pump was shown to be cost effective by the calculations reported in Chapter 2 (Figure 5). This measure was also implemented in the Danish case. The calculations show also that if this measure is followed by improving thermal performance of the walls, floors and the roofs, then the later measure would be cost effective as well. However, the later measure was not implemented in the case study.
- The upgrade of the windows is shown to not be costs effective only from the point of view of energy savings. This means that co-benefits, such as indoor comfort, noise reduction, dust reduction etc., also influence the decision to implement this measure. This was proved in practice in the Romanian case.
- The calculations in Chapter 2 highlight the effectiveness of changing the replacement of the heating system, either to district heating systems, heat pumps (with various ambient heat sources), or possibly to natural gas. Such change, especially to gas heating systems, has been undertaken in many smaller cities in Romania. This means that the cost effectiveness of the measure is supported by empirical observations.
- By the case studies two aspects of recent renovation trends are highlighted
    - the impact of high-tech to renovations by deployment of active control for optimizing resource use, and
    - the unavoidable complexity and multidisciplinary of profound renovation interventions
- The role of the stakeholders is crucially highlighted in the case studies and has a strong influence on both ambitious and realistic renovation targets. This is, especially, shown in the Swedish and Romanian cases where the ownership is arranged in different ways. In the Swedish case, the municipality is the owner of the buildings and the energy utility company that creates strong synergies along common goals with all stakeholders in the project. In the Romanian case, the ownerships are more fractured so the synergies and common goals are more difficult to create.

- The example above of the impact of the stakeholders’ role in the renovation project shows the imperative need to develop instruments tailored to the market situation in each country in order to create or facilitate the creation of synergies and common goals between stakeholders and avoid a negative impact of different ownership structures.
- The case studies raise the discussion about financing and co-financing instruments that seem to play an important role in implementing energy renovations. For financial instruments, two improvements are suggested:
    - The focus of financial support has to be broadened from strictly energy focus, to also include aspects of material efficiency and social sustainability.
    - Financial support should be directed more pointedly to areas of best cost to benefit ratios; these are already attractive to owners.

All in all, the results of the case studies are in line with each other and confirm the calculations in the Chapter 2 and the outcome of policy and actor analysis in Chapter 3.

Conclusions and recommendations

Based on the conclusions drawn in the three previous chapters and the general experience derived from the international collaboration in the INSPIRE project, some general recommendations are highlighted here-below:

- The results of this study indicate that in order to reduce greenhouse gas emissions at lowest possible costs, promoting a shift to renewable energies is recommended.
- Promoting retrofitting measures of the building envelope is also important for both primary energy and GHG emissions reduction, and the measures are in many cases cost effective. They also reduce the required capacity and costs of (renewable) energy systems in the building and thus, these measures should be implemented as a first step.
- From a perspective of reducing GHG emissions or primary energy at lowest costs it is advisable to promote the renovation of as many building elements as possible, rather than setting high energy performance levels of single elements.
- In order to use the full potential of renewable energies and energy efficiency measures to reduce greenhouse gas emissions and primary energy use, it is furthermore important to combine a switch to a renewable energy system with energy efficiency measures of the building envelope to make use of related synergies. This approach also contributes to finding the renovation package with the lowest costs possible.

- It is important that policy interventions promote sustainable building renovations specifically at the moment of the replacement of the heating system for a given building. To make use of synergies, energy efficiency measures shall be combined with, or carried out before, the replacement of the heating system.
- Besides barriers of energy renovations at the market level, the value of energy savings in people's minds competes with other non-energy related needs (e.g. a new kitchen) and this creates other barriers for energy renovations. Therefore, policy measures are important to promote and support energy renovations. Additionally, there is a strong need for new financial solutions or development of existing models, such as energy conversation service, that can work around the problem of building owners' access to capital.
- The complexity of energy renovations, including multiple factors and actors, calls for strategies and policies promoting learning, networking for advanced knowledge and knowledge exchange as well as improved building processes and interaction. Over the long term these processes require different types of policy instruments promoting learning at different stages. In addition, the choice of instruments and strategies also requires knowledge and constant evaluation. Evaluations are presently scarce; more and more strategic evaluations are needed to understand how to improve learning and the dissemination of best practices in energy renovation.
- The focus of financial support has to be broadened from strictly energy focus, to also include aspects of material efficiency and social sustainability.
- The financial support should be directed more pointedly to areas of best cost to benefit ratios; these are already attractive to owners.
- As renovations are becoming increasingly complex, more sophisticated planning and coordination of technical, legal and economic aspects are required. There is a need for appropriate "integrators" to do the related planning and coordination. It is important to create or delegate the integrator role to one stakeholder in each country context. Certainly, if the intention is to encourage owners to start thinking about complex renovations in large numbers, then expert advice is needed on an integrated level.

At a more general level, the following conclusions, recommendations and suggestions have been formulated for further research:

- *The solutions are available, but the implementation is slow:* The main challenges are related to the organisational and the institutional side of the implementation.
- *From energy to resource efficiency:* Resource efficiency is becoming the key focus, and more attention has to be given to the choice of materials and to the end-of-life of buildings.

- *Integrated solutions:* Much more attention has to be given to all environmental aspects of buildings such as the use of water, electricity, heating, waste, etc. and solutions are emerging that combine smart meters with user interfaces that increases the awareness of the users and offer easy options for managing the resource use in households – efficiently and sufficiently (Section 4.1).
- *Social practices of users:* The role of users is significant for the use of heating, electricity, etc. in the households. Energy renovation is not just about technical solutions.
- *Total cost of ownership and new business models:* The major important barrier to energy renovation is the initial investment, and that the running cost of heating and electricity is not really considered in the planning of renovations and new buildings. In order to increase the standards and levels of ambitions, the total cost of ownership/life cycle costing has to be an integral part of the decision-making processes.
- *From energy efficient buildings to sustainable communities:* The traditional linear thinking of energy supply and consumption has to be changed to a dynamic and interactive understanding, moving from energy efficient buildings to sustainable communities by involving buildings as an active part of the energy system.
- *Intermediaries matter:* The competences of the craftsmen, the advice of the banks, the procedures of the building officials in the municipality, etc. are all crucial for the choices and behaviour of the users. Socio-economics and socio-technic research should address these issues, preferably in a systemic approach.
- *Policy mixes:* A broad spectrum of policy instruments has to be available in the toolbox tailor-made for the context (ideally with the input of ex-post and ex-ante policy evaluations) in order to increase the energy renovation of buildings.

1 Background, research questions and objectives

1.1 Background and research questions

The building sector accounts for 40% to 50% of the final energy consumption in the countries participating in this project. While in the European Union (EU) energy-related requirements for new buildings are constantly increasing (e.g. EPBD; nearly zero energy buildings up to 2020), the improvement of energy performance of the existing building stock constitutes a major challenge for the future, especially with relation to the greenhouse gas emissions reduction goals of 2050 and ambitious resource efficiency targets. The mastering of this challenge requires the identification of cost optimal retrofit strategies to achieve maximal reduction of energy consumption and carbon emissions through and within building renovation.

The increasing number of building retrofits meeting the requirements of advanced building standards is an indicator for the availability and feasibility of energy efficient technologies and buildings. Before the project INSPIRE has been started in fall 2010 efficiency potentials and cost-curves of building envelope measures and renewable energies are quite well-known, at least for standard applications and new buildings (see Jakob et al. 2002; Menti et al. 2010; Ott et al. 2011; Ott et al. 2009; Jakob et al. 2006; Tommerup, Rose & Svendsen 2007; Tommerup, Svendsen 2006; Harvey, 2009; Feist, 2006; Ürge- Vorsatz et al., 2012; Wegner et al. 2010; Zeyer 2008). In the case of building renovation, there are often object-specific additional costs for integrating energy-related retrofit measures into existing buildings, which give rise to an extended cost range and to uncertainties regarding resulting costs of building retrofit (Jakob et al. 2002; Jakob et al. 2010; Ott, Klinger 2007; Ott et al. 2011). At the same time, when renovating existing buildings, the broader picture of social sustainability goals are often accompanying, or even amending optimal energy retrofit targets.

Yet back in 2010 two main missing points were identified to achieve a comprehensive economic evaluation were identified:

a) Potentials, costs and benefits of other (efficiency) measures were less known. For instance potentials of more energy efficient appliances or of building automation & control were less known in 2010. The cost and benefits of said potentials of building automation and control in operational building reality has yet to be proven. Presumably such potentials are influenced very much by user behavior, user instruction as well as long term stability and reliability of automation and control devices.

b) Only very few consistent analysis was available about the cost-effectiveness considering both the reduction of primary energy consumption and GHG emissions. Particularly, the synergies and conflict of goals (trade-offs) and the interaction of different measures and the impact of such interaction was barely unknown. For some measures synergies between primary energy (PE) and GHG are obvious (but their extent varies depending on the measures), but for others they were less obvious.

Moreover the economic effectiveness and the viability of building retrofits depend on many factors, e.g. scope of retrofit project, time horizon, costs of retrofit measures, including information and transaction costs, performance risks, interest rate and energy price expectations as well as user preferences. Optimal energy related retrofit strategies for typical types of buildings to achieve ambitious targets for primary energy reduction and CO_2 mitigation either haven't emerged yet or have been systematically analyzed.

Hence, building owners were missing holistic and integrated strategies for various building types and there is a need for ready-to-use recommendations and standard solutions.

From previous policy analysis it can be derived that the understanding of cost-benefit trends and the knowledge of ready-to-use recommendations and standard solutions is necessary, but not sufficient to foster the rehabilitation of the building stock and to reduce its PE and GHG intensity. Particularly, a better understanding of different actors' ways of thinking and decision-making patterns facilitating and actually implementing PE and GHG mitigation measures is needed. In addition, ultimately, framework conditions, barriers and enabling factors have to be understood and possibly adjusted to tap existing potentials.

Accordingly, within INSPIRE specific research questions in the three following fields are addressed.

a) Techno-economic assessment of energy efficient building retrofit strategies

b) Assessment of actors and policy instruments for energy efficient renovations

c) Case studies of sustainable renovation

Techno-economic assessment of energy efficient building retrofit strategies

In the field of techno-economic assessment of primary energy (PE) efficiency and greenhouse gas (GHG) mitigation measures and strategies in particular the following research questions are addressed:

a) What are the characteristics of representative buildings in the countries investigated that can be used for generic calculations?

b) What are the costs and associated impacts on greenhouse gas emissions and primary energy consumption of renovations without or with improvements in the energy performance of the building?

c) Regarding cost-effective measures, what is the contribution of retrofit measures improving energy performance of building envelope as compared to the use of renewable energies (including ambient heat) to reduce the use of non-renewable energy?

d) Accordingly, what is the relation of building retrofit measures as compared to building technology options?

Assessment of actors and policy instruments for energy efficient renovations

The involvement of actors and the application of policy instruments in energy efficient building retrofits are highly context-dependent which often is neglected in policy studies. In Ott et al. 2005 barriers and drivers were surveyed and classified related to different types of owners but further type of actors were included in the analysis only to a minor extent. Gross (2009) highlighted the relevance of architects in energy efficient retrofit projects. In this study we focus on municipalities, actors and networks as well as knowledge development and learning in different policy regimes in energy related building retrofits. In terms of actors and policy instruments, the following research questions are addressed in particular:

a) How can different institutional factors affect the development and diffusion of energy efficient refurbishment?

b) What are the main barriers for development, dissemination and employment of (new and currently available) technologies and retrofit practices? How is energy efficient retrofitting integrated within larger retrofit actions?

c) To what extent is energy efficiency the driver of the retrofitting? Which actors are the most interested in energy retrofitting, and how can less interested actors be motivated by targeted policy measures?

d) Which policy measures are the most appropriate to foster efficient and effective building renovation strategies and portfolios of retrofit measures? Does time horizon matter – short term and long term effects of policy measures? How and to what extent will different types of policy instruments facilitate the development and dissemination of energy efficient retrofit measures?

Case studies of sustainable renovation

The case studies exemplify specific constraints and how they can be faced. The research questions investigated in the case studies are linked to the context of the techno-economic assessment and the assessment of actors and policy instruments. Based on a selection of typical case studies the following research questions are addressed:

a) What are the typical constraints professionals facing when renovating buildings designed with different priorities and requirements than the ones used today?

b) To what extent are targets of energy savings initiators of the retrofit actions?

c) What policy measures are successful in stimulating energy retrofits in the contexts of the different country and economic-social contexts?

d) Which stakeholders are active in promoting retrofit and energy retrofit in particular? Who drove the decisions in the analyzed case studies?

e) Economic feasibility of the energy retrofits carried out in the real world case studies, and how they relate to the findings of cost-optimal solutions suggested by the models developed in this project?

1.2 Objectives

The goal of the project is to systematically address the above stated research questions for different building types in different institutional and/or country contexts. The research aims to result in

a) guidelines and specific inputs for retrofit strategies for different building types, aiming at low primary energy consumption and carbon emissions and being technically and economically favorable, as well as a tool to evaluate and compare packages of renovation measures taking into account the specific characteristics of any given building. This objective is covered in Chapter 2.

b) intervention points for policy approaches as well as typical institutional settings and guidelines for policy measures to foster energy efficient retrofitting (Chapter 3).

c) case-specific insights, exemplifying constraints and how they can be faced. The case studies are thought to be relevant for the building stock of the countries where they are located and carry valuable learning (Chapter 4).

Moreover the goal of INSPIRE is to

- identify business opportunities in the EU and particularly in Eastern Europe with regard to the retrofitting of the prefabricated panel building typology
- involve relevant actors, stakeholders and industries

Activities related to achieving these latest goals are not described in full in this report, but are reflected in an extensive list of workshops and meetings with actors, communications and conference contributions (Botici 2011, Botici et al 2011, Tuca, D. Dubina 2011 Nagy-György et al 2012, Fülöp & Riihimäki 2013, Fülöp et al 2013, Botici et al 2013, Nagy et al. 2013, Ungureanu & Fülöp 2013, Botici et al 2013, Botici et al 2014) as well as by the development of a tool that will be used by stakeholders.

For the different chapters of the present report, the goals are specified in more details as follows.

1.3 Overall methodological approach

1.3.1 Techno-economic assessment of energy efficient building retrofit strategies (Chapter 2)

In the techno-economic assessment of energy efficient building retrofit strategies technologies and retrofit practices are evaluated with respect to technical performance, primary energy needs, range of application, costs and CO_2 emission reduction potential, for commonly available technologies and for best practice technologies.

The existing building stock is classified (country-wise) into the most common building types with respect to appropriate energy-efficiency retrofit measures: One- and two-family houses, multi-family houses, office buildings, and school buildings.

For the different building types technology mixes to fulfill ambitious energy standards are determined. A focus is put on cost efficient reduction of primary energy consumption and greenhouse gases. The exploration of favorable packages of measures to reduce energy losses of buildings as well as of measures to tap renewable energies within the building perimeter is of special interest.

1.3.2 Assessment of actors and policy instruments for energy efficient renovations (Chapter 3)

In the assessment of actors and policy instruments for energy efficient renovations, the focus is placed on the role of learning and networking in the realm of energy efficient (EE) renovations.

(1) The challenges of (current) policy strategies with regard to the implementation of EE retrofit technologies are identified. EE strategies and policy instruments for more EE and cost effective retrofitting in Europe are reviewed.

(2) Building projects, including broadly applied and best practice retrofit measures are assessed, focusing on the role of knowledge development, learning, networking, actors and institutions.

(3) Based on these assessments, key success factors are identified for the development and implementation of different EE retrofit measures.

(4) To support future design of different policy instruments, more efficient energy use in existing buildings and related cost efficient retrofit measures are identified. Furthermore, points of intervention in the technology development and implementation phases are identified for policy design (in terms of both new and currently applied solutions). Innovative policy instruments are highlighted with the focus on network support.

1.3.3 Case studies of sustainable renovation (Chapter 4)

In the case studies it is investigated, if the findings of the Chapter 2 and Chapter 3 are validated in real life case studies. For this purpose, case study examples have been selected from Denmark, Sweden, Romania and Switzerland, broadly covering the range of single and multi-family residential buildings. From each country the most prevailing building typologies have been selected. The intention was to focus the case studies on what would qualify as “ambitious” option from the range of existing retrofit cases.

It was intended that the retrofit cases under consideration should be carried out independently of this project. Therefore, their comparative study can provide basis for benchmarking outcomes of this project by: (1) assessing if the cost-optimal retrofit options found by INSPIRE can be recognized in the case studies, and (2) by comparing the behavior of actors and impacts of policy instruments in real world applications.

Hence, the techno-economic solutions identified in Chapter 2 are reviewed from the points of view of: (i) technological applicability in the context of the case studies, (ii) compatibility with other, non-energy focused retrofit needs of the buildings and (iii) economic feasibility in the different market environments.

The outcomes of Chapter 3 are reviewed in the light of the behavior of stakeholders and the impacts of the policy instruments used, as observed in the real retrofit cases.

The knowledge based on the techno-economic assessment, policy and actor analysis and the context specific case studies will be critical in designing, developing, implementing and evaluating policy instruments supporting effective retrofit strategies for the future.

1.4 Scope and limitations

The scope of the study includes an overview and assessment of retrofit strategies and policy portfolios, through the evaluation of generic strategies and comparative case study analysis. The study focuses on the retrofit of residential buildings and simple office buildings. The methodology includes up-stream life cycle greenhouse gas emissions of energy carriers used. Embodied energy and associated emissions of building materials or installations are taken into account in selected cases or within the context of the sensitivity analysis. For district heating, calculations are made only from the building perspective, i.e. the heat from district heating is considered as an external energy carrier which is brought to the building, no calculations are made regarding costs of district heating systems on their own. Finally, mobility is not taken into account.

Due to the methodological approach, with regards to the case study methodology, policy review, and actors’ analysis, more generic conclusions and the transferability and usability of findings in other contexts shall be applied and handled with caution.

2 Techno-economic assessment of energy efficient building retrofit strategies

2.1 Methodological approach

2.1.1 Overview

The goal of the techno-economic assessment of energy efficient building retrofit strategies is to systematically address the following research questions for different building types and in different institutional and/or country contexts.

a) Regarding resulting costs, what is the contribution of retrofit measures improving energy performance of building envelope as compared to the use of renewable energies (including ambient heat) to reduce the use of non-renewable energy?

b) Accordingly, what is the relation of building retrofit measures as compared to building technology options?

c) What is the impact on the results if embodied energy and related emissions are taken into account?

d) What conclusions can be drawn based on these results as recommendations for policy instruments, in order to foster efficient and effective building renovation strategies and portfolios of retrofit measures in an appropriate way?

The research aims to result in

a) guidelines and specific inputs for retrofit strategies for different building types and energy-related building standards.

b) a tool to evaluate and compare packages of renovation measures taking into account the specific characteristics of any given building in terms of building dimensions, energy performance of building before renovation and available retrofit measures. Retrofit measures comprise energy efficiency measures on the building envelope, related to the heating system and other technical components of a building (e.g. building control devices) respectively as well as use of renewable energy sources.

The methodology focuses on residential buildings and simple office buildings without cooling needs. Methodology applied does not account either for building related mobility or for co-benefits of retrofit measures. The methodology includes embodied energy use, up-stream life cycle primary energy use for energy carriers and related carbon emissions.

The evaluation methodology is structured into the following steps:

- Step 1: Characterization of the building stock and selection of buildings for case studies.

- Step 2: Definition of basic parameters: Development of interest rate and energy prices; time period of the evaluation; electricity mix.
- Step 3: Gathering of techno-economic data regarding primary energy and GHG mitigation measures.
- Step 4: Definition of the reference situation and of the potential measures to reduce primary energy use or GHG emissions.
- Step 4: Calculation of energy related impacts of measures.
- Step 6: Calculations of cost-effectiveness, i.e. of impact on GHG emissions, PE use and life-cycle-costs, of different measures in the context of various strategies.
- Step 7: Comparison of different options and conclusions concerning cost effective and sustainable mixes of measures on the building envelope, the heating system and energy related building equipment.

2.1.2 Indicators considered

Strategies and policy instruments for retrofitting buildings are evaluated using a methodology which takes into account the following indicators:

— Greenhouse gas (GHG) emissions: Direct and upstream GHG emissions (in CO_{2eq}) of energy carriers

— Costs: investments costs, operational and maintenance costs, energy costs. Costs refer to yearly lifecycle costs.

— Primary energy (PE) use: Direct and upstream primary energy use of energy carriers consumed as well as embodied energy use for retrofit measures.[1]

— Non-renewable primary energy use: Direct and upstream non-renewable primary energy demand of energy carriers

Generally spoken these indicators are normalized to an adequate functional unit, typically per unit of heated (or conditioned) floor area. For solar thermal energy and heat from the outside used by heat pumps only the associated electricity consumption is considered for calculating their primary energy demand.

These indicators are determined on the basis of the calculated or actual annual energy consumption in a building with typical use in order to provide the following energy services:

— maintain specific temperature conditions inside by space heating and cooling, including pumps and controls;

[1] In this report renewable energy of ambient heat (air, water, soil) is **not** included within the boundary conditions of total primary energy use

— cover domestic hot water needs;

— provide other energy services such as ventilation, lighting or appliances (white goods) and other consumer products.

2.1.3 Assessment of measures and development of strategies

In order to assess potential measures and develop integrated strategies for retrofitting buildings, the following steps are taken:

1. Reference cases are defined.
2. A list of measures is defined.
3. The impacts in terms of energy-efficiency and economics of these measures are assessed compared to the reference cases.
4. For each building type a set of potential measures to improve the energy performance of the building is identified that fits best the targets of reducing primary energy demand and greenhouse gas emissions. Based on the results it is in particular possible to draw conclusions what balance is best between energy efficiency improvements and the use of renewable energies to achieve the targets.

Prior to applying the method to all cases considered, the methodology is applied on case studies to test and demonstrate applicability of the method as well as to refine it. For this purpose, a model is developed to select different input parameters describing the state of the building before renovation, to apply renovation measures and evaluate the resulting impacts on the indicators describing the energy and greenhouse gas performance of the building.

Based on the energy model and the inputs from different parameters, standardized procedures are carried out to explore effects of different types of measures or policy instruments when the methodology is applied to reference buildings from the different countries investigated.

Based on the results of these evaluations, optimized strategies are developed for retrofitting buildings and for setting corresponding policy instruments. When investigating optimization procedures, particular attention is paid to packages of reduction measures and their associated impacts.

Sensitivity analyses of relevant parameters are carried out, concerning the level of the real interest rate, the time span of amortization, the level of energy prices, the level of costs for the technologies applied and the building type. The objective is to find the most favorable sets of retrofit measures regarding energy-efficiency, climate and economic assessment.

2.1.4 Strategies considered

Strategic elements: renovation packages, choice of energy-mix

There are different strategic options for increasing efficiency of primary energy use and reducing greenhouse gas emissions within building renovation:

Increasing primary energy efficiency and mitigating greenhouse gas (GHG) emissions in the building sector may be achieved by different types of measures which are of quite different character. The generic measures considered within INSPIRE for the development of energy efficient building strategies are classified by three different dimensions (see Table 1):

- Effect: Direct (useful) energy need vs. GHG emissions vs. primary energy (PE) reduction
- Phase: Investment type vs. operational type
- Building element: Construction type vs. technology type

Measures	Description	Effect: Energy need / PE / GHG reduction	Phase: Investment/ Operational type	Technology type: Construction / Building technology
S 1	Improvement of the thermal protection, in terms of building envelope insulation	Energy need/ PE/GHG	Investment	Construction
S 2	Choice of energy carrier/ Change in the heating system	Energy need / GHG	Investment / Operational	Technology
S 3	Implementation of ventilation system with heat recovery functions	Energy need/PE	Investment	Technology
S 4	More efficient electricity based services (lighting, cooling, appliances)	Energy need/PE	Investment	Technology
S 5	Choice of electricity mix	PE/GHG	Operational	
S 6	Construction and materials	PE/GHG	Investment	Construction
S 7	Control and regulation of the energy-related building systems and applications	Energy need/PE	Operational	Technology
S 8	Implementation of solar thermal panels and PV	PE/GHG	Investment	Technology
S 9	Improvement of the sun- and the overheating protection (especially non-residential buildings)	Energy need (if cooling is used)	Investment	Technology

Table 1: Description and classification of the retrofit measures considered.

The different strategic options influence each other. There may be synergies or trade-offs. Within this report, the focus is put on the relationships between the improvement of the energy performance of the building envelope, the change of the heating system, and the increase in the efficiency of electricity consumption. For Switzerland, a more detailed investigation, involving more strategic options is carried out and reported separately.

Approach for investigating and comparing renovation packages

When investigating different renovation packages for the purpose of this report, the following approach is chosen:

- First, calculations are carried out for oil heating system or fossil fuel system as a reference heating system. The effects of different single renovation measures on costs, energy consumption and carbon emissions are determined. Based on these results, renovation packages are composed, starting with the most efficient renovation measure, and adding more and more measures which are less cost effective.
- In a second step, the calculations are replicated for other heating systems.

It is assumed that within the building retrofit the heating system needs to be replaced by a new one. Therefore, an investment in the heating system is done also in the reference case. Similarly, assumptions are made regarding the necessity of rehabilitating the building in the reference case.

The effects of the different renovation packages and the distinction of these effects based on the choice of the heating system are displayed graphically in diagrams that show greenhouse gas emissions or primary energy use on one axis, and life cycle costs on the other axis, always on a yearly basis.

2.1.5 Calculation methodology

The methodology to calculate the above mentioned indicators includes the following steps (see Figure 1):

- Energy consumption for space heating is determined on the one hand by calculating energy loss to colder environment outside due to transmission and ventilation losses and on the other hand by accounting for passive solar and internal heat gains as energy gains (for example due to lighting). Factors used in this calculation also include thermal capacity, insulation and thermal bridges. The calculations are performed with country specific climate data
- The methodology for calculating useful heating needs is based on the Swiss Norms SIA 380/1:2009 for calculating thermal energy use in buildings and SIA 382/2. These Norms use the same calculation principles as the standard ISO 13790:2008 "Energy performance of buildings - Calculation of energy use for space heating and cooling" and the common general framework for the calculation of energy performance of

buildings according to the European Energy Performance of Buildings Directive 2010/31/EU from May 2010.

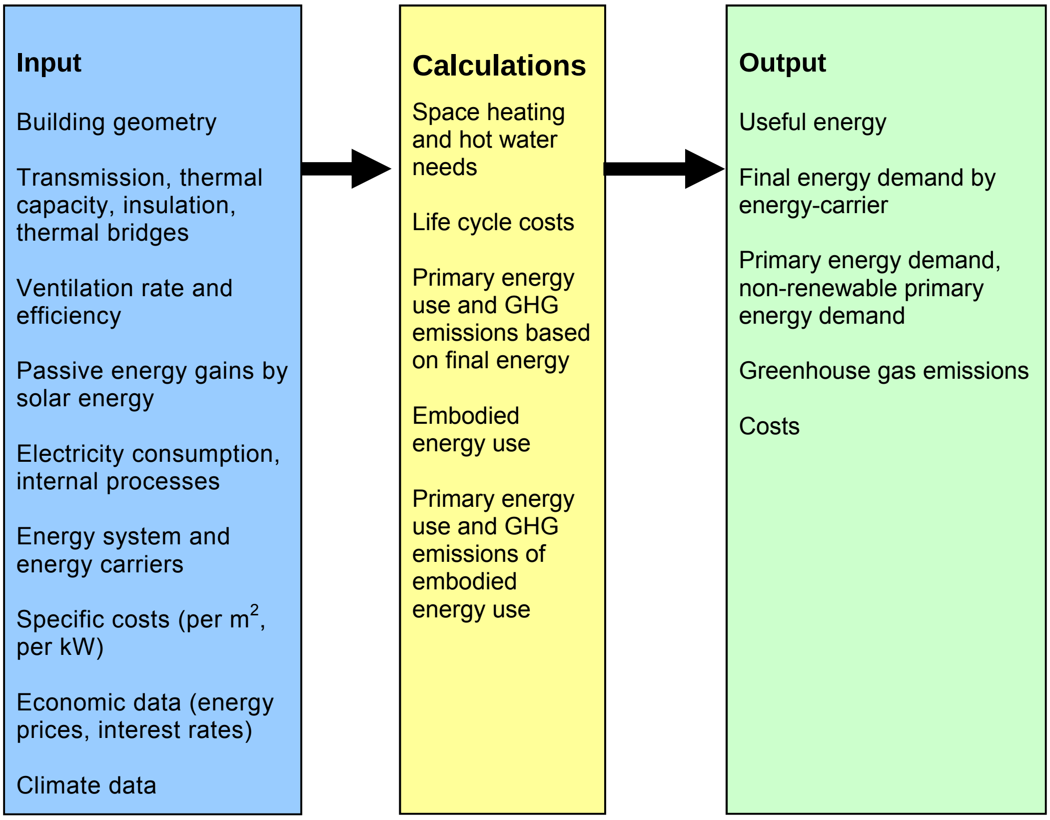
— Depending on the heating system, greenhouse gas emissions and primary energy factors (PEF) are applied, taking into account the efficiency of the heating system.

— To this calculation energy used for hot water and energy used for cooling with related emissions are added.

— Embodied energy use for retrofit measures is determined, comparing embodied energy use for building renovation with energy related measures with embodied energy use for the measures for building rehabilitation (without energy-efficiency improvement) in the reference case.

— The unit used to compare size of buildings is the gross conditioned floor area (or simply "conditioned floor area"): The horizontal projection of that portion of space which is contained within exterior walls (including the walls themselves) and which is conditioned directly or indirectly by an energy-using system.

— All parameters used within the methodology are determined as country-specific values where possible.



econcept / TEP Energy

Figure 1: Simplified model of used methodology

2.2 Economic evaluation system

2.2.1 Costing methodology

For each package of energy related measures the following costs are taken into account:

- upfront investment costs
- yearly capital costs (yearly comprising interest and pay-off of upfront investments)
- yearly energy costs
- yearly operational and maintenance costs, and
- indirect taxes (VAT).

Investment costs are taken into account comprehensively, comprising costs for planning, project design, permission procedures and disposal of replaced elements. However, to simplify the approach, these disposal costs are not taken into account in the calculations, except for measures which typically cause extraordinary disposal costs which do not occur for alternative measures.

Costs for energy, operation and maintenance comprise the costs for all energy use and the operational costs and maintenance costs that occur during the lifetime of the building elements considered.

The dynamic cost-benefit-calculations are carried out with the annuity method. Costs are determined as real costs, referring to yearly capital costs (annuities) with real interest rates. The calculations are based on real prices, real interested rates and technical lifetimes of the building elements. Often these technical lifetimes are longer than the observable average life spans of real building elements since building renovation might combine various measures comprising several building elements of which not all might have arrived at the end of their lifetime. Building retrofit might have also been launched before the end of the lifetime of retrofitted building elements because of changes in the building use or in the tenancy. Furthermore (professional) building owners might carry out calculations taking into account specific or risk based life spans to allow for uncertainties regarding the future use or rental potential of the building.

For the economic evaluation, comparisons are carried out between packages of energy-efficiency retrofit measures applied to a building on the one hand and a **reference case** for the same building on the other hand. The reference case in general includes only overhauling measures to restore the functional use of the building after the building elements have been considered to have reached the end of their lifetime. Overhauling measures are not carried out with the objective of improving the energy performance of the building but only for the sake of restoring functionality and replacing building elements at the end of their lifetime. Because of technological progress the reference case might also include in some energy efficiency improvements even though the measure was not chosen to improve energy efficiency.

In the following, some peculiarities of different PE efficiency and GHG measures and their reference cases are specified.

For **windows**, there are two different types of reference cases to be considered:

1. The window does not yet need to be replaced, but rehabilitation measures for example related to the painting or the sealing of the window need to be carried out. In this case the reference costs are the costs associated with such rehabilitation measures. A rehabilitated window, however, will have a shorter remaining lifetime than a new window. This needs to be taken into account in the calculations.
2. The window is at the end of the lifespan and needs to be replaced. In this case the reference costs correspond to the investment costs for a new low-cost window that does not have an advanced energy performance, but usually it is still better than the window to be replaced.

Because it is unclear or dependent on each individual case how the shorter remaining lifetime of a rehabilitated window compares to a new window, it is in general more adequate to take the replacement of the window with a new low-cost window as the reference case to compare with energy related measures concerning the windows. Instead the rehabilitation measures of painting or sealing can also be taken as a reference case to investigate effects of renovating windows. But in that case the cost-effectiveness of the energy-efficiency renovation measure is underestimated compared to this reference case.

For the **roofs**, the reference case is distinguished as follows: For a flat roof, the reference case is defined as rehabilitation of the roof restoring full functionality regarding weather protection but without improving energy performance. For the pitched roof, the reference case is the replacement of the roofing, yet again without improvement of energy performance.

If replacements of the **heating systems** are taken into account, the reference case is a new heating system of the same type as previously installed, taking into account an improvement of the energy efficiency due to technological progress.

Scope of cost assessment and boundary conditions

Besides reducing (non-renewable) energy consumption many energy related measures have further benefits, i.e. co-benefits. They can be taken into account if information is available regarding the economic value of such co-benefits.

Subsidies are considered to be temporary measures to promote the distribution of certain technologies or behaviors. In this study, the main interest is to investigate cost optimal packages of measures from a societal perspective. For this reason, the calculations in this study are carried out without taking into account subsidies to obtain a realistic assessment of costs and resource use incurred by energy related measures.

From a societal perspective, it makes sense to take into account external costs of energy consumption. The inclusion of such external costs leads to perspectives which allow identifying packages of measures that are optimal for society as a whole. However, the possibility of an internalization of related aspects into a global cost assessment framework depends on the availability of monetary data regarding external costs. A part of external costs of climate change due to carbon emissions is internalized by existing CO_2 taxes. VAT and mineral oil taxes on energy carriers are cost elements of the energy related measures and are also taken into account.

2.2.2 Survey of techno-economic data on primary energy efficiency and GHG mitigation measures

Building envelope

For a set of pre-defined insulation or energy efficiency measures of wall, roof, cellar or window the following inputs are taken into account:

— Investment cost (average cost of equipment and installation, ready to use, including insulation material, plaster and coating, alignment and mounting, excluding working platforms) for maintenance /overhaul or energy efficient retrofits.

— λ-value (conductivity), U-value.

— Lifespan.

The set of considered building envelope measures varies according to:

— Construction types such as compound or ventilated for wall, or plastic, wood or metal frame and two or three glasses for windows, etc.

— Insulation material such as EPS or mineral wool.

— Thickness of insulation material or different U-values for windows (U-value of window referring to the entire window).

For each of the insulation elements, the set comprises also reference cases for overhaul/maintenance measures without energy-efficiency improvements.

Space heating technologies

For each of the technologies of heating installations described below, the following inputs are taken into account:

— Investment cost curve [EUR/kW]. Investments refer to all costs incurred for a ready to use installation (for example including oil tank, connection to local gas/electricity grid, special boiler/storage for solar heat collectors, PV including inverter and connection to grid). The cost curve is described as a function of the installed capacity (kW).

— Lifespan.

— Average fix and/or variable yearly maintenance costs over lifespan (% of investment costs).

— Conversion efficiency from delivered energy to useful heat (for the operation of heat pumps and for solar thermal collectors, the efficiency is larger than 1 and it is the ratio of useful heat to electricity input).

Hot water technologies

For each of the heating technologies indicated above, additional costs for producing also hot water with the compound system are assumed, as well as related lifespan, yearly maintenance costs and conversion efficiency. In addition, selected hot water systems, running independently from the heating system are taken into account.

Energy carriers

For each of the energy carriers used by one or more of the options described above for heating and hot water, the following inputs are used:

— Consumption prices per unit of energy [EUR / kWh] for end users. Actual prices and the share of taxes have to be indicated.

— Greenhouse gas emissions [t $CO_{2\ eq}$ / GJ_{Input}]: Greenhouse gas emissions refer to entire lifecycle emissions including “grey emissions”.

— Conversion factor from primary energy to final energy.

The following energy carriers are considered (Table 2):

Type of energy carrier	Comments
Wood (wood chips)	
Wood (pellets)	
District heating	Distinctions according to the source of heat (municipal solid waste incineration plant, wood, biogas, sewage heat obtained with heat pump, average mix in country).
Oil	Country mix of Light Fuel Oil and Heavy Fuel Oil in buildings
Natural gas	
Electricity	Distinctions are made between average electricity mix provided to cover the country’s electricity consumption (today and in a scenario for the future) and specific individual sources of electricity

Table 2: Types of energy carriers

Solar thermal energy and ambient energy used by heat pumps is considered to be free of charge, producing no emissions and is not accounted for as energy consumption. Instead, electricity consumed to use these energy sources is taken into account.

For district heating, calculations are made only from the building perspective, i.e. the heat from district heating is considered as an external energy carrier, which is brought to the building and for which a price for the heat delivered has to be paid (no calculation of costs of district heating system).

Electricity based energy services

Measures are described to reduce electricity demand. Details on investment and maintenance costs (either in absolute terms or expressed as additional costs) are included as well as obtained reduction in electricity demand for the following types of measures, or other measures:

- Appliances
- Lighting (e.g. LED) as compared to incandescent, or ESL
- Cooling appliances

Ventilation

New ventilation systems provide defined air exchange rates and reduce energy losses for ventilation by heat recovery from exhaust air. Besides investment costs and energy cost savings, electricity consumption for ventilation and related maintenance costs are relevant and are accounted for in the cost benefit assessment.

With regards to non-residential buildings, the measures are described to improve the electrical efficiency of ventilation systems.

On-site energy production

Electricity production on site with PV or co-generation with biomass is considered to be used completely or partially in the building. Electricity, that is not consumed on-site, is assumed to be sold to the grid, creating revenues based on feed-in tariffs and a benefit in terms of greenhouse gas emissions and primary energy use.

2.3 Framework parameters

2.3.1 Basic economic parameters

To improve the readability and comparability across countries some basic economic parameters have been harmonized:

- Exchange rates
- Energy prices
- Interest rates

Cost and price data are expressed in a common currency, i.e. in EUR. The assumed exchange rates are:

1 EUR = 1.2 CHF

1 EUR = 7.44 DKK

1 EUR = 4.5223 RON

1 EUR = 8.6 SEK

Country-specific energy prices used for the calculations in Chapter 2 are listed in Table 3.

Parameter	Unit	Denmark	Romania	Sweden	Switzerland
Oil	EUR/kWh	0.15	n.e.[3)]	0.16	0.1
Natural gas	EUR/kWh	n.e.[3)]	0.021[1)]	n.e.[3)]	n.e.[3)]
Wood pellets	EUR/kWh	0.08	n.e.[3)]	0.08	0.08
Electricity	EUR/kWh	0.33	0.07[1)]	0.18	0.2
District heating	EUR/kWh	n.e.[3)]	0.06[2)]	0.08	n.e.[3)]

Table 3: Energy prices for households and for the tertiary sector (including taxes) used in calculations. Prices refer to assumed average prices over the next 20 years as used in calculation for life cycle costs. (References: Danish Energy Agency 2011a, [1)]E-On Romania, [2)] www.ANRSC.ro National Authority for Public Utilities.),[3)] n.e = not estimated

Interest rates (both from a private and a societal perspective)

Discount and interest rates are typically in the range of 2% and 6% for real estate, depending on the country and its economy. Guidelines to EPBD recast suggest to use an average real social discount rate of 4% per year (Official Journal of EU, 19.4. 2012, p. C 115/18). A higher discount rate (4 - 6%) is attributed to a private, investor or commercial short term perspective. A lower real discount rate of 2 - 4% is attributed to a social perspective (climate policy, building occupants, policy for sustainability). Private discount and interest rates are usually higher because of higher time preference or risk aversion of private persons and often because of higher risks of private investments. Due to long life cycles typical for buildings it is appropriate to adopt a best guess for average future real interest rates during the life cycle of the building.

Hence, the real interest rate assumed for (societal) cost assessment is 3% per year.

2.3.2 Emission factors and primary energy factors

Emission factors and primary energy factors used refer to greenhouse gas emissions or primary energy use of energy carriers consumed including upstream emissions associated with the production, transport and delivery of these energy carriers. Emissions from CH_4 and N_2O are converted into CO_2 equivalents using the UNFCCC global warming potentials of 21 for CH_4 and 310 for N_2O. Country mixes for electricity are based on electricity sources as demanded by the market, and not the national production. The emission factors and primary energy factors used in this project for the countries involved are indicated in Table 4.

Parameter	Unit	Denmark	Romania	Sweden	Switzerland
GHG Emission factor					
Oil	kg CO_2 eq / MJ	0.083	0.083	0.075	0.083
Natural gas	kg CO_2 eq / MJ	-	0.066	0.057	-
Wood pellets	kg CO_2 eq / MJ	0.01	0.01	0.01	0.01
Country mix for electricity	kg CO_2 eq / MJ	0.081	0.194[1)]	0.014	0.042
Country mix for district heating	kg CO_2 eq / MJ	-	0.0833[2)]	0.0264	-
Primary non-renewable energy factor					
Oil	-	1.1	-	1.23	1.23
Natural gas	-	-	1.12	1.12	-
Wood pellets	-	0.21	-	0.21	0.21
Country mix for electricity	-	1.64	2.78	1.58	2.63
Country mix for district heating	-	-	1.51	0.40	-
Primary energy factor					
Oil	-	1.1		1.24	1.24
Natural gas	-	-	1.12	1.12	-
Wood pellets	-	1.22	-	1.22	1.22
Country mix for electricity	-	1.75	2.96	3.05	3.05
Country mix for district heating	-	-	1.56	0.40	-

Table 4: Greenhouse gas emission factors and primary energy factors used in calculations. The table contains empty cells, as only data actually used for calculations is indicated. (Sweden: Statens Energimyndighet, Profu, IIIEE, Energimarknadsinspektionen Danish Energy Agency 2011a).

1) *Technical annex to the SEAP template instructions document*
http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf
www.anre.ro – National Authority for Energy Regulations, 2008 gives the value of 0.138kg CO_2/MJ (496g/kWh), http://www.anre.ro/activitati.php?id=323. This value was given also in the excel file?!
2) EH&P 2009, http://www.euroheat.org/

2.3.3 Climate data

For calculating temperature differences between the interior of the building and the outside, monthly average temperatures are required as an input into the ISO 13790: 2008 calculation tool. Furthermore, monthly average global radiation from East, West, South and North is needed in MJ/m^2. Climate conditions are assumed to be constant over time.

In Denmark the climate is characterized by winters with an average temperature around 0°C and summer temperatures around 15°C as outlined in Table 5. Denmark is situated in climate zone 3, and the climate conditions are similar within the country, even though the costal climate makes the temperature, amount of sun and rain vary in the different regions of the country.

Month	Monthly average temperatures	Monthly average global radiation on horizontal surface	Monthly average global radiation from East on vertical surface	Monthly average global radiation from West on vertical surface	Monthly average global radiation from South on vertical surface	Monthly average global radiation from North on vertical surface	Heating-Degree-Days (interior temperature 20°C)
	[°C]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	
January	-0.5	53	30	26	81	20	636
February	-1.0	107	68	56	140	36	593
March	1.7	243	143	109	217	75	567
April	5.6	384	213	179	259	117	432
May	11.3	539	283	235	289	157	270
June	15.0	602	296	255	291	189	150
July	16.4	586	280	257	297	177	112
August	16.2	456	239	195	273	136	118
September	12.5	279	145	131	205	94	225
October	9.1	152	84	74	144	56	338
November	4.8	61	37	29	75	24	456
December	1.5	38	24	18	61	15	574

Table 5: Climate data for Denmark (Danish Metrologic Institute 2012).

From the point of view of yearly temperatures the territory of Romania is divided into two regions. The division is following the zoning map of the standard SR 1907-1/97 (1997). Zones 1 and 2 of SR 1907-1/97 are considered the first/warmer region, and Zones 3 and 4 of SR 1907-1/97 the second/colder region.

The city of Cluj-Napoca was chosen to represent colder region's temperatures, while for the warmer region’s temperatures Bucharest was chosen to be representative (Table 6). In SR 1907-1/97 the conventional design temperatures for Zone 1 and 2 (Region 1) are given as θe= -12°C and θe= -15°C, while for Zone 3 and Zone 4 (Region 2) are θe= -18°C and θe= -21°C.

Due to year by year fluctuations of the weather, it is important to use representative yearly values for multi-annual energy modeling as presented in this study. For the modeling here the US Department of Energy, Energy Plus weather data was used for both Cluj-Napoca and Bucharest (DOE – Weather Data). The ultimate source of the dataset is the “IWEC - 227 International Location weather data” published by ASHRAE (IWEC CD-ROM). This data was generated from a longer period of record (e.g. 30 years) to be representative and suitable for use in heating/cooling load calculations at the specified locations. The data is representing “typical” years, suitable for long span energy calculations. However, because the logic of using “typical” years is staying away from extremes (e.g. extreme cold periods) the data is not suitable for sizing heating or cooling equipment.

Month	Monthly average temperatures	Monthly average global radiation from East on vertical surface	Monthly average global radiation from West on vertical surface	Monthly average global radiation from South on vertical surface	Monthly average global radiation from North on vertical surface	Heating-Degree-Days (interior temperature 22°C)
	[°C]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	
January	-1.7	66	57	141	42	735
February	0.8	115	90	231	51	599
March	5.0	184	151	278	79	527
April	11.4	209	184	242	114	318
May	16.5	275	219	250	137	171
June	20.4	308	237	233	144	48
July	22.7	303	263	252	131	0
August	21.8	259	220	287	107	6
September	16.2	191	166	291	83	174
October	11.2	134	111	253	61	335
November	4.5	75	57	140	40	525
December	0.1	66	49	144	32	679

Table 6: Climate data for Romania (average values of the climate zones I and II, which include South and south-west of Romania, including the major cities Bucharest and Timisoara).[2]

In Sweden climate conditions greatly vary within the country. Sweden is also divided into different climate zones. As most of the population is located in the southern third of the country, climate zone 3 was used, with Stockholm being a representative location (Table 7).

[2] http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm, Heating Degree-Days from calculations

Month	Monthly average temperatures	Monthly average global radiation on horizontal surface	Monthly average global radiation from East on vertical surface	Monthly average global radiation from West on vertical surface	Monthly average global radiation from South on vertical surface	Monthly average global radiation from North on vertical surface	Heating-Degree-Days (interior temperature 20°C)
	[°C]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	
January	-3	30.9	19.1	15.7	54.7	11.9	744
February	-3	78.8	51.2	38.0	108.0	28.2	672
March	0	201.0	114.2	106.9	208.2	59.9	651
April	5	406.3	225.8	192.7	321.0	98.9	480
May	11	591.7	317.7	261.9	350.8	147.0	310
June	16	576.7	277.7	252.9	303.4	170.0	150
July	18	560.6	274.9	259.4	305.1	167.7	93
August	17	406.2	208.1	176.3	254.9	131.6	124
September	12	256.0	132.1	122.6	219.6	80.7	270
October	8	121.6	73.4	65.2	150.2	38.9	403
November	3	47.6	31.2	26.07	98.6	16.4	540
December	-1	20.9	14.3	0.0	53.3	7.2	682

Table 7: Climate data for Sweden. The data corresponds to the average values measured in Climate zone III, with Stockholm as a representative location of this area. (WorldBank, Swedish Meteorological and Hydrological Institute).

Month	Monthly average temperatures	Monthly average global radiation on horizontal surface	Monthly average global radiation from East on vertical surface	Monthly average global radiation from West on vertical surface	Monthly average global radiation from South on vertical surface	Monthly average global radiation from North on vertical surface	Heating-Degree-Days (interior temperature 20 °C)
	[°C]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	[MJ/m2]	
January	0.42	110	90	96	207	58	607
February	1.72	175	144	150	277	85	516
March	5.34	321	220	226	334	122	455
April	8.34	420	257	263	301	140	350
May	13.35	542	316	329	300	193	206
June	15.99	573	332	339	279	206	120
July	18.30	603	351	362	309	210	53
August	18.16	522	309	323	332	165	57
September	14.06	357	224	233	312	113	178
October	10.10	223	142	148	259	79	307
November	4.32	115	79	83	177	46	470
December	1.81	85	63	65	153	42	564

Table 8: Climate data for Switzerland

2.3.4 Time frame

The length of considered time period can be chosen to match different points of view. The starting point for determining the considered time period is the technical life span of the building parts in question. But it needs to be taken into account that some parts are usually renewed before the end of their technical lifetime, in particular if the life span of these building elements is longer than the life span of the bulk of other components considered. The assumed lifetimes of different building envelopes is indicated within the description of different renovation packages. For heating systems, in general a lifetime of 20 years is assumed.

On a case by case basis, also shorter time spans can be assumed, for example if from a business perspective investments need to be amortized over a period shorter than their technical life span.

2.4 Building typology

2.4.1 Overview on typology of each country

The current section will provide an overview on the existing building stock of the countries being objective of the current research. The focus is on the residential building sector and both single- and multi-family dwellings will be covered. Due to the changing building traditions both in time (over years) and in space (geographically) it was essential to gain knowledge about the following characteristics of the building typology. This information is used to define different building types being target of this investigation:

- Building type – presented in Figure 2
- Construction period – presented in Table 9
- Shares of heating systems – presented in Table 10 and Figure 3
- Heated floor area by construction period – presented in Figure 4

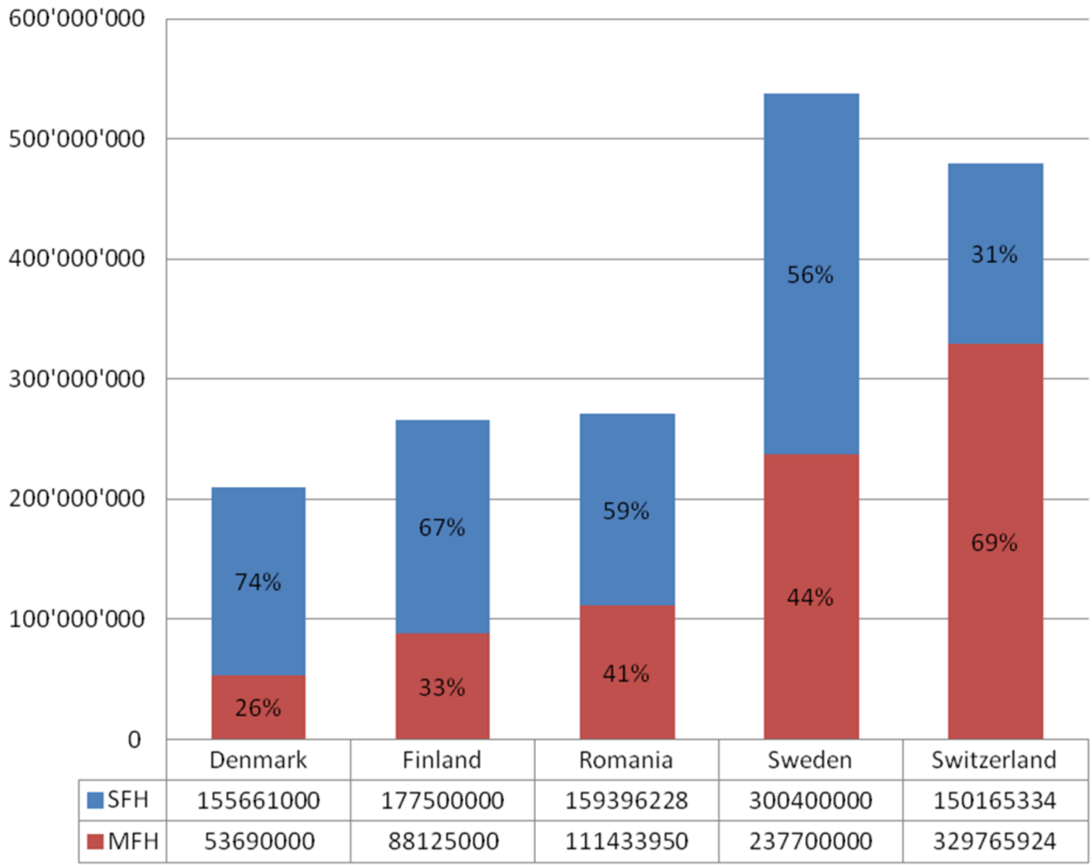


Figure 2: Area of single (SFH) and multi-family houses (MFH) and of total residential building block area (in m^2)

Construction period	Building construction periods in the different countries				
	Denmark	**Finland**	**Romania**	**Sweden**	**Switzerland**
0		-1920	-1909		
1	1931-1950	1921-1939	1910-1944	-1960	-1946
2	1951-1960	1940-1959	1945-1960		1946-1970
3	1961-1972	1960-1969	1961-1970	1961-1975	
4	1973-1978	1970-1979	1971-1980	1976-1985	1971-1980
5	1979-1998	1980-1989	1981-1989	1986-1995	1981-1990
6	1999-2006	1990-1999	1990-1999	1996-2005	1991-2000
7	2007-2011	2000-2008	2000-2002		2001-2010

Table 9: Building construction periods in the different countries

Energy carrier	Share of the heating systems and related energy carriers				
	Denmark 2010	**Finland** 2009	**Romania** 2010	**Sweden** 2005	**Switzerland** 2010
Oil	15%	17%	0%	4%	51%
Gas	15%	1%	29%	-	15%
Coal	0%	0%	1%	-	-
District Heating	66%	69%	22%	7%	2%
Wood	3%	12%	47%	-	12%
Electric	-	-	1%	22%	10%
Heat Pump	-	-	-	-	10%
Oil+ Bio-fuel	-	-	-	4%	-
Oil+ Bio-fuel+ El	-	-	-	6%	-
Oil+ El	-	-	-	4%	-
Bio-fuel +El	-	-	-	32%	-
Bio-fuel	-	-	-	7%	-
Other combinations	-	-	-	14%	-
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Table 10: The share of the heating systems in the distinct countries. The empty cells mean 1) the particular carrier was not used or 2) the data was not available in the statistics. (Sources: Odyssee, Statens Energimyndiget and SCB (2007 and 2010) for Sweden)

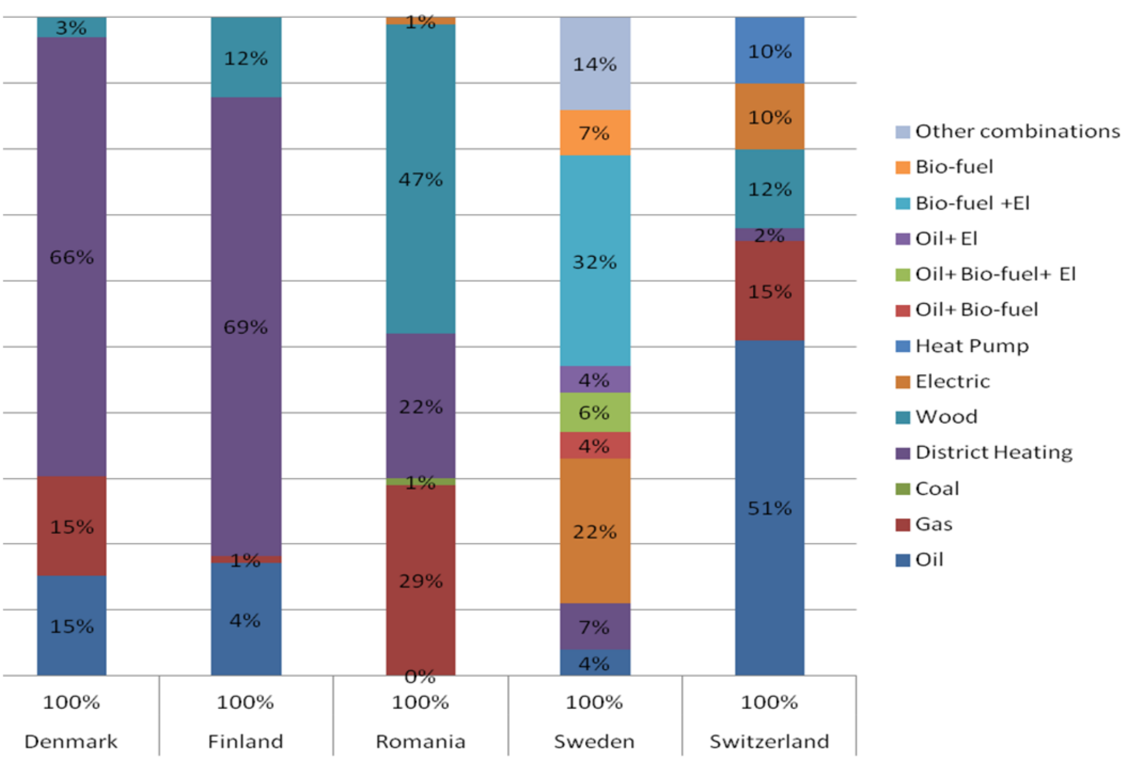


Figure 3: The chart represents graphically the data of Table 10

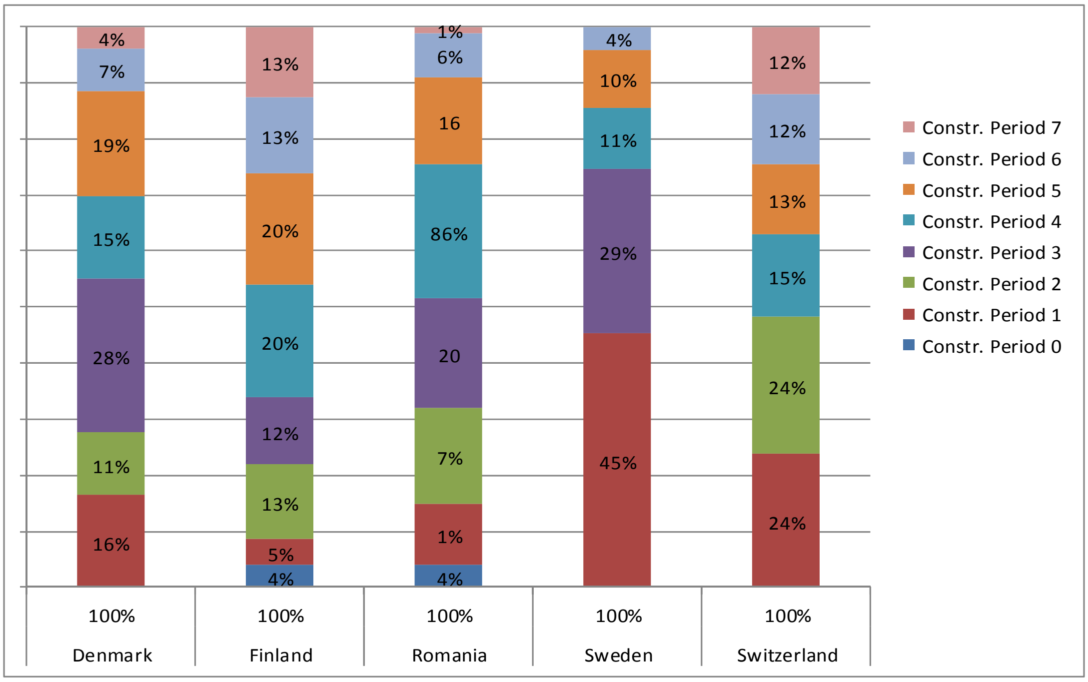


Figure 4: Gross heated area by construction period and country. The different construction periods are presented in Table 9

After the thorough literature review on the building typologies, a building period and thus building constructions with high potential for improving the energy performance were chosen. This initial step was essential for being able to evaluate the existing building stock and for the further development of applicable energy efficient building retrofit strategies. Detailed overview on the selected building types is presented in the next section of the report.

The gross heated floor area of the single- and multi-family houses within the different construction periods is numerically presented in Table 11 and Table 12, respectively.

Construction period	Housing stock in the different countries/ SFH gross heated area				
	Denmark	Finland	Romania	Sweden	Switzerland
0		8 125	7 689		
1	20 066	7 500	24 804	145 600	39 625
2	15 628	26 250	40 537		28 397
3	43 787	16 250	35 222	81 800	
4	26 426	30 000	23 329	44 400	19 038
5	31 600	40 000	9 172	18 000	21 918
6	11 905	25 000	15 734	10 600	20 150
7	6 249	24 375	2 909		21 037
Total	**155 661**	**177 500**	**159 396**	**300 400**	**150 165**

Table 11: Gross heated floor area (in Tsd. m^2) of single-family houses by construction period (as defined in Table 9) and country.
*The number corresponds to the sum of the total area for detached and attached buildings

Construction period	Housing stock in the different countries/ MFH gross heated area				
	Denmark	**Finland**	**Romania**	**Sweden**	**Switzerland**
0		2 500	3 202		
1	14 358	5 000	4 944	98 500	74 863
2	7 704	8 750	5 365		88 859
3	13 826	15 625	17 750	75 600	
4	4 361	23 750	41 483	14 300	51 196
5	7 750	12 500	32 988	37 800	38 591
6	3 640	10 625	5 404	11 500	39 060
7	2 051	9 375	299		37 197
Total	**53 690**	**88 125**	**111 435**	**237 700**	**329 766**

Table 12: Gross heated floor area (in Tsd. m^2) of multi-family houses by construction period and country

Denmark

The total residential building stock in Denmark accounts for 1.4 million buildings out of the total 2.4 million constructions. That constitutes about a half of the total building stock and 62% of the population. It also covers more than the half of the total building stock area, which is 637 million m^2. The average size of the Danish dwellings is 136m^2 or average of 56 m^2 per occupant for the SFH and 45 m^2 for the MFH. That accounts for one of the highest average area per occupant in EU. Two thirds of the owner-occupied dwellings are detached houses. Only 9% of owner-occupied dwellings are flats. The typical detached house property covers 800 m² (Statistikbanken - http://www.statistikbanken.dk/))

When looking at a specific construction period, for instance 1961-1972, the total number of the residential buildings was calculated to 222 916 and it consists of 85% detached houses, 7.5% terraced, linked or semi-detached buildings and 7.5% multi-dwellings (Statistic Denmark, 2010). This typology of building is particularly interesting, not only because during that period a relatively high number of SFH buildings was erected, but also because the first energy efficiency requirements were not introduced in Denmark before the late 1960s. This type of buildings was hence constructed without particular regard to energy efficiency, and it is where interventions may yield the best results in terms of cost-effectiveness.

The most widely spread heating method in Denmark is the district heating system (49%), followed by systems supplied by gas (28%) and oil (19%) (Statistikbanken.dk, BYGB33).

Finland

According to Statistics Finland 2008, there were 1 421 188 buildings in the country and the total number of dwellings was 2 767 925. The residential buildings account for 85% of the total building stock. That makes 1 203 649 constructions, majority of which are detached houses (1 203 649 or 76% of the total building stock).The attached houses and the residential blocks of flats account for 75 109 (5.3%) and 55 925 (3.9%), respectively (Building Stock, Statistics Finland).

The share of the total floor area of the building stock, which is 422 million m^2, is represented by 64% for the residential buildings compared to the 36% for the industrial buildings, at the end of 2008. Dwellings with permanent occupants were numbered to 2 499 000, most of them one or two-person household- dwellings. These rather small units make up 73% of the total number dwelling units. The average number of occupants is estimated to 2.09 persons per unit.

The most widely used method for heating, average speaking, is the district heating system (49%), followed by oil and electricity (17% of share for each), as a source.

When considering a specific construction period, for instance 1961-1972, the most commonly used heating system was the oil one (57%), followed by the systems supplied by wood (23%) and electricity (17%) (Statistic Finland, SBi 2012:4).

Romania

The housing stock in Romania consists of approximately 8.5 million dwellings in some 5.1 million buildings (2011 Population and Housing Census in Romania). In the urban area, the majority of dwellings (72%) are found in blocks of flats, in contrast to rural areas, where the majority (95%) are individual dwellings. Individual single-family buildings represent around 95.3% of the Romanian residential buildings stock. There are around 83 800 blocks of flats, mainly concentrated in urban areas, representing around 2% of the building stock but accounting for 38.3% of Romanian dwellings (around 3.11 million apartments).

According to the preliminary results of the 2011 Population and Housing Census in Romania (http://www.recensamantromania.ro/), the provisional results obtained show the following:

Households: 7.1 million (7 086 717) households

Dwellings (including other housing units): 8.5 million dwellings (of which: 8 450 607 conventional dwellings and 8 149 other housing units)

Buildings: 5.1 million buildings (5 117 940 buildings of which: 5 103 013 buildings with dwellings and 14 927 buildings classified as collective living quarters)

In these dwellings there were 22 739 thousand rooms for habitation of which total useful floor space amounted to 398 037 thousand square meters. In the urban area the conventional dwellings have a smaller average number of rooms than in the rural area, but the average floor space of the dwellings and rooms for habitation is larger.

In the year of 2008, the user primary energy consumption in the residential building sector was estimated to be 32% of the total consumption (12 746 toe) for natural gas 24% (9 719 toe) for oil products, and 24% (9 649 toe) for coal.

Sweden

In the year of 2010 it was calculated that 56% of the Swedish population lives in one- or two- dwelling buildings versus the 44% living in multi-dwelling buildings. According to the statistics, the number of dwellings in one- or two-family buildings was calculated to be about two million (45% of the total stock) and two and a half million dwellings (55% of the total stock) were found in the multi-family constructions (SCB, 2010).

- The average area per unit of the residential building stock is 124 m^2 for the single family- and two-family dwellings and 67 m^2 per flat.
- The average number of occupants in the Swedish residential building stock is 0.014 per m^2 for SFH and 0.017 occupants per m^2

When comparing the construction periods by size of heated floor area, the second biggest effect on the share has the construction period within 1961-1975. It also means that retrofits and thus energy-efficiency improvements of the buildings of this specific period would have significant results in terms of PE reduction, when looking at the performance of the country's building sector.

After identifying the specific construction period as a case with high potential for energy-efficiency improvements, a more detailed review on it was obtained.

According to the Swedish statistics, there are variable types of combined heating systems:

Construction period	Number of buildings	Heating sources (%)								
		Oil only	Electricity only	Oil + Bio-fuel	Bio-fuel only	Oil+ Electricity	Bio-fuel+ Electricity	Oil+ Bio-fuel+ Electricity	Ground heat pump	Other
1961-1970	270 000	7	31	2	4	4	15	-	10	25
1971-1980	407 000	0	49	1	4	1	19	1	4	18
2001-	42 000	-	50	-	2	-	17	-	7	26

Table 13: Share of the different heating systems within a specific construction period in Sweden. The number of buildings corresponds to all one- or two-dwelling houses built within the chosen period. The data source is Statistics Sweden, 2009.

When looking at the construction period of 1961-1970, the share of the different heating systems is represented by sole electricity (31%) or in a combination with bio-fuel (15%), as a source. These are followed by the heating system, solely supplied by oil (7%). The oil is also used in combined systems, for instance, with bio-fuel (2%) or with electricity (4%). However, that is in relatively small terms.

After 1970 the usage of oil heating systems in the new construction became out of practice. In contrast to that, the electricity became a prevalent method (49%), together with the combined bio-fuel + electricity supplied systems. It also means that in the latter construction period the buildings with electric heating systems were 2.4 times more than in the previous construction period.

The long traditions and the quite early implementation of heat pumps in Sweden (since 1970s) and also in other European countries, e.g. Switzerland, were supported by their national strategies for improvements in the energy-efficiency and security, reduction of the environmental degradation and mitigation of the climate change (IEA, 2008). The later decrease of the ground source heat pump usage is explained by the increased implementation of air-to-air heat pumps, which in 2008 consisted more than 60% of the total heat pumps sales (Nowacki, 2007, SVEP, 2007).

In 2005, the residential energy use was estimated to 26 TWh for the consumed electricity, 5.3 TWh for oil and 11.2 TWh for biomass .For the multi-family buildings was used mostly the district heating system, with consumption of 25 TWh in 2005 and an average share of 75% when looking into the all different types of systems (SCB, 2006).

Considering that, Sweden was seen in the role of extreme case, where two reference cases were defined, due to variable existing heating system offering different options of renovations.

Switzerland

The total number of the single family residential buildings is calculated to 945 110 and for multi-family constructions it is equal to 419 723 according to the Swiss statistics of 2010.

The total number of dwellings for SFH is estimated to 1 080 812 and for MFH is 2 998 248 (GWS2010).

According to the statistics of the year 2000, the most commonly used heating system in the SFH is the one fed by oil as a source. It represents the share of 51%, of the different heating systems usage, followed by wood (15%), electricity (14%) and gas (12%). For hot water production, most commonly used are the electricity with 49% and the oil with 33% of the total share.

For multi-family residential buildings, the average share of heating systems is represented by oil with 67%, and gas with 21%. For hot water was priory used oil (61%) and gas (19%). The share of the heating systems is presented in Table 10.

Energy carrier	Share of the heating systems and related energy carriers				
	Denmark 2010	Finland 2009	Romania 2010	Sweden 2005	Switzerland 2010
Residential buildings	1.4 million	1.2 million	5.1 million		1.4 million
Residential building block area	209.4 million	265.6 million	270.8 million	538.1 million	479.9 million
Dwellings		2.8 million	8.2 million	4.5 million	4.1 million
MFH of total residential building area	26%	33%	41%	45%	69%
SFH of total residential building area	74%	67%	59%	56%	31%
Total number of buildings	2.4 million	1.4 million	5.3 million		2.0 million
Total floor area of building stock	637 million m^2	422 million m^2			

Table 14: Summary of the building stock in different countries

2.4.2 Overview on selected building types

In this project, focus was put on residential buildings, both single-family and multi-family houses. For each type of building, reference buildings were defined in at least two countries. The reference buildings serve as the basis for carrying out calculations applying the methodology based on which results are produced and conclusions are drawn.

For each of the reference buildings, the following parameters are taken into account:

— Average building geometry and dimensions: conditioned floor area, area or length of energy related building elements, etc.

— Average assumptions on the use of the buildings: conditioned floor area per person, average hot water consumption per conditioned floor area, presence time of users, etc.

Average energy characteristics of the buildings: average U-values for roof, walls, windows, cellar slab; energy need; share of energy carriers, system performance, etc.

For the countries included in this project, the following reference buildings were chosen:

— A single-family residential building from Denmark

— A multi-family residential building from Romania

— A single-family residential building from Sweden

— A single-family and multi-family residential building from Switzerland

The characteristics of the reference buildings that were investigated in the project are summarized in Table 15.

Parameter	Unit	Denmark – SFH	Romania - MFH	Sweden - SFH	Switzerland SHF	Switzerland - MFH
Gross heated floor area (GHFA)	m^2	180	2225	160	210	730
Façade area (excl. windows)	m^2	121	1774	146	206	552
Roof area pitched	m^2	180	-	88	120	
Roof area flat	m^2	-	445	-		240
Area of windows to North	m^2	10.2	72	7.3	3.3	31.6
Area of windows to East	m^2	8.5	72	9.1	8.3	39.5
Area of windows to South	m^2	8.5	72	10.9	13.2	47.4
Area of windows to West	m^2	6.8	72	9.1	8.3	39.5
Area of ceiling of cellar	m^2	160	445	80	80	240
Average gross heated floor area per person	m^2	56	25	70	60	40
Form factor (A_{TH}/A_E)	m^2	2.75	1.33	2.19	2.09	1.63
Typical indoor temperature (for calculations)	°C	20	22	21	20	20
Average electricity consumption per year and m2 (excluding heating, cooling, ventilation)	kWh/ $(a*m^2)$	44	65	42	22	28
U-value façade	$W/(m^2*K)$	0.63	0.52	0.31	1	1.3
U-value roof pitched	$W/(m^2*K)$	0.28	-	0.21	0.85	0.85
U-value attic floor	$W/(m^2*K)$	-	-	-	1	1
U-value roof flat	$W/(m^2*K)$	-	0.83	-	1	1
U-value windows	$W/(m^2*K)$	2.52	2.33	2.3	3	3
g-value windows	–	0.7	0.7	0.7	0.75	0.75
U-value ceiling of cellar	$W/(m^2*K)$	0.39	0.78	0.2	0.9	0.9
Energy need for hot water	MJ/m^2	50	119	43	60	75

Table 15: Characteristics of reference buildings for Denmark, Romania, Sweden, and Switzerland. Data sources: Ott et al. (2011), INSSE (2002), Wittchen and Kragh (2012), SIA (2009), Danmark Statistics (2011). SFH refers to single family residential buildings, MFH to multi-family residential buildings, Statistics Sweden 2009, Boverket 2009, Tabula Project

As a reference building for Denmark, a single-family residential building within the construction period 1961 to 1972 was used, based on the Danish contribution to the TABULA project (Wittchen and Kragh, 2012, p.46/47). The building exists and it is representative of a large proportion of the building stock in Denmark.

The construction period spanning from 1961 to 1972 is characterized by the fact that the first energy requirements were introduced in 1961.

— Single houses built in this period are hence built considering energy efficiency although only on a summary basis. In the 1950s a requirement regarding cavity walls was introduced which entails that almost all of the single family houses built in the period 1961-1972 have cavity walls

— The average U-values for these constructions are estimated to be around 0.39 for floors, 0.63 for walls, 0.29 for ceilings and 2.52 for windows and a single family house built in this period is estimated to consume about 166 kWh per square meter per year (Wittchen and Kragh, 2012)

— However, the final consumption for heat and hot water also depend on the energy system, with houses powered by heat pumps consuming as less as 73 kWh per square meter per year and those with oil boiler as much as 224 kWh per square meter per year

— A typical house built on that period has 30 cm thick cavity walls and double glaze wood windows and natural ventilation

— About 306 000 houses equivalent to 39.2 million square meters heated area or 22% of the country's heated area are single-family houses built between 1961 and 1972

As a reference building for Romania, a multi-family residential building of the «Precast Concrete Block Type» was used. The building itself is an average 5 floor configuration based on the national statistical data INSSE 2002. For deriving this configuration, the following methodology was used:

— INSSE 2002 reports 57 431 prefabricated concrete panel buildings (PCPB) to exist in Romania. From these, 10 750 have between 7 and 11 floors (tower configuration), and the majority less than 6 floors (low-rise). 85% of the tower blocks have 9, 10 and 11 floors. 88% of the low-rise PCPB's have 5 floors.

— INSSE 2002 reports 36 957 low-rise PCPB's to have been built in the period 1970-1989 from the total of 46 681 in all periods. This include a variety of configurations and sizes;

— INSSE 2002 reports 2 426 615 apartments in PCPB buildings. Assuming that tower configurations have twice the number of apartments of low-rises, the average number of for 5 floor PCPB's is 35.6 apartments/building. Totally, the 5 floor PCPB's built between 1970-1989 (36957 buildings) have 1 315 329 apartments.

— Living areas, designed in 1970-1989, ranged between 33 - 35.5 m^2 per apartment, while useful areas were between 52 - 57.5 m^2 per apartment. Making practical assumptions concerning the remaining heated area (e.g. common spaces, stairwells, corridors etc.) we arrive at an average of 2 225 m^2 heated area for the average building on the 5 floors.

— The assumptions concerning window to floor (0.13) and wall to floor ratios (0.8) was made for a specific building typology IPCT Type 1340.

The methodology used here has the advantage to result in a statistically average building. However, this building does not exist in reality. Also, it has been taken into account that the total PCPB portfolio used in the project must respect all the boundary conditions available from the statistics (INSEE 2002). Hence, the totals for the number of buildings, the number of apartments, the number of rooms, total useful areas ("utila" according to INSSE terminology) and number of occupants matches the available statistical data. The assumptions refer to quantities unreported in statistics. E.g. the heated area of the buildings was estimated from increasing useful area with a 10% increase. The external cladding areas of the building are also based on estimates.

U-values of the cladding system have been estimated from typical design targets used in 1970-1989. Typical thermal insulations for the prefabricated concrete panels were 6 cm of mineral wool (MW) insulation before 1975, and 8 cm of MW after 1975. The thermal bridges of panels could be quite high for today standards considering that the outer and inner concrete layers were bridged by 4-6 cm wide strips of concrete on the perimeter of the walls and around windows.

The U-values presented for windows also correspond to the design targets of 1970-1989. Since large scale window renovation has been carried out for PCPB buildings after 1989, it is assumed those windows U-values are outdated. Unfortunately, no reliable statistical data was available concerning the impact of window renovations on the building stock.

As a reference building for Sweden, a single-family residential building is addressed. The construction period is within 1961-1975. Data used is based on Statistics Sweden, 2009; Boverket, 2009 and TABULA project ("Byggnadstypologier Sverige", p.11/12)

— Concerning the building construction and materials, building blocks of light weight concrete are used for walls, the roof is pitched and the windows are simple double glazed. The buildings from that construction period are detached buildings and are known as buildings of the Million Program - "Miljonprogrammet". The majority of them have natural ventilation and the average heated floor area is 160m2.

— The most commonly used heating system for buildings with earlier construction period was the oil heating system. After 1960 the implementation of electric heating system is increasing and it becomes the dominant heating method in houses built after this year. (Energy statistics for one-and two-dwelling buildings in 2005, p.11).

— It is observed that by 2005, around 40% of the single and two-dwelling houses are heated with electricity as a sole fuel and 13% of the same are heated with oil. That makes a total energy use in terms of electricity 26 TWh and in terms of oil 5.3 TWh (Mundaca, L. 2009). For that purpose, two reference buildings were developed. First – building, exclusively heated with oil and second – building, exclusively heated with electricity.

— For performing optimally accurate calculations and results, a specific geographic region is addressed. Climatically, Sweden is divided into three zones (North, Central and South), corresponding to different energy criteria. Our focus is on buildings, located in climate zone 3 (South). For that purpose a specific climate data for the area of Stockholm is used. The data is collected and indicated in Table 7 of this report.

As reference buildings for Switzerland, average values for a single-family and multi-family residential building are used based on data sources from Ott et al. 2011. Average values were derived from a class of single-family buildings with a gross floor area between 0 and 500 m^2, and from a class of multi-family buildings with a gross floor area between 500 and 1200 m^2.

2.5 Generic assessment of retrofit strategies in single-family residential buildings in different countries

2.5.1 Denmark

Measures and renovation packages

For the reference building in Denmark, the impacts of six packages of measures on the building envelope are calculated, while distinguishing the effects of replacing the existing heating system with three different heating systems: a new oil heating system, a geothermal heat pump or wood pellets.

The different packages applied to the building envelope are:

— Ref: In the reference case, the windows need to be repainted as the only necessary rehabilitation measure.

— M1: Insulation of the cavity wall with an insulation equivalent to 7 cm of rock wool.

— M2: Additionally to M1, the roof is insulated with 14 cm of rock wool.

— M3: Additionally to M1, the roof is insulated with 20 cm of rock wool.

— M4: Additionally to M3, windows are replaced with new windows with a U-value of 1.0.

— M5: Additionally to M3, windows are replaced with new windows with a U-value of 0.8.

— M6: Additionally to M5, the cellar ceiling is insulated with 8 cm of rock wool.

Table 16 describes the characteristics of the different renovation packages that are taken into account.

Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6
Wall – Costs	EUR/m² wall	-	27.9	27.9	27.9	27.9	27.9	27.9
Wall thickness of insulation material	cm	-	7	7	7	7	7	7
Wall λ insulation material	W/mK	-	0.04	0.04	0.04	0.04	0.04	0.04
Wall - lifetime of renovation measure	years	-	40	40	40	40	40	40
Window - Costs	EUR/m² window	16.9	16.9	16.9	16.9	333	536	536
Window - U-Value	W/m²K	2.52	2.52	2.52	2.52	1	0.8	0.8
Window - g-value		0.7	0.7	0.7	0.7	0.6	0.5	0.5
Window - lifetime of renovation measure	years	30	30	30	30	30	30	30
Roof – Costs	EUR/m² roof	6.7	6.7	32	40	40	40	40
Roof - thickness of insulation material	cm	-	-	14	20	20	20	20
Roof - λ insulation material	W/mK	-	-	0.04	0.04	0.04	0.04	0.04
Roof - lifetime of renovation measure	years	30	30	30	30	30	30	30
Cellar ceiling - Costs	EUR/m² cellar ceiling	-	-	-	-	-	-	112
Cellar ceiling - thickness of insulation material	cm	-	-	-	-	-	-	8
Cellar ceiling - λ insulation material	W/mK	-	-	-	-	-	-	0.04
Cellar ceiling - lifetime of renovation measure	years	-	-	-	-	-	-	40
Energy need for heating	MJ/m²	571	487	435	425	320	306	262
Peak heating capacity required	kW	9.6	8.5	7.8	7.7	6.3	6.1	5.5

Table 16: Data for different packages of renovation measures M1 to M6 and the reference case in Denmark. For explanations concerning the building type see previous table. Data sources: V&S PrisData (2012), Kragh and Wittchen (2010), Wittchen and Kraggh (2012). The energy need was calculated based on the input parameters for the different building envelope elements taking into account both the original U-values of the buildings and the changes due to the renovation.

Results

The results of the calculation are shown graphically Figure 5 and the numeric values are indicated in Table 17.

All renovation packages investigated are cost effective compared to the reference case. The changes in the heating system dominate the effects on costs, greenhouse gas emissions and primary energy use. The second largest effect on these parameters has the number of building elements which are affected by energy-efficiency renovations. The extent of the insulation for a specific building element, however, has relatively little impact on costs, primary energy or greenhouse gas emissions: The differences between insulation of the roof with 14 cm or 20 cm of insulation, or between a window with U-values of 1.0 or 0.8 are relatively small.

The most cost efficient renovation packages are those involving a change to a wood pellet heating system. Related renovation packages also lead to the most significant reduction in CO_2 emissions. However, these renovation packages only slightly decrease or even increase primary energy use. The most cost efficient renovation package with a change to a wood pellets system is M2, which includes insulation of the wall and the insulation of the roof with 14 cm of rock wool.

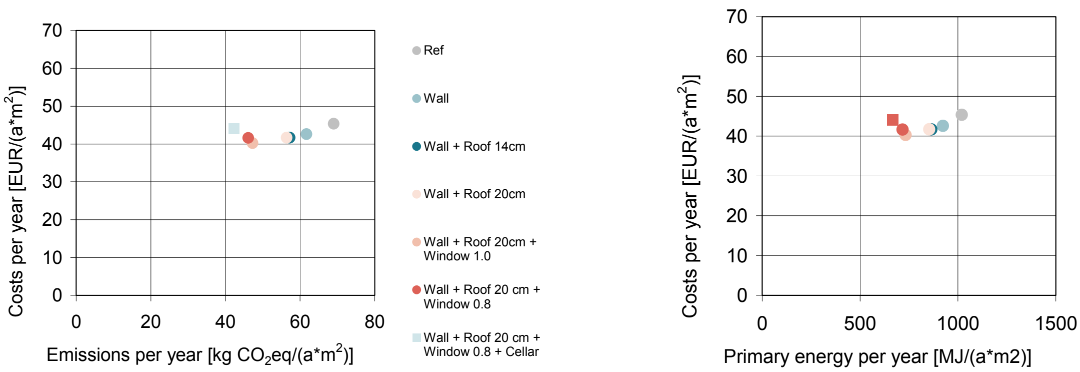
Renovation packages involving a change to a geothermal heat pump are slightly more cost efficient than those involving the replacement of the heating system with a new oil heating system. At the same time, both CO_2 emissions and primary energy use are reduced significantly compared to the reference case. The most cost efficient renovation package with a change to a geothermal heat pump is M4, which includes insulation of the wall, insulation of the roof with 20 cm of rock wool and replacement of the windows with new windows having a U-value of 1.0.

When considering the building with an oil heating system, the most cost efficient renovation package is M4 as for the case with the geothermal heat pump.

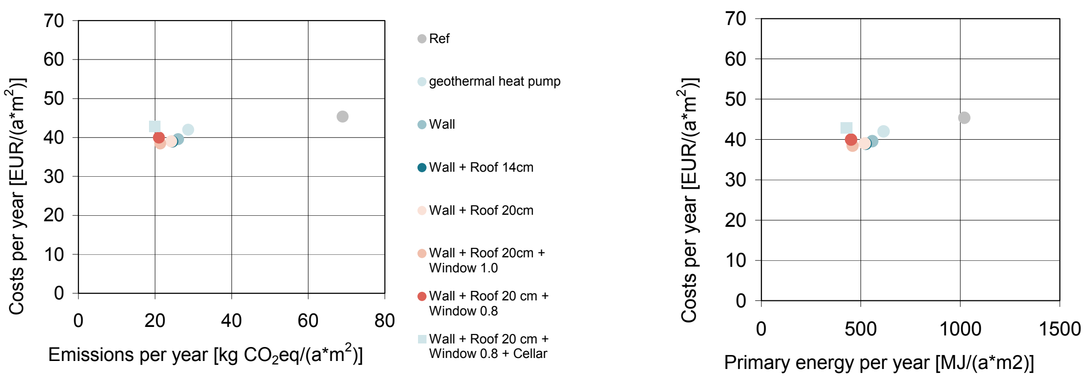
Discussion

For renovation packages applied to a building with an oil heating system, the effects of adding more and more measures into the renovation package on CO_2 emissions and primary energy is relatively large. Few changes in cost bring relatively big changes in greenhouse gas emissions/primary energy. In contrast to that, the effect is rather small for the CO_2 emissions in case of a heat pump or a wood pellet heating system, as these RES technologies already reduce CO_2 emissions significantly on their own, independent of the insulation measures of the building envelope. For the primary energy use, a similar effect is observed in case of a heat pump system, however, not for a wood pellet system, as wood energy lowers CO_2 emissions significantly, yet not primary energy use.

Heating System: oil



Heating System: geothermal heat pump



Heating System: wood pellets

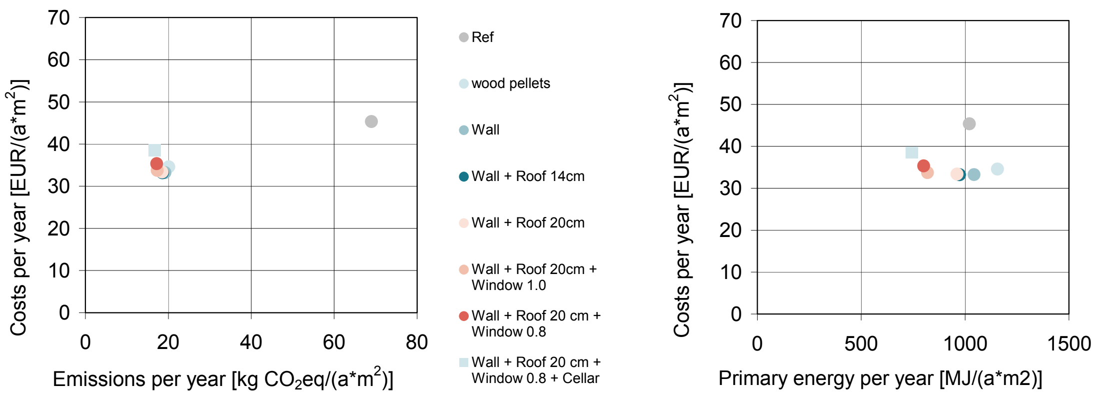


Figure 5: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference single-family building in Denmark. In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

The insulation of the wall is the most attractive measure on the building envelope in the reference building investigated; the filling of the cavity in a brick wall is a rather cost effectiveness measure. Also the energy-efficiency renovation of the roof is a cost effective measure, with little difference between 14 cm and 20 cm insulation in terms of costs, greenhouse gas emissions or primary energy. Including installation of new windows reduces emissions and primary energy use more strongly than any of the other measures on the building envelope, and it is cost effective if a new window with a U-value of 1.0 is chosen and if an oil heating system or a geothermal heat pump is used. A window with a U-value of 0.8 is still cost effective with respect to the reference case, yet less close to the cost optimum. For a wood pellet system, including the installation of new windows is not the most cost effective renovation package, yet it is still cost effective when compared to the reference. The insulation measure of the cellar ceiling is the least cost effective of the investigated measures, yet also the inclusion of this measure is still cost effective in comparison with the reference case.

Heating system	Parameter	Unit	Reference / new heating system without further measures	New type of heating system	M1	M2	M3	M4	M5	M6
Oil	Life cycle costs	EUR/ (a*m²)	46		43	42	42	41	42	45
	Yearly GHG emissions	kg CO2eq/ (a*m²)	71		63	59	58	49	48	44
	Yearly primary energy consumption	MJ/ (a*m²)	1043		946	886	875	573	737	686
Geothermal heat pump	Life cycle costs	EUR/ (a*m²)	43		40	40	40	39	40	43
	Yearly GHG emissions	kg CO2eq/ (a*m²)	29		27	25	25	22	21	20
	Yearly primary energy consumption	MJ/ (a*m²)	629		571	537	531	469	461	437
Wood pellets	Life cycle costs	EUR/ (a*m²)	35		34	34	34	34	36	39
	Yearly GHG emissions	kg CO2eq/ (a*m²)	20		19	19	19	18	17	17
	Yearly primary energy consumption	MJ/ (a*m²)	1183		1069	998	986	843	824	765

Table 17: Resulting life cycle costs, yearly greenhouse gas (GHG) emissions and yearly primary energy consumption for different renovation packages applied to the reference building.

When comparing the different heating systems, there is no difference in the cost optimal renovation package for an oil heating system or a geothermal heat pump; there is a slight difference in cost optimality if a wood pellet heating system is chosen instead; then cost optimality is reached already with less renovation measures of the building envelope; however, the difference in the life cycle costs is relatively small compared to including also other building elements in the energy-efficiency renovation.

In the calculations, a linear decrease of heating costs was assumed as the need for delivered energy decreases. In case a district heating system was taken into account in the comparisons, a distinction between the regular fees associated with the connection to the district heating system on the one hand, which are fixed and independent of consumption, and the actual energy costs on the other hand, which depend on the quantity of energy consumed. It can be expected that the cost-effectiveness of building renovation measures for the building envelope is reduced, when heating costs are to a significant extent composed of fixed costs, independent of the amount of energy consumption.

2.5.2 Sweden

Measures and renovation packages

For the case of Sweden, eight renovation packages of measures on the building envelope are constructed. Their impacts on the two reference single family buildings are calculated. The effects of replacing the existing heating system with three different heating systems: renewing the existing heating system with the same, but more efficient one (oil and electricity respectively), a geothermal heat pump and wood pellets are distinguished.

The different packages applied to the building envelope are:

— Ref: In the reference case, an additional investment for renewing the heating system is made.

— M1: The walls are insulated with 7 cm of rock wool

— M2: Additionally to M1, the roof is insulated with 20 cm of rock wool.

— M3: Additionally to M1, the roof is insulated with 30 cm of rock wool.

— M4: Additionally to M3, the windows are replaced with new wooden frame windows with a U-value of 1.3.

— M5: Additionally to M3, the windows are replaced with new wooden frame windows with a U-value of 1.0.

— M6: Additionally to M3, the windows are replaced with new wooden frame windows with a U-value of 0.8.

— M7: Additionally to M6, the cellar ceiling is insulated with 10 cm of rock wool.

— M8: Additionally to M7, a ventilation system is implemented.

The following table (Table 18) describes the characteristics of the different renovation packages that are taken into account.

Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6	M7	M8
Wall - Costs	EUR/m² wall	-	35	35	35	35	35	35	35	35
Wall thickness of insulation material	cm	-	7	7	7	7	7	7	7	7
Wall λ insulation material	W/mK	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Wall - lifetime of renovation measure	a	-	40	40	40	40	40	40	40	40
Window - Costs	EUR/m² window	16.9	16.9	16.9	16.9	495	544	598	598	598
Window - U-Value	W/m²K	2.3	2.3	2.3	2.3	1.2	1.0	0.8	0.8	0.8
Window - g-value		0.7	0.7	0.7	0.7	0.6	0.5	0.45	0.45	0.45
Window - lifetime of renovation measure	a	-	40	40	40	40	40	40	40	40
Roof - Costs	EUR/m² roof	6.7	6.7	40	50	50	50	50	50	50
Roof - thickness of insulation material	cm	-	-	20	30	30	30	30	30	30
Roof - λ insulation material	W/mK	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04
Roof - lifetime of renovation measure	a	-	40	40	40	40	40	40	40	40
Cellar ceiling - Costs	EUR/m² cellar ceiling	-	-	-	-	-	-	-	112	112
Cellar ceiling - thickness of insulation material	cm	-	-	-	-	-	-	-	8	8
Cellar ceiling - λ insulation material	W/mK	-	-	-	-	-	-	-	0.04	0.04
Cellar ceiling - lifetime of renovation measure	a	-	-	-	-	-	-	-	40	40
Energy need for heating	MJ/m²	465	423	399	394	299	288	273	263	182
Peak heating capacity required	kW	6.74	6.28	6.00	5.95	4.79	4.58	4.36	4.26	3.42

Table 18: Data for different packages of renovation measures M1 to M8 and the reference case in Sweden. Sources: Energimyndigheten 2009; Bostadts- och byggnadsstatistik ärsbok, 2010, TABULA Project. The energy need was calculated based on the input parameters for the different building envelope elements taking into account both the original U-values of the buildings and the changes due to the renovation.

Results

The results of the calculation are shown graphically in Figure 6 and the numeric values are indicated in Table 19 which exemplifies the results of the life cycle costs, yearly greenhouse gas emissions and the yearly primary energy consumption for different renovation packages applied to the reference buildings for Sweden.

The purpose of this part of cost, GHG emissions and PE use comparison is to examine the profit from one side- of the conversion to different heating systems and from the other- of the implementation of different packages of measures within the individual heating systems.

All renovation packages investigated are cost effective compared to the reference case. Dominating effects on cost, greenhouse gas emissions and primary energy use have the renovation packages associated with changes in the heating system. The most significant effects of the four heating systems have the case of geothermal heat pump, followed by the cases of wood pellets and district heating systems.

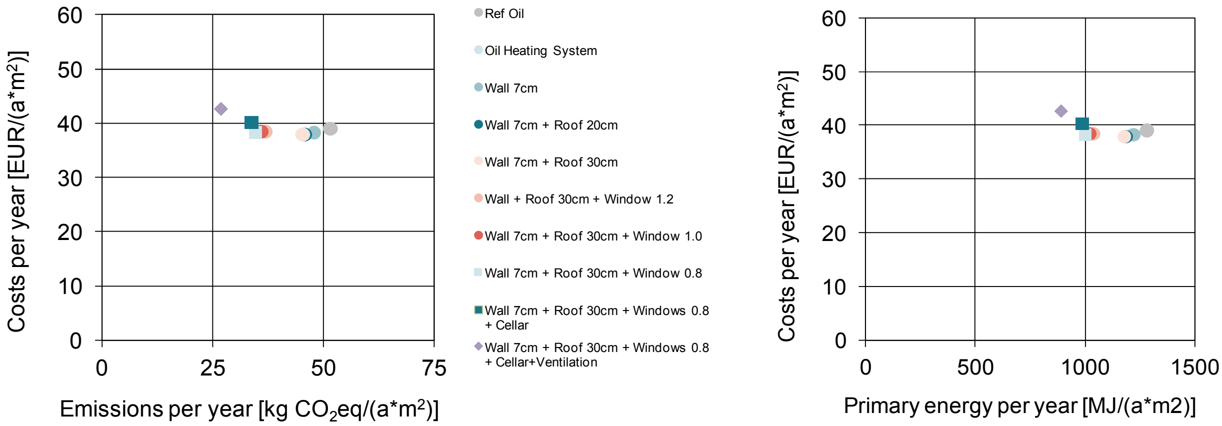
The second largest effect on these parameters has the number of building elements which are affected by energy-efficiency renovations. The extent of the insulation for a specific building element, however, has relatively little impact on costs, primary energy or greenhouse gas emissions. That can particularly be seen on the graph showing different insulation packages in combination with oil heating system and it is also valid for the other heating systems: the differences between insulation of the roof with 20cm or 30cm of insulation material or between windows with U-values of 1.2, 1.0 or 0.8 W/m^2K are relatively in the same terms.
A better distinguish is made when comparing the packages without and with windows replacement. In the case of oil the effect in terms of reduction of the greenhouse gases is the most explicit. This measure has also significant effects in terms of primary energy use, when applied to electric heating systems. For the cases of heat pump, wood pellets and district heating, the installation of new windows decreases the GHG and PE performances as well, but in smaller terms and with a contrast to life cycle cost performance, where the values are increasing.

The most cost efficient renovation packages are those involving a change to a geothermal heat pump, wood pellets and district heating systems. These are packages M1, M2, and M3 for all three cases which include a single measure of 7cm wall insulation and a combination with 20cm or 30cm of roof insulation material. The difference between the results of the three packages is relatively small.

Renovation packages involving a change to a different heating system are more cost efficient than those involving a replacement of the existing heating system with the same type. They perform a lot better on both CO_2 emissions and primary energy than even the most far reaching renovation package, which is based on an oil heating system. An exception is the case of wood pellets, which primary energy performance is more similar to the oil heating system.

When considering a building with an oil heating system, the most cost efficient renovation package is M6, which include insulation of the wall with 7cm of insulation material, insulation of the roof with 30cm of insulation material and replacement of the windows with new ones having a U-value of 0.8 W/m^2K.

Oil



Electricity

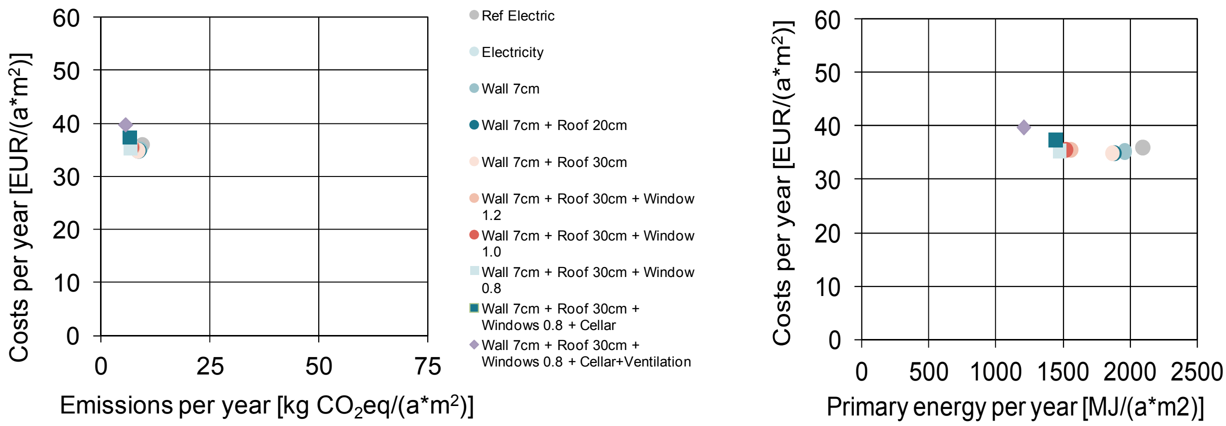
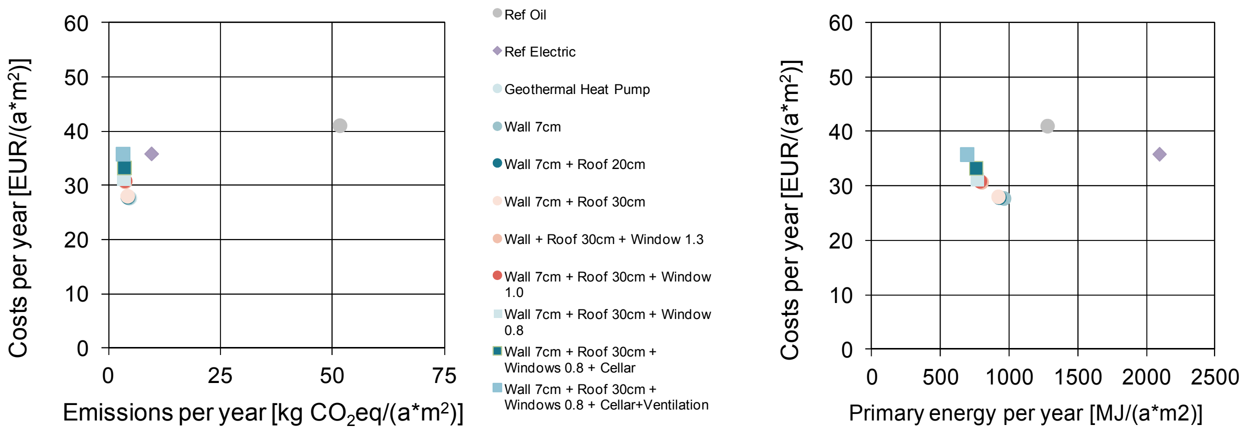
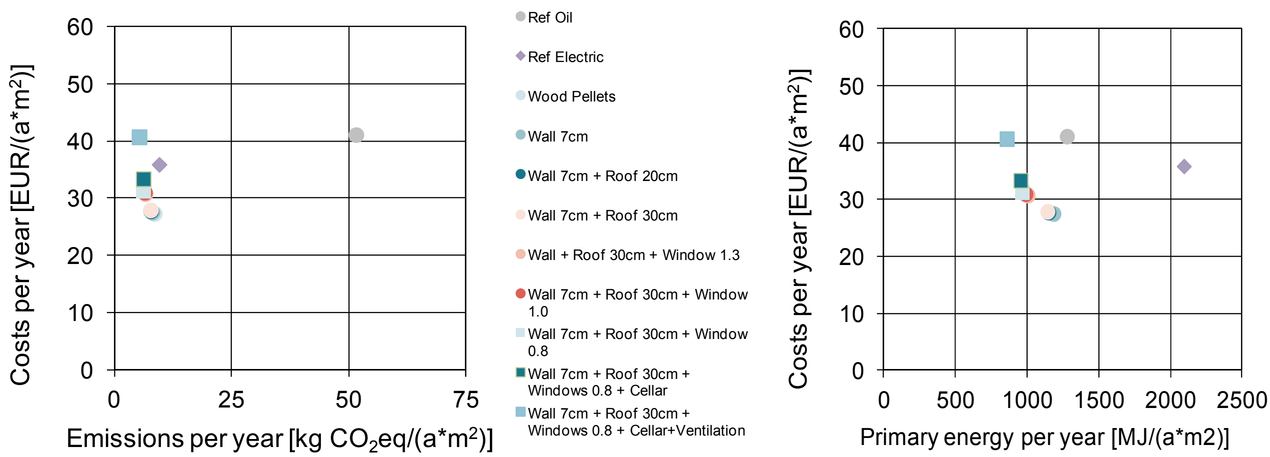


Figure 6: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference single-family building in Sweden, oil heated (above) and electricity heated (below). In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

Heat Pump



Wood Pellets



District Heating

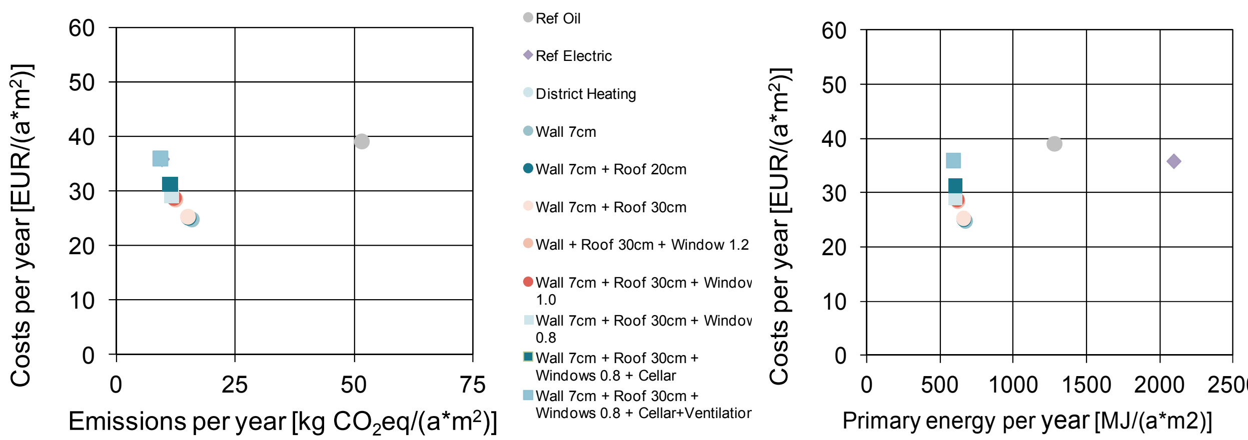


Figure 7: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference single-family building in Sweden. In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, and the reference shown with purple rhombus refers to a situation with replacement of the electric heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

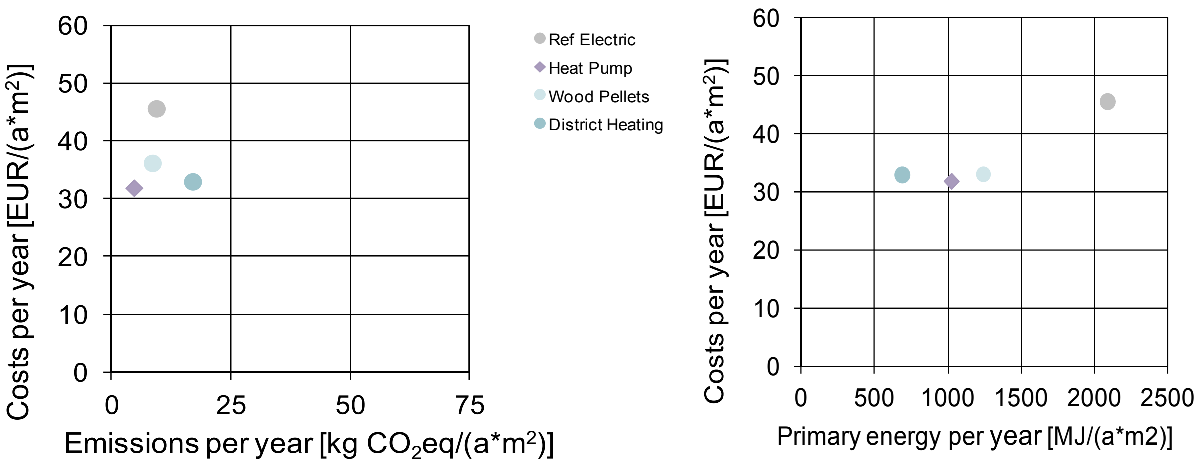


Figure 8: Starting points of the different heating systems after the implementation of the additional costs for the case of existing electric heating system with direct-acting electric radiators.

Heating system	Parameter	Unit	Ref. Oil /new heating system	Ref. El. /new heating system	New Heating System	M1	M2	M3	M4	M5	M6	M7	M8
Oil	Life cycle costs	EUR/ (a*m²)	50	-	50	48	47	47	45	44	44	45	46
	Yearly GHG emissions	kg CO_2eq/ (a*m²)	52	-	52	48	46	45	37	36	35	34	27
	Yearly primary energy use	MJ/ (a*m²)	1280	-	1280	1220	1184	1177	1037	1021	1000	986	888
Electricity	Life cycle costs	EUR/ (a*m²)	-	46	46	44	43	43	41	41	40	41	42
	Yearly GHG emissions	kg CO_2eq/ (a*m²)	-	10	10	9	9	8	7	7	7	7	5
	Yearly primary energy use	MJ/ (a*m²)	-	2092	2092	1959	1880	1865	1558	1523	1475	1445	1205
Geotherm. HP	Life cycle costs	EUR/ (a*m²)	50	46	29	29	28	28	30	30	30	31	35
	Yearly GHG emissions	kg CO_2eq/ (a*m²)	52	10	5	4	4	4	4	4	3	3	3
	Yearly primary energy use	MJ/ (a*m²)	1280	2092	1022	960	925	919	797	784	767	757	691
District Heating	Life cycle costs	EUR/ (a*m²)	50	46	30	30	30	30	31	31	31	33	36
	Yearly GHG emissions	kg CO_2eq/ (a*m²)	52	10	17	16	15	15	12	12	12	11	9
	Yearly primary energy use	MJ/ (a*m²)	1280	2092	686	669	658	656	616	611	605	601	587
Wood pellets	Life cycle costs	EUR/ (a*m²)	50		31	30	30	30	31	32	32	33	38
	Yearly GHG emissions	kg CO_2eq/ (a*m²)	52		9	8	8	8	7	6	6	6	5
	Yearly primary energy use	MJ/ (a*m²)	1280		1243	1183	1148	1141	1004	988	967	953	857

Table 19: Resulting life cycle costs, yearly greenhouse gas (GH) emissions and yearly primary energy consumption for different renovation packages applied to the reference building for Sweden.

Discussion

Looking into the individual renovation packages and the measures applied, the installation of cellar insulation is rather expensive measure. The investment cost for the particular insulation measure is much higher comparing to the investment cost of both wall and roof insulations. Implementing such of insulation significantly increases the life cycle costs and reduces just slightly the energy demand of the building. Renovation packages related with this measure have the most efficient performances in terms of greenhouse gas emissions and primary energy use, but are also similar to the previous renovation packages, which do not involve the particular measure. That is valid for all the cases of different heating systems. That renovation package is not a single measure, but a combination, which includes also 7cm of wall insulation, 30cm of roof insulation and replacement of the windows with new ones, having a U-value of 0.8 W/m^2K.

As already mentioned, dominating effects on cost, greenhouse gas emissions and primary energy reduction have the renovation packages associated with a change to geothermal heat pump, wood pellets or district heating systems. The cost optimality there is reached already with less renovation measures on the building envelope.

When implementing a ventilation system with heat recovery functions, the greenhouse gas emissions and the primary energy are even more reduced (package M8).The energy demand for heating purposes has also decreased. However, this measure increases the life cycle cost because it also requires higher investments, some additional maintenance costs and electricity consumption.

The most significant results, in terms of level of reduction, are observed for the case of oil heating system, since for the other cases, the decrease was already made by the implementation of the heating systems themselves, due to the low emission factor of the related energy carriers.

Another important issue is when the existing heating system is with direct-acting electric radiators. Additional costs for the installation of hydronic radiators, chimney and storage place are taken under consideration.

The results of implementing different renovation package (M1-M8) will basically follow the same curve on the graph with the only difference in the starting point.

These starting points, on which the further implementation of different renovation packages is based, are graphically shown on. They are calculated with respect to the additional investments required for the replacement of the existing state- direct-acting electric heating system.

2.5.3 Switzerland

Measures and renovation packages

For the reference single family residential building in Switzerland, the impacts of nine packages of measures on the building envelope are calculated. The effects are distinguished for replacement of the existing heating system with three different heating systems: an oil heating system, a geothermal heat pump or wood pellets.

The different packages applied to the building envelope are:

- Ref: In the reference case, the plastering of the wall is restored, the wall is repainted, and the roof is refurbished, yet all those measures do not improve the energy performance of the building.
- M1: The wall is insulated with 12 cm of rock wool.
- M2: The wall is insulated with 30 cm of rock wool.
- M3: Additionally to M2, the roof is insulated with 12 cm of rock wool.
- M4: Additionally to M2, the roof is insulated with 36 cm of rock wool.
- M5: Additionally to M4, the cellar ceiling is insulated with 10 cm of rock wool.
- M6: Additionally to M4, the cellar ceiling is insulated with 16 cm of rock wool.
- M7: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 1.3.
- M8: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 1.
- M9: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 0.8.

The following table (Table 20) describes the characteristics of the different renovation packages that are taken into account.

Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6	M7	M8	M9
Wall - Costs	EUR/m² wall	62	142	167	167	167	167	167	167	167	167
Wall thickness of insulation material	cm	-	12	30	30	30	30	30	30	30	30
Wall λ insulation material	W/mK	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Wall - lifetime of renovation measure	a	40	40	40	40	40	40	40	40	40	40
Window - Costs	EUR/m² window	33	33	33	33	33	33	33	763	832	875
Window - U-Value	W/m²K	3	3	3	3	3	3	3	1.3	1	0.8
Window - g-value		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.45	0.45
Window - lifetime of renovation measure	a	-	40	40	40	40	40	40	40	40	40
Roof - Costs	EUR/m² roof	63	63	63	183	233	233	233	233	233	233
Roof - thickness of insulation material	cm	-	-	-	12	36	36	36	36	36	36
Roof - λ insulation material	W/mK	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Roof - lifetime of renovation measure	a	30	30	30	30	30	30	30	30	30	30
Cellar ceiling - Costs	EUR/m² cellar ceiling	-	-	-	-	-	87	96	96	96	96
Cellar ceiling - thickness of insulation material	cm	-	-	-	-	-	10	16	16	16	16
Cellar ceiling - λ insulation material	W/mK	-	-	-	-	-	0.04	0.04	0.04	0.04	0.04
Cellar ceiling - lifetime of renovation measure	a	-	-	-	-	-	40	40	40	40	40
Energy need for heating	MJ/m²	778	535	492	353	325	264	256	172	157	147
Peak heating capacity required	kW	16	12	11	8.3	8.0	6.7	6.5	5.0	4.7	4.5

Table 20: Data for different packages of renovation measures M1 to M6 and the reference case in Switzerland. Sources: Lifetimes of building elements: AHB 2009, SIA 2004, Bund Technischer Experten (BTE) 2008, Bundesministeriums für Verkehr, Bau- und Wohnungswesen (BVBW) 2001, SIA 2010. The energy need was calculated based on the input parameters for the different building envelope elements taking into account both the original U-values of the buildings and the changes due to the renovation.

Results

Most renovation packages investigated are cost effective compared to the reference case (see Figure 9 and Table 21.). The changes in the heating system dominate the effects on costs, greenhouse gas emissions and primary energy use. The second largest effect on these parameters has the number of building elements which are renovated, as can be seen particularly from graph showing different insulation packages in combination with an oil heating. The extent of the insulation for a specific building element, however, has relatively little impact on costs, primary energy or greenhouse gas emissions: The differences between insulation of the roof with 12 cm, or 36 cm, or the cellar with 10 cm, or 16 cm of insulation are relatively small. The same is found for insulation of the wall with 12 or 30 cm of insulation, or between windows with U-values of 1.3, 1.0, or 0.8 W/m^2K respectively.

The most cost effective measure on the building envelope is to renovate the wall, followed by renovating the roof, and the cellar. Installing new windows is not a cost effective measure, despite assuming rehabilitation works in the reference case.

The most cost efficient renovation packages are those involving a change to a geothermal heat pump system. The cost optimal renovation package is M3. M4, M5, and M6 are close in terms of costs and greenhouse gas emissions or primary energy use. Any renovation package will perform better on CO_2 emissions than even the most far reaching renovation package which is based on an oil heating system. The effect for primary energy is similar, but less pronounced.

Renovation packages involving a change to a wood pellet heating system have similar costs as in the case of a replacement of the heating system with a new oil heating system, for all renovation packages. Related renovation packages lead to a significant reduction in CO_2 emissions. However, these renovation packages only slightly decrease or even increase primary energy use. The most cost efficient renovation packages with a change to a wood pellets system is M3, which include insulation of the wall with 30 cm of insulation material, and the insulation of the roof with 10 cm of insulation material.

When considering the building with an oil heating system, the most cost efficient renovation packages are M5 and M6.

Discussion

For renovation packages applied to a building with an oil heating system, the effects of adding more and more measures into the renovation package on CO_2 emissions and primary energy is relatively large. Few changes in cost bring relatively big changes in greenhouse gas emissions/primary energy. In contrast to that, the effect is rather small for the CO_2 emissions in case of a heat pump system: The renovation packages investigated have relatively similar CO_2 emissions. This is partly due to the fact that in Switzerland, the electricity mix has a low CO_2 emission factor, because it is based to a large extent on hydro and nuclear energy.

It is rather expensive to install new windows, in particular with a wood frame as in the reference building investigated here. However, windows are often also installed for other reasons than improving energy efficiency; there co-benefits are rather big in terms of improved noise protection, indoor climate, and the visual impression of the building.

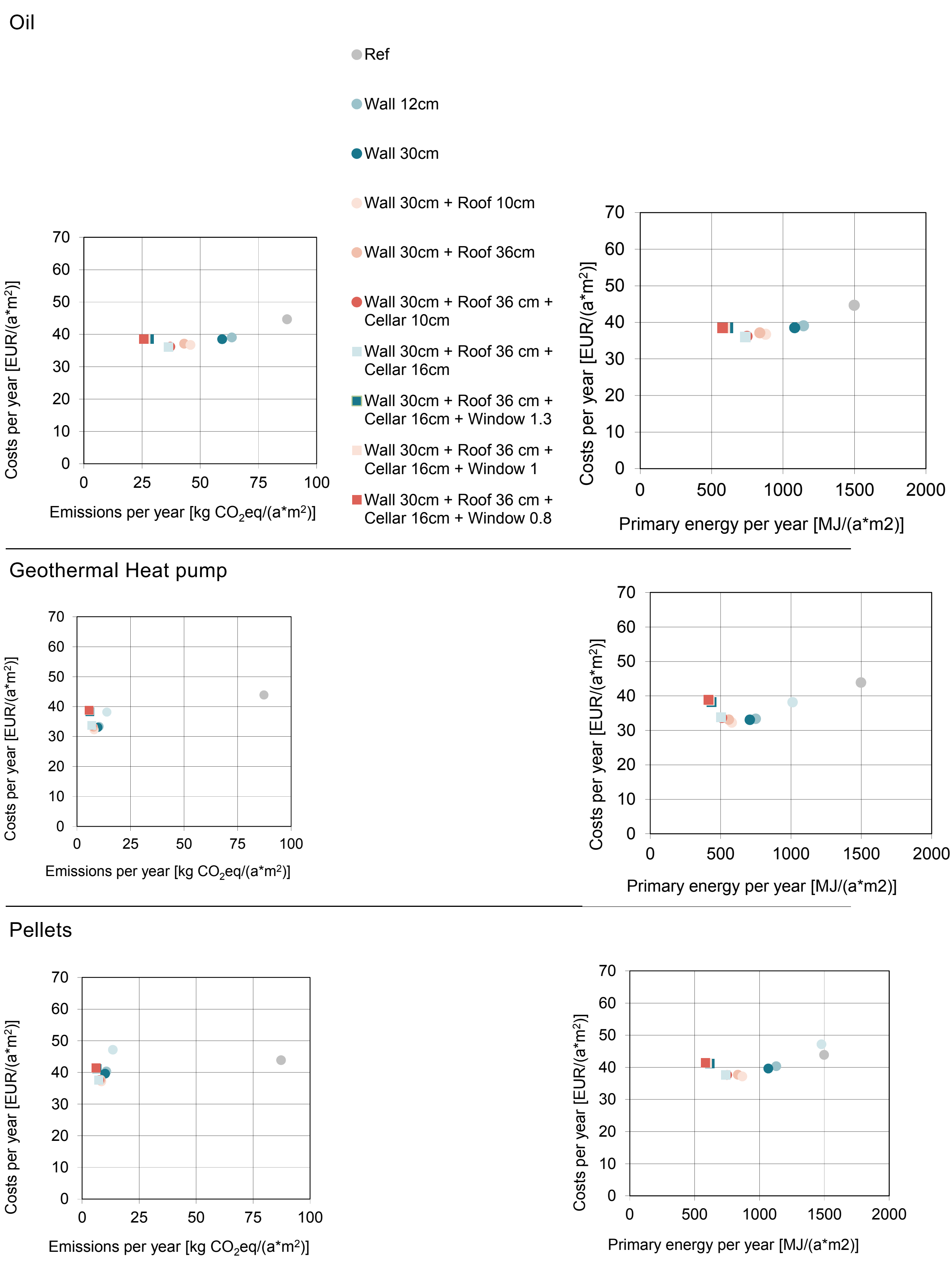


Figure 9: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference single-family building in Switzerland. In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

Heating system	Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6	M7	M8	M9
Oil	Life cycle costs	EUR/ (a*m²)	45	39	39	37	37	36	36	38	38	38
	Yearly greenhouse gas emissions	kg CO2eq/ (a*m²)	87	64	59	46	43	37	36	28	27	26
	Yearly primary energy consumption	MJ/ (a*m²)	1498	1143	1081	878	837	748	737	613	592	578
Geothermal heat pump	Life cycle costs	EUR/ (a*m²)	38	33	33	32	33	34	34	38	39	39
	Yearly greenhouse gas emissions	kg CO_2eq/ (a*m²)	14	10	9.7	8.0	7.7	7.0	6.9	6.0	5.8	5.7
	Yearly primary energy consumption	MJ/ (a*m²)	1011	749	708	579	558	510	503	435	423	416
Wood pellets	Life cycle costs	EUR/ (a*m²)	47	40	40	37	38	38	38	41	41	41
	Yearly greenhouse gas emissions	kg CO2eq/ (a*m²)	13	11	10	8.5	8.2	7.5	7.4	6.4	6.2	6.1
	Yearly primary energy consumption	MJ/ (a*m²)	1477	1129	1068	867	833	751	740	618	597	583

Table 21: Resulting life cycle costs, yearly greenhouse gas emissions and yearly primary energy consumption for different renovation packages applied to the reference building.

2.5.4 Comparison of results for generic assessments

In the reference examples investigated, parallels can be found from different countries in the fact that the cost optimal renovation package in terms of measures on the building envelope is the same, independent whether an oil heating system or a geothermal heat pump is used. In case of a wood pellets system, in one country cost optimality is reached already with less renovations on the building envelope compared to other heating systems, however, the differences in terms of costs are small. This can be interpreted as an indicator that the trade-offs between the use of renewable energies on the one hand and investing in measures to improve the building envelope, although they may exist to some extent, are not pronounced in typical buildings in the countries investigated.

In the reference buildings from both Denmark and Switzerland, energy-efficiency renovation measures on the wall and the roof are the most cost effective. The energy-efficiency ambition level regarding a single building element has little effects on costs, greenhouse gas emissions, or primary energy use. Regarding the cost effectiveness of the insulation of the cellar ceiling, differences exist between Denmark and Switzerland: While in Switzerland, this measure is cost effective, it is not in Denmark.

2.6 Generic assessment of retrofit strategies in multi-family residential buildings

2.6.1 Romania

Measures and renovation packages

For the reference multi-family residential building in Romania, the impacts of seven packages of measures on the building envelope are calculated. The effects are distinguished for three different heating systems: a district heating system (Reference), a centralized gas heating system and a water source heat pump.

The different packages applied to the building envelope are:

— Ref: In the reference case, the mortar patching and the coating of the wall are restored, the wall is repainted, and the roof is refurbished with a 1-layer rubber bitumen membrane; all those measures do not improve the energy performance of the building.

— M1: The wall is insulated with 5 cm of EPS and a cement coating of 10 mm.

— M2: The wall is insulated with 10 cm of EPS and a cement coating of 10 mm.

— M3: Additionally to M2, the cellar ceiling is insulated with 5 cm of EPS.

— M4: Additionally to M3, the flat roof is insulated with 10 cm thermal insulation mineral wool, a timber structure and bitumen based water insulation.

— M5: Additionally to M4, windows are replaced with new windows with a plastic frame and a U-value for the entire window of 1.3

— M6: Additionally to M4, windows are replaced with new windows with a plastic frame and a U-value for the entire window of 1.0

— M7: Additionally to M4, windows are replaced with new windows with a plastic frame and a U-value for the entire window of 0.8

The following table (Table 22) describes the characteristics of the different renovation packages that are taken into account.

Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6	M7
Wall - Costs	EUR/m² wall	12	22	24	24	24	24	24	24
Wall - thickness of insulation	cm	-	5	10	10	10	10	10	10
Wall λ insulation material	W/mK	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Wall - lifetime of renovation measure	a	50	50	50	50	50	50	50	50
Window - Costs	EUR/m² window	-	-	-	-	-	156	213	267
Window - U-Value	W/m²K	2.33	2.33	2.33	2.33	2.33	1.5	1	0.8
Window - g-value		0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5
Window - lifetime of renovation	a	25	25	25	25	25	25	25	25
Roof - Costs	EUR/m² roof	16	16	16	16	75	75	75	75
Roof - thickness of insulation	cm	-	-	-	-	10	10	10	10
Roof - λ insulation material	W/mK	-	-	-	-	0.04	0.04	0.04	0.04
Roof - lifetime of renovation measure	a	50	50	50	50	50	50	50	50
Cellar ceiling - Costs	EUR/m² cellar ceiling	-	-	-	7	7	7	7	7
Cellar ceiling - thickness of insulation	cm	-	-	-	5	5	5	5	5
Cellar ceiling - λ insulation material	W/mK	-	-	-	0.04	0.04	0.04	0.04	0.04
Cellar ceiling - lifetime of renovation	a	-	-	-	50	50	50	50	50
Energy need for heating	MJ/m²	366	309	284	262	224	164	142	134
Peak heating capacity required	kW	88	77	72	68	61	49	44	43

Table 22: Data for different packages of renovation measures M1 to M7 and the reference case in Romania. Data sources: Costs of energy renovation have been estimated by averaging two independent offers from suppliers active on the market (www.ursa.ro, www.steelcenter.ro). The energy need was calculated based on the input parameters for the different building envelope elements taking into account both the original U-values of the buildings and the changes due to the renovation.

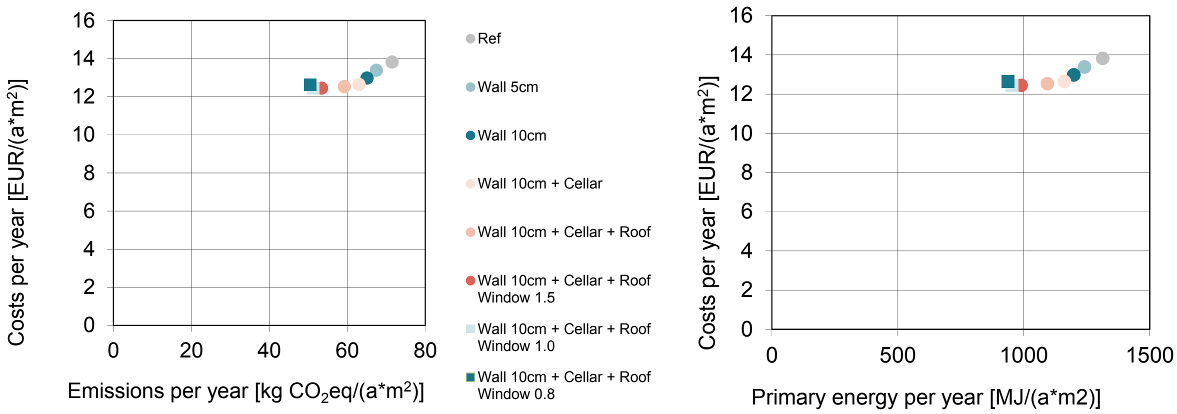
Results

All renovation packages investigated are cost effective compared to the reference case. The changes in the heating system dominate the effects on costs, greenhouse gas emissions and primary energy use. The most cost efficient renovation packages include the installation of natural gas heating system or a water source heat pump. Both have about similar costs, yet the water source heat pump has significantly less CO_2 emissions. Primary energy use is for both similar (see Figure 10 and Table 23).

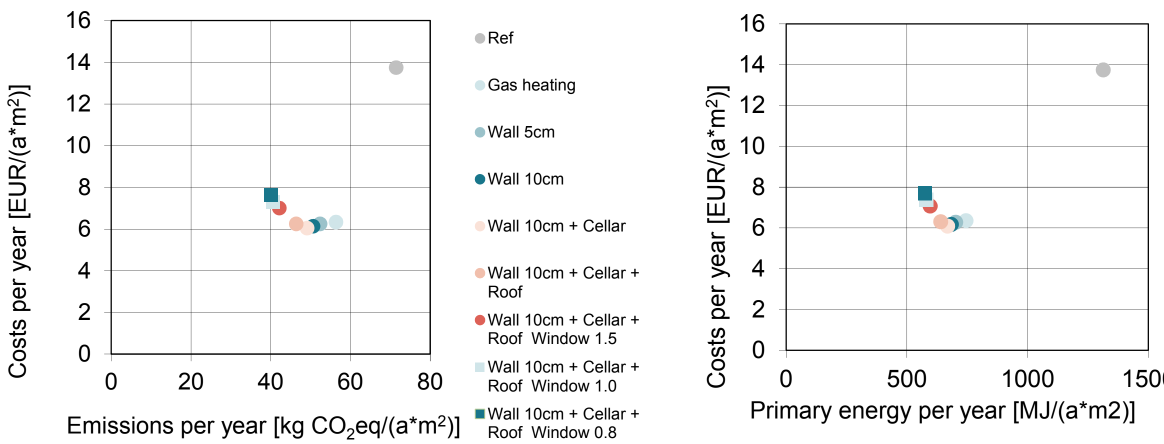
When installing a water source heat pump, the most cost efficient renovation package is M3, which includes the insulation of the wall with 10 cm of EPS and an insulation of the cellar ceiling with 5 cm EPS. For a gas heating system, the same renovation package is cost optimal. For a district heating system, however, significantly more renovation packages are cost effective, up to the package M6 which includes also the insulation of the roof, and the replacement of the windows with new windows with a U-value of 1.0.

The effects of different renovation packages on greenhouse gas emissions and primary energy use are comparable for all three heating systems.

District heating



Natural gas



Water source heat pump

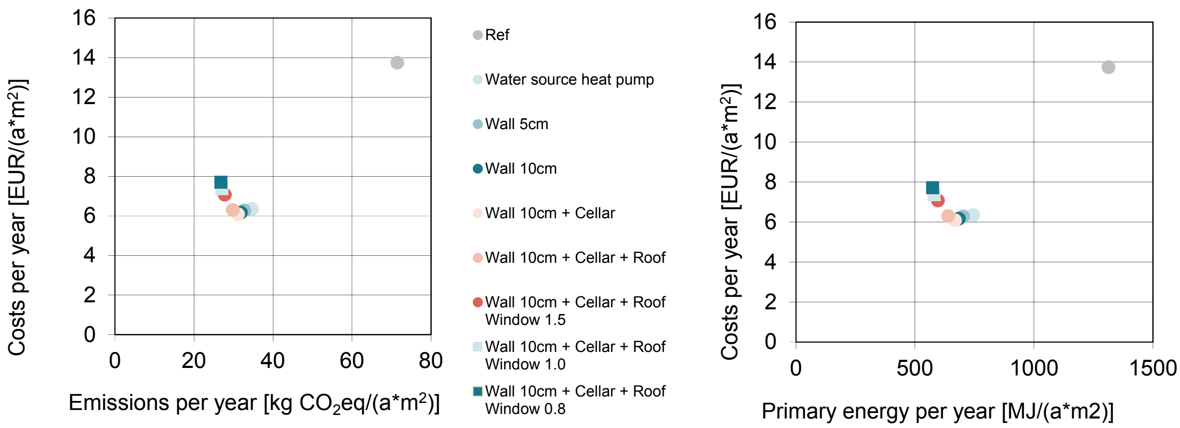


Figure 10: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference multi-family building in Romania. In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

Heating system	Parameter	Unit	Reference / new heating system without further measures	New heating system	M1	M2	M3	M4	M5	M6	M7
District heating system	Life cycle costs	EUR/ (a*m^2)	14	14	13	13	13	12	12	13	13
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)	71	71	67	65	63	59	53	51	51
	Yearly primary energy consumption	MJ/ (a*m^2)	1313	1313	1241	1198	1161	1093	989	958	938
Gas heating	Life cycle costs	EUR/ (a*m^2)	14	6	6	6	6	6	7	7	8
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)	71	56	52	51	49	46	42	42	40
	Yearly primary energy consumption	MJ/ (a*m^2)	1313	997	929	899	874	827	756	730	720
Water source heat pump	Life cycle costs	EUR/ (a*m^2)	14	6	6	6	6	6	7	7	8
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)	71	35	33	32	31	30	28	27	27
	Yearly primary energy consumption	MJ/ (a*m^2)	1313	745	702	684	668	640	596	581	575

Table 23: Resulting life cycle costs, yearly greenhouse gas (GHG) emissions and yearly primary energy consumption for different renovation packages applied to the reference building.

Discussion

When comparing a natural gas heating system and a water source heat pump system, no significant differences are found regarding the cost effectiveness of different renovation measures on the building envelope. However, such differences exist when comparing district heating and natural gas or water source heat pump. The reason is that for a district heating system, there are no energy installation costs to the building user; instead, heating costs are just proportional to the energy need; this may partly explain why in the case of a district heating system, investments in saving energy are more cost effective than for other heating systems. This is based on the assumption that the fixed amount that needs to be paid per month, is not high compared to the costs for the actual energy consumed; if this was the case, the cost effectiveness of measures on the building envelope would decrease for district heating systems.

The energy-efficiency renovation of the wall and the insulation of the cellar ceiling are cost effective measures for all heating systems. Windows did not feature as cost effective renovation measures; however, windows have other advantages than saving energy. Despite being not a cost effective measure in terms of saved energy use vs. investment costs, it may nevertheless be an attractive option to install windows because of co-benefits such as noise reduction, improved indoor climate or others.

Water source heat pumps are attractive both in terms of cost effectiveness and in terms of CO_2 reduction; however, there is still little experience with such heating systems in Romania, and it may therefore be difficult to find installers with the necessary experience to ensure proper functioning of such systems.

2.6.2 Switzerland

Measures and renovation packages

For the reference multi-family residential building in Switzerland, the impacts of nine packages of measures on the building envelope are calculated. The effects are distinguished for replacement of the existing heating system with three different heating systems: an oil heating system, a geothermal heat pump or wood pellets. The same renovation packages are investigated as for single-family houses; however, the costs of the related measures and their impacts on the energy performance differ because of the different building types.

The packages applied to the building envelope are:

— Ref: In the reference case, the plastering of the wall is restored, the wall is repainted, and the roof is refurbished, yet all those measures do not improve the energy performance of the building.

— M1: The wall is insulated with 12 cm of rockwool.

— M2: The wall is insulated with 30 cm of rockwool.

— M3: Additionally to M2, the roof is insulated with 10 cm of rockwool.

— M4: Additionally to M2, the roof is insulated with 36 cm of rockwool.

— M5: Additionally to M4, the cellar ceiling is insulated with 10 cm of rockwool.

— M6: Additionally to M4, the cellar ceiling is insulated with 16 cm of rockwool.

— M7: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 1.3.

— M8: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 1.

— M9: Additionally to M6, windows are replaced with new windows with a wooden frame and a U-value for the entire window of 0.8.

The following table (Table 24) describes the characteristics of the different renovation packages that are taken into account.

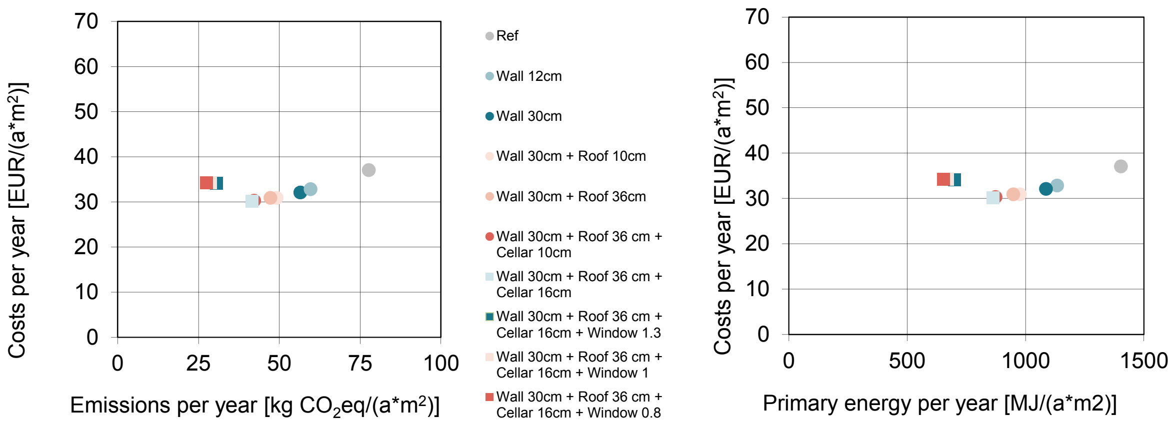
Parameter	Unit	Reference / new heating system without further measures	M1	M2	M3	M4	M5	M6	M7	M8	M9
Wall - Costs	EUR/m² wall	62	128	140	140	140	140	140	140	140	140
Wall thickness of insulation material	cm	-	12	30	30	30	30	30	30	30	30
Wall λ insulation material	W/mK	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Wall - lifetime of renovation measure	year	40	40	40	40	40	40	40	40	40	40
Window - Costs	EUR/m² window	33	33	33	33	33	33	33	763	832	875
Window - U-Value	W/m²K	3	3	3	3	3	3	3	1.3	1	0.8
Window - g-value		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.45	0.45
Window - lifetime of renovation measure	year	-	40	40	40	40	40	40	40	40	40
Roof - Costs	EUR/m² roof	63	63	63	146	188	188	188	188	188	188
Roof - thickness of insulation material	cm	-	-	-	10	36	36	36	36	36	36
Roof - λ insulation material	W/mK	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Roof - lifetime of renovation measure	year	30	30	30	30	30	30	30	30	30	30
Cellar ceiling - Costs	EUR/m² cellar ceiling	-	-	-	-	-	87	93	93	93	93
Cellar ceiling - thickness of insulation material	cm	-	-	-	-	-	10	16	16	16	16
Cellar ceiling - λ insulation material	W/mK	-	-	-	-	-	0.04	0.04	0.04	0.04	0.04
Cellar ceiling - lifetime of renovation measure	year	-	-	-	-	-	40	40	40	40	40
Energy need for heating	MJ/m²	623	445	413	338	318	267	260	148	129	116
Peak heating capacity required	kW	48	37	35	30	29	25	25	17	16	15

Table 24: Data for different packages of renovation measures M1 to M9 and the reference case in Switzerland. The energy need was calculated based on the input parameters for the different building envelope elements taking into account both the original U-values of the buildings and the changes due to the renovation.

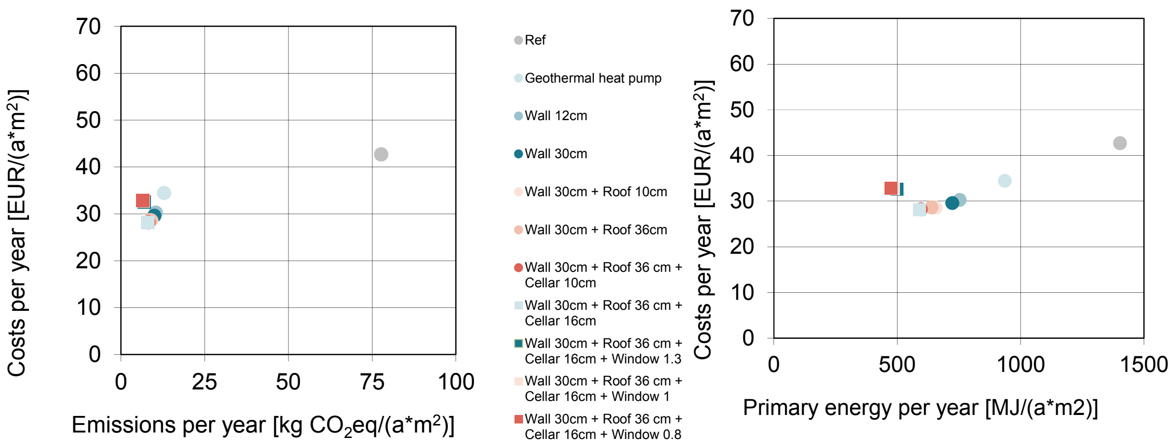
Results

Costs, greenhouse gas emissions and primary energy demand for different renovation packages and energy systems in a multi-family building are similar to the single-family residential building from Switzerland (see Figure 11 and in Table 25). Costs are slightly lower because of reduced prices per m^2 for renovation measures of multi-family buildings and because of lower costs per unit of installed heating capacity, due to economies of scale. The structures of the cost curves and the cost optimal renovation packages are essentially the same as in the case of a single-family building.

Oil



Geothermal heat pump



Pellets

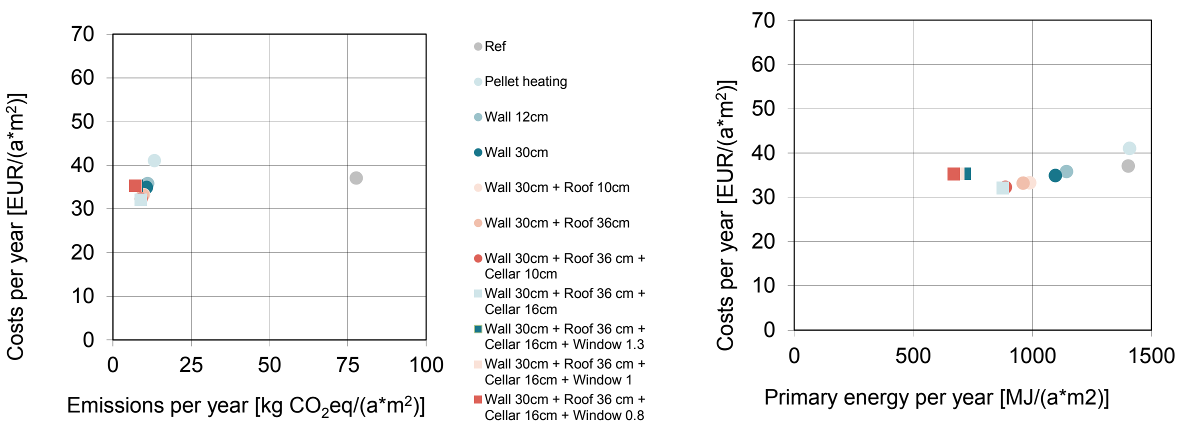


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Figure 11: Impacts of different renovation packages on costs, greenhouse gas emissions and primary energy for a reference single-family building in Switzerland. In all graphs, the reference shown as a grey dot refers to a situation with a replacement of the oil heating system, rehabilitation works on the windows, and no energy-efficiency improvements on the building envelope.

Heating system	Parameter	Unit	Reference / new heating system without further measures	New heating system	M1	M2	M3	M4	M5	M6	M7	M8	M9
Oil	Life cycle costs	EUR/ (a*m^2)		37	33	32	31	31	30	30	34	34	34
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)		78	60	57	49	47	42	42	31	29	28
	Yearly primary energy consumption	MJ/ (a*m^2)		1403	1134	1086	977	948	873	863	699	672	654
Geo-thermal heat pump	Life cycle costs	EUR/ (a*m^2)		35	30	30	29	29	28	28	33	33	33
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)		13	10	10	9.0	8.8	8.2	8.1	6.9	6.7	6.6
	Yearly primary energy consumption	MJ/ (a*m^2)		936	753	723	656	639	595	590	500	486	476
Wood pellets	Life cycle costs	EUR/ (a*m^2)		41	36	35	33	33	32	32	35	35	35
	Yearly GHG emissions	kg CO_2eq/ (a*m^2)		13	11	11	9.8	9.6	9.0	8.9	7.6	7.4	7.2
	Yearly primary energy consumption	MJ/ (a*m^2)		1408	1143	1097	989	961	887	877	716	689	671

Table 25: Resulting life cycle costs, yearly greenhouse gas (GHG) emissions and yearly primary energy consumption for different renovation packages applied to the reference building.

Discussion

Comparison of the calculations for the multi-family building and for the single-family building show that in Switzerland, the conclusions drawn regarding the dominant effect of the heating system on CO_2-emissions and costs and regarding the cost effectiveness of different renovation measures, are to a large extent independent from the size of the building investigated. However, measures insulating the building envelope are to a higher degree cost effective in the case of a combination with a renewable energy system. This is partly due to the fact that in multi-family buildings, renovation measures are more cost effective because of economies of scale. Partly this is also due to the fact that in multi-family buildings the installed heating capacity is higher, which means that also for the lowest heating capacities required in case of many renovation measures, there are correspondingly small heating systems available, whereas for single-family houses a minimum size is reached for the heating system beyond which further renovation measures have no longer an impact in reducing the cost of the installed heating system. There are furthermore other differences in building typologies which may affect the outcomes, and which have not been investigated here, for example regarding building period and associated U-values, regarding the comparison of different material options for renovations and associated impacts on costs, greenhouse gas emissions and primary energy use.

2.6.3 Comparison of results for generic assessments of multi-family buildings

When comparing results of the calculations for multi-family buildings from Romania and Switzerland, the following conclusions can be drawn:

— The choice of the heating system dominates the results regarding costs and greenhouse gas emissions. Heating systems based on renewable energies reduce greenhouse gas emissions significantly, and are cost effective or at least not significantly more expensive in comparison to fossil fuel based heating systems. The effect on primary energy use is smaller. This may be explained by the fact that both biomass or electricity from non-fossil sources have benefits in terms of CO_2 emissions, however, they do not decrease primary energy use as strongly, or may even lead to an increase in primary energy use.

— In both countries, to some extent renovation measures on the building envelope are cost effective, for all heating systems investigated. Romania has much lower energy prices than Switzerland, yet at the same time, also renovation measures cost much less. These two differences when comparing the two countries partly cancel each other out when looking at the cost effectiveness of renovation measures. There are nevertheless indications that in Romania, the effect of the low fuel prices is stronger, since less renovation measures are cost effective than in the case of the multi-family buildings in Switzerland.

— In both countries, the trade-offs between renewable energy measures and energy efficiency measures are not significant when comparing fossil fuel and renewable energy systems: If a measure on the building envelope is cost effective with one type of heating system, it is likely to be also cost effective with a different heating system. This conclusion, however, does not apply in the case of district heating, if it is assumed that all energy related costs are then proportional to the heat demand. In the case of district heating, more measures on the building envelope are cost effective, compared to other energy systems.

— There are indications that in both countries, the effect of increasing the ambition level of the energy performance of a single building element is small compared to the effect of involving more building elements in an energy-efficiency renovation. At least for the windows, there are parallels regarding this point in both countries. Nevertheless, for the renovation of the wall, the difference between 5 cm and 10 cm of insulation in case of the reference building in Romania is still relatively large in terms of effects on greenhouse gas emissions. The marginal effects on greenhouse gas emissions and life cycle costs probably decrease more strongly with higher insulation levels, as in the case of the reference building from Switzerland, where the differences in the impact of renovation measures involving an insulation of 12 cm or 30 cm of the wall are relatively small.

— The energy-efficiency renovation of the wall is the most cost effective renovation measure of the building envelope in both Romania and Switzerland.

2.7 Conclusions

2.7.1 Cost effectiveness of building renovation measures

For reference buildings in the countries Denmark, Romania, Sweden, and Switzerland, it could generally be shown that many renovation measures to improve the energy performance of a building are cost effective, when taking into account the following boundary conditions:

— Costs are taken into account as life cycle costs over the entire lifetime of each building element, including investment costs, maintenance costs, and energy costs. Since in retrofit reality usually a part of the building elements retrofitted is replaced before they arrived at the end of their technical life span, these cost assessment tend to underestimate really incurring costs. This might be because of use- or user-driven premature building renovation or because of functionally composed retrofit packages comprising building elements at different stages of their life span.

— Further uncertainties with respect to the costs assessment result from the fact that additional costs not accounted for in generic cost calculations are often incurring because of building specific alignment costs to fit retrofit measures to the existing building structures. Especially in the case of building renovation, these costs can be very relevant, depending on the building specific situation.

— For energy prices, future price increases during the (typically long) life span of retrofit measures are taken into account to reflect the expectation that worldwide rising energy demand induces an upward pressure on energy prices.

— Renovations are assumed to be carried out in situations where some investments would have to be made anyway as well in the reference case, to rehabilitate a building, without improving the energy efficiency; according to the cost assessment methodology, costs for energy-efficiency renovations are then compared to the costs in the reference situation to evaluate cost-effectiveness. This approach determines the cost-effectiveness of energy-efficiency renovations independent of the question, whether the law requires building owners to carry out certain energy improvements to their building envelope or not.

The cost effectiveness of renovation packages depends on the reference situation: If in the reference situation, a wall needs to be refurbished, simultaneous energy-efficiency improvement of the wall is more cost effective than if the insulation of the wall is carried out in a situation where no refurbishment would have to be done otherwise.

2.7.2 Comparison between use of renewable energy sources and higher performance of building envelope

The choice of the heating system dominates the assessment of different renovation packages, both in terms of costs and greenhouse gas emissions. Heating systems based on renewable energies reduce greenhouse gas emissions significantly, and are cost effective or at least not significantly more expensive in comparison to fossil fuel based heating systems. The effect of renewable energy use on primary energy use is less distinct than on greenhouse gas emissions.

Energy efficiency measures on the building envelope reduce particularly primary energy use. Resulting reduction of greenhouse gas emissions is depending on the energy system and the energy carrier covering residual heat or electricity demand. Normally the reductions of greenhouse gas emissions are significantly smaller than the reductions of primary energy use (e.g. primary energy consumption is reduced significantly if a change from a fossil fuel system to geothermal heat pumps is made, but it is reduced little or even increases if carrying out a change to wood pellets). It is difficult to achieve low levels of greenhouse gas emissions with efficiency measures alone. Such a retrofit approach would not be the most cost effective.

The importance of using renewable energies within building renovation also arises from the fact that with increasing energy-efficiency performance of the building envelope the share of energy needs for domestic hot water and for electricity is increasing and difficult to significantly reduce, at which point renewable energy sources can contribute to further lower the environmental impact.

Nevertheless, retrofit measures increasing energy efficiency of the building envelope are economically attractive and important for reducing greenhouse gas emissions and primary energy use as well. They reduce capacity or size of (renewable) energy system needed to cover remaining energy demand.

2.7.3 Synergies and trade-offs between renewable energy measures and energy efficiency measures

The cost effectiveness of energy-efficiency renovations of the building envelope does not depend significantly on the choice of the heating system. This may be explained as follows: When renovations of the building envelope are carried out reducing energy demand, energy cost savings of renewable energy systems are smaller compared to conventional fossil fuel based systems, as their marginal energy costs are usually lower (higher share of capacity costs on total unit costs in the case of renewable energies). On the other hand, renewable energy systems usually they benefit more than conventional fossil fuel based systems from the reduction of the maximum needed heating capacity associated with the renovation of the building envelope. These two trends cancel each other out to a large extent. Furthermore, energy-efficiency renovation of the building envelope reduces the temperature difference between the source and the heat distributed in the heating system, which increases the efficiency of heat pumps. Taking these effects into account, in the reference examples investigated, the cost-effectiveness of energy-efficiency renovations of the building envelope did not vary significantly according to the choice of the heating system.

The moment of replacement of the heating system is a good opportunity to combine it with measures on the building envelope: As the energy need of the building is reduced, peak capacity of the heating system can be reduced as well, which is a key driver for making many renovation measures of the building envelope cost effective also when renewable energies are used as the main source for heating. If this opportunity is missed, and the dimensions of the renewable energy based heating system are set without taking into account renovations on the building envelope, subsequent energy-efficiency improvements of the building envelope will be less cost effective.

2.7.4 Cost-effective packages and ambition levels of building envelope retrofit measures

The effects on costs, greenhouse gas emissions or primary energy consumption of varying ambition levels for a single element of the building envelope are relatively small. If an energy-efficiency renovation is done on a single building element of the envelope, the energy-efficiency ambition level of a single element of the building envelope, as expressed by the thickness of the insulation or the U-value of the windows, does not influence strongly greenhouse gas emissions, primary energy use or costs. When different ambition levels for a single building element are compared, it can be seen that the most significant benefits in terms of greenhouse gas emissions or primary energy use are achieved with the first few cm of insulation added, when changing from a building element without specific insulation to a building element renovated in terms of energy-efficiency.

Once a minimal insulation standard is achieved, the marginal effects on both the U-value and costs are relatively small if the insulation level is increased: It does not cost much more to increase the insulation level to a higher insulation standard. At the same time, increasing the insulation level to a higher insulation for a single building element does not lower the U-value strongly either. Increasing the ambition level for a specific building changes little the benefits in terms of greenhouse gas emissions or primary energy. Also the additional costs are relatively small, since the majority of the costs are due to the renovation works in general, and not the difference of the material costs between a measure with a high energy efficiency ambition level or a measure with a low energy efficiency ambition level.

Therefore, it is more significant, how many building elements are retrofitted within an energy-efficiency building renovation, than how high the energy-efficiency ambition level for a single building envelope element is set.

2.7.5 Policy recommendations

The results found in this study indicate that from a perspective of reducing greenhouse gas emissions at least costs, it can be recommended to focus on promoting a shift to renewable energies. Such a change of the heating system to a renewable energy based heating system has the biggest effects at the lowest costs. However, energy efficiency measures by retrofitting the building envelope are nevertheless important to achieve emission reductions, and are in many cases cost effective. The effect of renewable energies for reducing primary energy need and greenhouse gas emissions depends significantly on the type of renewable energy source, and the electricity mix of the country when making use of heat pumps.

When looking at energy-efficiency renovations of the building envelope, from a perspective of reducing greenhouse gas emissions or primary energy at least cost, it is advisable to promote in particular the renovation of as many building elements as possible. It can therefore be recommended not to increase insulation standards for renovations for single building elements to higher and higher efficiency levels, but to encouraging the renovation of many different elements of the building envelope.

In order to use the full potential of renewable energies and energy efficiency measures to reduce greenhouse gas emissions and primary energy use at the lowest possible costs, it is important to combine a switch to a renewable energy system with energy efficiency measures of the building envelope and use related synergies. Energy efficiency measures allow the installation of smaller renewable energy heating system units with lower costs. This requires, however, that energy efficiency measures are combined with or carried out before the replacement of the heating system. Only if renewable energy systems can benefit accordingly from the reduction of the peak heat demand as made possible by energy efficiency measures on the building envelope, can the potential of synergies between the two approaches of improving energy efficiency and switching to renewable energies be harnessed.

3 Policy instruments for energy efficient renovations

In Chapter 3, the role of different actors involved in energy efficient building retrofits, in particular municipalities, as well as the role of policy instruments in energy related building retrofitting are investigated.

The starting point of this chapter is found in the lack of knowledge about how actors and policy instruments can intensify the quantity and quality of energy efficient retrofit processes (Heiskanen et al., 2010; Kiss and Neij, 2011). Therefore, this Chapter aims at providing an understanding of the role of actors and policy instruments in contributing to the dissemination of energy efficient retrofit practices. This is done by focusing on good practices and strategies in energy efficient renovation processes at different levels. In particular, the study provides good examples about the role of municipalities, actors and networks as well as knowledge development and learning in different policy regimes.

In conclusion, if we share the assumption that energy efficient renovations are a collective and societal challenge and that no actor or policy instrument alone is able to provide a comprehensive solution to the wide array of barriers impeding a higher rate of energy renovations, municipalities can be seen as one of the players providing a planning and coordinating dimensions to the renovations. This can happen by for instance promoting and coordinating initiatives addressing market barriers and increasing capacity in the refurbishment and improvement industry.

The structure of this chapter is as follows: Section 3.1 describes the used method, the actors and networks that are present in the process of renovation of buildings are presented in the Section 3.2, policy instruments for energy efficient renovations in the five countries which are the object of this report are outlined in Section 3.3, with the focus on the level of national ambitions, specific policy instruments, and the level of governance and the presence of policy evaluations. The role of municipalities in each country is presented in Section 3.4, including the traditional role of municipalities, best practice initiatives and the drivers behind them. The discussion (Section 3.5) tackles the role of policy initiatives, municipalities, actors and networks in promoting energy efficient retrofits, as well as knowledge development and learning as well as policies supporting these.

3.1 Methodology

Case study methodology is applied to provide good examples of the different levels of analysis. The analysis can be thought of as developing at two different policy and practice levels: national and local. At the national level, the focus is on policy instruments promoting innovation, learning and networking, building on previous findings (Kiss and Neij, 2011; Kiss et al., 2012; Nair, 2012; Whyte and Sexton, 2011; Sheffer and Levitt, 2010). The policy overview is based on a literature review, extended by interviews with national experts. At the municipal level, due to the plurality of actors usually involved in energy renovations, a social learning approach is taken, building on empirical data on the experiences and practices of municipalities. The approach on municipalities is chosen under the considerations that:

- Buildings and building regulations (including energy-relevant codes), although decided at a national level, are often re-regulated by municipalities in terms of planning, building permits, aesthetics and historical preservation and, sometimes, stricter energy efficiency codes.
- Municipalities are in a favorable position in relation to planning local (sustainability) initiatives and coordinating local actors and players.
- The involvement of local actors and players is necessary since energy efficient retrofit is often performed by small and medium size entrepreneurs and craftsmen operating at a local level.
- Municipalities play a double role of local policy makers (including in some countries compliance authorities) and of building owners, which allows them to be in contact with a variety of actors who operate in the value chain of energy efficient retrofits.
- Finally, there is an increasing tendency of municipalities to adopt custom-made, local climate plans, to drive (or meet) climate change policy goals.

The information in this Chapter is collected through interviews, reviews of literature and policy documents and review of local programs for energy efficiency in buildings. (See list of interviewees in Annex 2.)

Interviews were conducted with local experts and officers in charge of running programs for energy efficiency at a local level in Denmark, Finland, Romania, Sweden and Switzerland. For each country a thorough analysis of national policy instruments was carried out. Local energy efficiency and energy retrofit programs were chosen on the basis of their relevance and ambition in the context of energy efficiency policy.

3.2 Actors and networks

Several actors are present in the process of renovation of buildings as described in Chapter 3 and 4. This Section will present the different actors and stakeholders present in different phases of the retrofit process. The actors vary from country to country and these differences are described here-below.

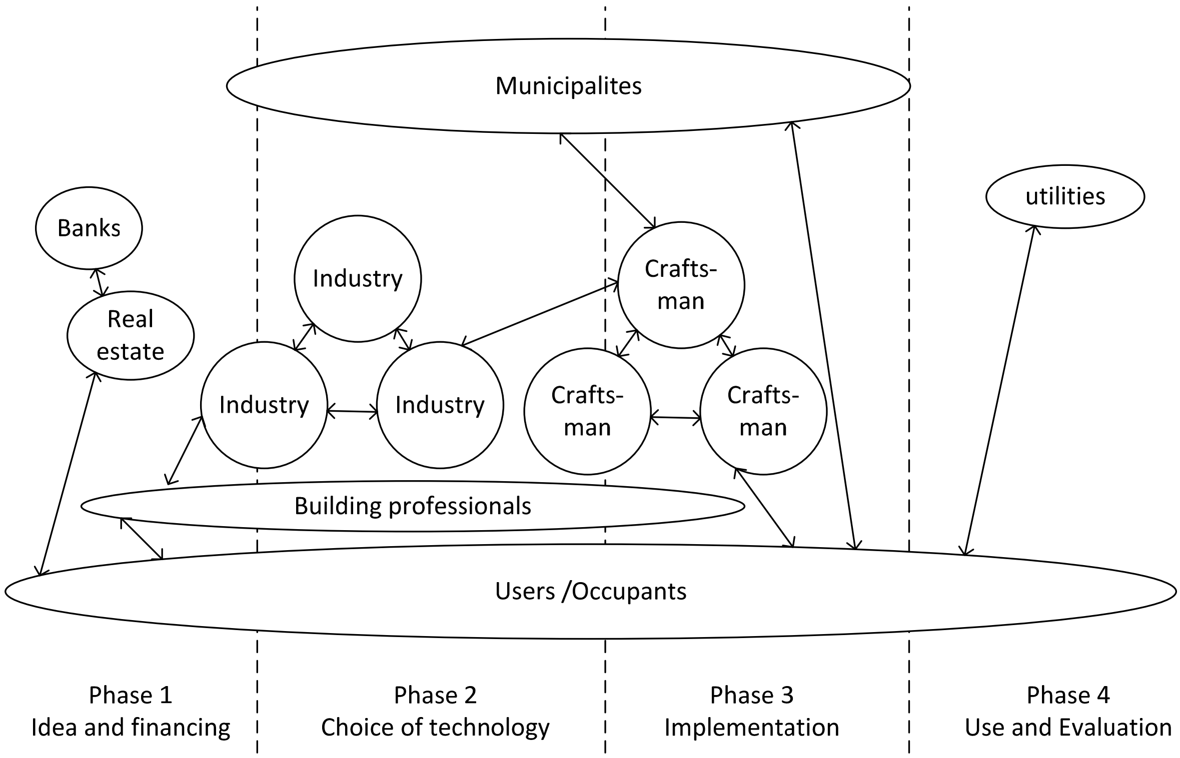

Figure 12: Illustration of the network of actors involved in energy efficient renovation. The arrows illustrate some of the potential links, but other actors may be involved in the networks as well. The real estate has, as mentioned, influence in Finland. The first phase involves contact to the bank, if a loan is required, and an awareness of the overall conditions. The industry in this context is related to manufacturers of building materials.

In the following, the actors outlined in Figure 12 are described with emphasis on their interests and legitimacy regarding energy efficient renovations.

Building owners

In general, the interests governing energy retrofitting of buildings are the aims to save energy; to have lower expenses of energy, and to increase the comfort level in the house. To some degree, the energy efficiency of alternative energy renovations thereby influences the building owners' choices of doing renovations. Another perspective is that the value of the house often increases when energy renovations are made. The house owners are usually interested in a short payback time of their investment due to the potential of having lower energy bills. A barrier to energy renovation can be the lack of an overview of the different initiatives needed to perform a full-scale energy retrofitting of the house, and also to get the solutions financed. The economic savings achieved through the renovation are important to the investment. Other investments in houses, like a new bathroom or kitchen, are not characterized by the same payback possibility, and that might make energy renovations attractive to the house owners.

Municipalities

The municipality plays different roles in the retrofitting of buildings in the described countries. Overall, the role can be characterized as the implementation of the national regulation or national initiatives. In each country, there are examples of municipalities setting stricter requirements for building regulation or special initiatives to help starting up the retrofitting process, which is seen in Malmö, Frederikshavn and Zürich. In Zürich, a Master plan was presented in 2003 to set the objectives. A different initiative in Zürich is the MINERGIE building standard, which is used to impose requirements on existing buildings. In Malmö, a similar approach has been applied using the international building standards (BREEAM and LEED). The standards help setting a baseline for requirements and securing the awareness of energy consumption and resources for building materials.

Malmö has defined an objective of being climate neutral in 2030 and this aim is to be fulfilled through several energy reducing initiatives. In Romania, the municipalities do not own buildings and are therefore in a different situation. Only some heritage buildings are owned by municipalities in Romania and, therefore, it is rather the private buildings that must be the focus for energy reduction of buildings.

Danish legislation offers the possibility of setting higher local requirements than national standards, through stricter building regulation in the local plans (Danish Energy Agency 2010a). For the renovation of houses, it is not possible to impose the same requirements. In Sweden, updated energy plans are mandatory regarding the distribution and production of energy. If the municipalities wish to do so, it is possible for them to implement energy renovation of their own buildings, as shown by examples from the countries where the municipalities actually own buildings. It can be harder to impose requirements on other building owners to implement energy efficient renovation. In Denmark, social housing areas are implementing urban renewal projects. For social housing, the same possibilities appear as for new buildings; that it is possible to impose higher requirements. In Copenhagen, all new building areas need to fulfill requirements of the low energy class 2015 (Københavns Kommune 2012). Other Danish municipalities have made the same requirements in new local plans; e.g., in Aalborg, where 3 new student accommodations are built after the 2015 energy class, which is required due to the climate strategy for Aalborg municipality (Aalborg Kommune 2011). The renovation of the council housing sector is another aspect of the energy renovation. 21% of the building mass in Denmark and 25% of the building mass in Sweden are social housing (Andersen 2007). In Malmö, an example of this is the energy renovation of 800 apartments. In this example, the city development managers represent that actor, which implements the climate goals.

In Denmark, the first version of the building regulation 2010 imposed requirements on all new installations, which must fulfill the current building regulation requirement for components, when a house is renovated or rebuilt (25 % of the building area or value of the building). The regulation should initiate all cost effective initiatives and fulfill the requirements on components equal to new buildings in order for the investment to be cost effective (Danish Energy Agency 2010b). The initiative did not work as intended so it was removed from the legislation. The current Danish building regulation requires that all cost effective energy saving steps are made in the renovation process (Danish Energy Agency 2011b).

Utility companies

In Sweden, the utilities are often owned by the municipalities and are obliged to make energy plans. In Denmark, the utilities are required to initiate energy savings and are therefore interested in energy savings from private houses to fulfill the national requirements. The Danish energy agreement has made it more interesting for utilities and energy companies to help increase energy savings of private houses and stricter requirements will be imposed on their energy savings in total, but it will be based on several smaller initiatives in buildings and companies (Togeby 2012). At the beginning, the funding was mainly given to provide information about potential initiatives to reduce energy consumption, but now most of the initiatives are subsidies. Other issues considered are the prioritizing factor of the different initiatives and the question of how to reduce the administrative costs of the system (Togeby 2012).

Networks

The establishment of networks of building professionals can help in education and interdisciplinary learning. The TAPRE project is coordinated by Tampere Real Estate Service and seeks to gather the actors and coordinate the initiatives of energy renovations in Finland. The project has established templates for energy efficient assessment tools through the presence of several municipalities, construction companies and maintenance companies to coordinate the initiatives. At the national level, the Motiva network is established giving high quality energy advice to building owners in Finland. The Danish approach is to increase the awareness of energy renovation through education and collaboration among building professionals. The education provides tools which make the building professionals more familiar with the new techniques and materials and more eager to use these (Strandgaard 2012). In the Danish context, the establishment of networks has increased the focus on networks of wider scales and several municipalities have established different types of green networks in relation to the education and network of building professionals. The role of the municipalities in these networks is to give guidance and support to the network in order to create trust among the building owners concerning the energy efficiency initiative. In this interdisciplinary collaboration, craftsmen have been able to broaden their horizon and become more aware of the focus points of other disciplines in the energy renovations. This awareness can contribute positively to the collaboration between the disciplines of building professionals (Strandgaard, 2012).

Financial institutes

Banks and other types of investment companies play an important role in terms of financing energy renovation initiatives. The collaboration between banks and building professionals can make it possible to fulfill energy renovation initiatives. In Frederikshavn, for instance, collaboration has been established in terms of securing the possibility of obtaining loans for the owners of the houses which have been participating in energy saving initiatives (Rask 2012). A Danish bank, for instance, has chosen to start collaboration with an energy company and a construction company with the aim to make thermal heating photos of the houses and then present ideas of new initiatives to be introduced in the building. Special loans with lower interest rates have been introduced in Denmark to the owners who perform energy renovation. The reason is that Danish building owners pay more for energy consumption than for loans because of higher energy prices and lower interest on loans. This makes the energy costs more important part of the budget (Conradsen 2012). Another advantage is the increased value of houses and the lower energy cost for building owners achieved through the energy renovation of the building. Reduced costs on energy consumption will make the building owner less vulnerable to increasing energy prices. This generates, at the same time, a higher security for the bank.

Networks

New types of business opportunities can be seen on different scale in different countries. A “One-stop-shop” or “full service renovation” has been described as a potential solution to make it easier for the building owner to have a full overview of initiatives. The purpose of this initiative is that the building owner needs to make only one contact involving a series of renovations. The concept has been introduced and described in Denmark, Sweden and Finland (Mahapatra et al, 2012). The establishment of a network of building professionals in Denmark is another approach, which focuses on educational collaboration within disciplines (Strandgaard 2012).

3.3 Policy landscape of energy efficient renovations

Climate mitigation calls for increasing ambitions in energy saving measures (Levine et al., 2007). The Kyoto Protocol and the European Union are framing the ambition levels of the European countries, which in return are mirrored in the National Energy Efficiency Action Plans (NEEAP). The national targets on energy and/or GHG emission reduction levels and efficiency improvements are then more or less reflected in different policy initiatives, for instance in the level of stringency of the building codes.

The EU has the goal of a 20% cut in Europe's annual primary energy consumption by 2020 (European Commission, 2011). The Energy Performance of Buildings Directive (EPBD, 2002/91/EC) lies down the framework for reaching this goal in the residential sector, which is pivotal to reach this target. The EPBD is indeed the first attempt at a European level to address renovations (of large buildings) in national building energy code requirements. In addition, the cost optimality concept was introduced by the recast of the EPBD in 2010 (2010/31/EU). Cost optimal levels will gradually converge to nearly zero energy standards which would comprise a requirement for new buildings from 2020 onwards.

The objective of this section is to provide a best practice introduction to the policy landscape of Denmark, Finland, Romania, Sweden and Switzerland on policy instruments, such as building codes, economic incentives and information tools, relevant for energy efficient renovations, including the recent trends and novelties. Special focus is given to initiatives promoting learning and networking. In addition, the level of governance is outlined briefly. The Section also tackles whether and to what extent these countries have a tradition of policy evaluations. The goal of this overview is not to provide a comparative study of the policy instruments to promote energy retrofits, but rather to highlight best practices, which may serve as a source of learning for, for instance, the future design of policy packages. For this reason, the research is based on the analysis of documents and interviews with professionals from the field regarding policy initiatives for energy renovations.

The policy landscape of each country is presented in the following section. The structure follows the level of ambition and some relevant policy initiatives with regards to energy efficient retrofitting. In addition, observations on the level of governance and/or relevant national actors as well as policy evaluations are highlighted. Hence, the following fields are addressed for each country:

— Level of ambition;

— Relevant policy initiatives;

— Level of governance and/or relevant national actors;

— Policy evaluations.

Concluding remarks on policy initiatives are presented in Section 3.5 focusing on the lessons to be derived from the experiences and best practices assessed including initiatives to support learning and networking in the different countries.

3.3.1 Denmark

Level of ambition

In Denmark, the overall ambition of the energy efficiency policy is generally rather high (ECEEE, 2012). To implement these high ambitions, the Danish Government has implemented “The Energy Strategy 2050”, describing the potential actions and goals needed to become independent of fossil fuels in Denmark before 2050 (Danish Government, 2011). This strategy is one of the first instances of long-term strategies detailing specific efficiency and renewable energy generation goals at a national level, describing actual measures for meeting the target of independence from fossil fuels.

The recently implemented (March 2012) new Energy Agreement contains a wide range of ambitious initiatives for the period of 2012-2020, bringing Denmark closer to the target of 100% renewable energy in the energy and transport sectors by 2050. The initiatives should result in a gross energy consumption reduction of 7.6% in 2020 relative to 2010 and a 34% reduction of greenhouse gases emissions as compared to 1990 (Ministry of Climate, Energy and Buildings, 2012). One of the initiatives contained in this agreement deals with stronger requirements of energy savings in the energy utilities. To fulfill these new restrictions, the utility companies will need to implement energy efficiency initiatives in buildings and industries and report these savings to the authorities. Another new initiative is the reduction of the amount of oil burners in Denmark by stopping installation of oil burners in new buildings starting from 2013 and, for existing houses in areas covered by district heating starting, from 2016. The new energy agreement also addresses the rental building stock and makes it possible for the owner to increase the rent of the house or apartment to cover the costs of energy renovation.

Policy initiatives

Since the 2008 **building code** there have been increasingly strict demands for the energy performance of buildings. In 2010, the ambitions have been further increased by reducing energy demand requirements by 25% compared to 2008 levels and further 25% reduction is set in the building code for 2015 and the 2020 level has yet another 25% reduction of the energy performance. This gives a total reduction of 75% compared to 2008 (Danish Enterprise and Construction Authorities, 2011). This building class fits to the EPBD requirements of nearly zero buildings to be implemented by 2020 (European Union, 2010). In order to reach these levels, component level requirements are required for building refurbishments regardless building size, for instance, for air change, facade windows, skylights, hatches and doors, roofs replacement and change of heat supply (Danish Energy Agency, 2011c; Danish Ministry for Economic and Business Affairs & Danish Enterprise and Construction Authority, 2010; Danish Energy Agency, 2011d: Fælles bestemmelser for bygninger omfattet af bygningsklasse 2020, 2012).

Grants and **tax deduction** have been available for private house owners using craftsmen for energy renovation works. The level of support is 25% (or DKK 10 000/year/residence) for equipment and 20% (up to DKK 10 000) for envelope. In terms of tax deduction, annually up to DKK 15 000 could be deducted, providing actual savings of around DKK 5000, for the period of 2011-2014 (Danish Government, 2012; SKAT, 2012).

Although **energy labeling** has a long tradition in Denmark, it has not been considered as a good tool to promote energy efficiency in retrofits. For instance, only around half of the sold single-family houses sold have the required label; one of the problems with labelling is the cost-benefit balance (Togeby, M., Dyhr-Mikkelsen, K., Larsen, A., Hansen, M.J. & Bach, P., 2009). Consultants are required for labelling buildings, making it an expensive activity; furthermore it was observed that building owners/buyers were not interested in the information provided by the label.

Since 1996 it has been a **legal obligation for the utilities** to promote energy savings. In the period between 2006 and 2013, electricity, gas and heat distributors were subject to annual energy-saving targets (Bertoldi, P., Rezessy, S., Lees, E., Baudry, P., Jeander, A. & Labanca, N., 2010). The utilities are free to choose their methods for securing energy savings but the energy authorities require documentation showing that the utilities have reached the targets. The focus has been on installing more efficient heat supply e.g. heat pumps instead of oil burners, which lead to few energy renovations of existing buildings (Gram-Hanssen and Christensen, 2011). Evaluations show that even though there is a large potential for energy savings in the existing housing stock, this sector has not been tackled by the utilities' activities. It might be due to the rules for calculating the energy savings where only savings from the first year are included. Thereby retrofit measures with a long payback time, are not an attractive area to pursue for the utilities (Gram-Hanssen and Christensen, 2011).

The **Knowledge Centre for Energy Savings in Buildings** (2008-2011) was a recent initiative, which supported the progressive building codes by raising the awareness among tradesmen, contractors, advisors and consultants on how to save energy (McCormick, K. & Neij, L. 2009).

Level of governance

Several actors are included in the different policy initiatives. The Danish Energy Authority plays an important role for implementing and evaluating energy policy. The Energy Saving Trust also works to promote energy efficiency. Municipalities are playing an increasingly active role in implementing national energy efficiency goals and often setting higher local targets.

Policy evaluations for learning

Policy evaluations are common practice in Denmark; while instrument based evaluations characterized the earlier era (e.g. Dyhr-Mikkelsen, K. Larsen, A. & Bach, P., 2005), since the mid 2000's more systemic evaluations have been done (e.g. UNFCCC, 2007; Energy Analysis, Niras, RUC and FourFacts, 2008). When new policy measures are implemented in Denmark, evaluation is often included in the budget. Evaluations often have a cost-benefit approach, but also discuss qualitative outcomes. The building code has been evaluated as an instrument which will have increasingly significant effect in increasing energy renovations. The energy labeling of the houses has been evaluated as an expensive and less efficient tool (see Togeby et al., 2009). The utilities obligations to promote energy savings have been evaluated as a successful, but the instruments do not address the building envelope as much as the heat supply. Some of the new and more innovative initiatives (e.g. Knowledge Center) have not been evaluated yet, but it is visible that a great interest for especially the subsidies for energy renovations.

The new Energy Agreement, coupled with progressive building codes, energy utility obligations and extensive information campaigns is indicated to be a successful strategy for energy savings in the existing building stock. The agreement also tackles the principle-agent problem in rented apartments – by financing energy renovations through higher monthly rents (and lower energy bills for tenants). The Knowledge Centre is essential in knowledge dissemination and awareness raising among professionals; while utilities play a key role in promoting energy efficiency measures in households.

3.3.2 Finland

Level of ambition

The National Energy Efficiency Action Plan (NEEAP) of 2007 and of 2011 outlines the targets of energy efficiency for Finland: 9% improvement in energy efficiency by 2016

(NEEAP, 2007) including an assessment of the energy savings effects of the (125 new and/or extended energy saving and energy efficiency) measures suggested by the plan (NEEAP, 2011). In 2010, based on the call from the Finnish Minister of Housing (Jan Vapaavuori), an expert group mapped out the best ways and set an ambitious goal for the country to be a pioneer in energy-smartness by 2017 (ERA17 – Energy-Smart Built Environment 2017), and to make the Finnish built environment the best in the world by 2050.

The implementation of the EPBD is intended to reduce energy use in existing buildings by about 25% and CO_2 emissions by about 45% by 2050 as compared. The savings arise from the reduction of heat losses, more efficient heat recovery equipment, and more efficient use of electricity and renewable energy sources, such as increasing use of geothermal energy. The effects of energy savings throughout the building stock would be about 6% by 2020.

In order to achieve the national goals, an implementation plan has been developed by the Ministry of the Environment for the Strategy for Renovation (2007–2017), complemented by the Government Resolution on Renovation (2008). The implementation plan consists of thirteen action points; the actions for renovations include stricter energy regulations, well-targeted financial incentives, development of services, customer-oriented implementation, such as (new) tools for building processes, provision of guidance on appropriate energy use, introduction of the best solutions to the market and the improvement of know-how and dissemination of knowledge.

Policy initiatives

In terms of “command and control” policies there are two regulations affecting building energy retrofits: one regards land use and buildings and the other regards energy certificates. The new **Land Use and Building Act** (in force since July 2012) and the new Decree of the Ministry concerning the building energy efficiency in repair and construction work (in force from 2013) implement the recast directive (2010/31/EU); articles relating to energy efficiency of the repair and alteration of buildings, as well as the assessment of the heating systems, apply only for large-scale renovations. Energy renovations are still voluntary, only large renovations require building permission. Once the renovation is, however, subject to building permission (e.g. heavy facade repair, pipeline renovation, changing the use of building or for the installation and expansion of ventilation), energy efficiency study is required. The provision offers the building owner three options to define the level and to prove the improvement of energy efficiency[3]. The regulation encourages the use of district heating and renewable energy and the new calculation method (E-numbers) allows for a gradual transition to nearly zero-energy building by 2021. These tighter regulations shall result in an average of 20% improvement in energy efficiency.

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[3] The three option include 1) to improve the thermal insulation of building elements and efficiency of technical systems so that they fulfill the requirements given in the regulations, 2) to fulfill the energy demand requirements given in the regulations, 3) to calculate the “E-number” of the building and decrease it by the amount given in the specification.

The **Energy Audit Programme** (EAP) and energy efficiency agreements are evaluated to be successful tools for promoting energy efficiency in the building sector (Khan, 2006; Salminen, 2009). EAP started as a subsidy policy in 1992; since 2004 EAP is a full-scale programme to which companies and municipalities can join to carry out energy audits on their properties and production plants (McCormick, K. & Neij, L. 2009). The Ministry of Trade and Industry provides support for energy audits, analyses, investments and subsidies up to 40-50% (BPIE, 2011; IEA, 2008). In addition to the energy audit subsidy scheme, grants (15%) and tax deduction (60% of labour cost) are also available for households (BPIE, 2012).

In terms of renovation activities, in the frame of the programme "**ERA17 for an Energy-Smart Built Environment 2017**"[4], the importance of verifying qualifications of building service providers, guidance to building developers, the development of long-lasting maintenance services has been highlighted as well as the need to integrate research results in renovation implementation activities.

Information tools are shown to be successful initiatives for more efficient energy use in buildings. **Omataloyhtiö.fi**, for instance, a web-based information sharing system among housing association managers tackles three major challenges of energy renovations: lack of experience of housing associations in renovation measures, lack of information and workmanship, and the different values on energy efficient and cost-effective renovation measures. Omataloyhtiö.fi was founded in 2009 as a response to the long-term planning obligation of housing associations[5]. The initially public funded initiative (TEKES) grew to be a business driven project with high level of information and knowledge sharing between housing associations and building professionals.

Building service manuals[6] are considered as another useful information tool for energy renovations[7]. The content of the manual[8], amongst others, refers to annual energy use, indoor climate, continuous inspections and repairs, including indicative operating values, responsibilities of different parties and action plans. The comprehensiveness of the manuals calls for special expertise; this demand is satisfied by specialized real estate management companies. The credibility and quality of the services of these companies are assured by an authorized licensing system managed by the building manager authorization association (ISA). With the help of the manuals and the expertise of the real

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[4] ERA-17 was drawn up as a collaborative effort of the Ministry of the Environment, the Finnish Innovation Fund (Sitra) and the Finnish Funding Agency for Technology and Innovation (Tekes). Additional support was provided by a task force, including leaders from business, research and the public administration by drawing up an action plan amongst others to improve the energy efficiency of the built environment. (http://era17.fi/en/ and http://era17.fi/wp-content/uploads/2010/10/ERA17_loppuraportti.pdf)

[5] The initiative has over 400 000 members, weekly e-mail and online magazine (50 000 pcs, three times per year) for housing associations (78 000 receivers).

[6] http://www.vtt.fi/inf/pdf/tiedotteet/2006/T2350.pdf

[7] Manuals are required for each building which is permanently used for living or working; in case of building repair, manual is required when permit is required.

[8] http://www.ymparisto.fi/default.asp?contentid=224892&lan=FI (only in Finnish)

estate management companies[9] it is possible to achieve the maintenance targets throughout the whole economical life time of the building.

In addition, in the frame of the **Energy Environment Expert Programme** (since 1995), resident volunteers are trained as energy experts to be able to promote and advise on, amongst others, energy efficiency measures in their own buildings. It has been estimated that there are energy experts in 7% of the rental apartment buildings in Finland (Heiskanen, E., Brohmann, B., Fritsche, U., Schönherr, N. & Aalto, K., 2010). This programme resulted in an estimated total direct saving of 14% of the total CO_2 emission saving requirement proposed in the Energy Saving and Efficiency Program (Heiskanen, et al., 2010).

Level of governance

Building energy regulations are under direct responsibility of the Ministry of the Environment; the provisions however apply only for large-scale renovations requiring building permission. The interpretation of the permit requirements for these renovations varies by municipality, because the practical application is based on the discretion of building permit authorities.

On municipal level, some municipalities have their own ERA17-action programs and energy-wise strategies to improve the properties energy efficiency and reduce emissions from energy production. Execution of the action belongs to the cities and to Association of Finnish Local and Regional Authorities[10]. In their renovation strategies the municipalities may require energy efficiency regulations of new buildings to be adopted also for large renovation projects. The action has started in October 2011. The Association of Finnish Local and Regional Authorities have together with several Finnish local authorities launched a national “Cities for Climate Protection” campaign. Good results have been achieved amongst others in energy saving schemes.

Policy evaluation for learning

In Finland, a number of evaluations have been performed over time and results have been presented in, for example, UNFCCC (2006a) and IEA (2007). Recently, in 2009, there have been two in-depth evaluations related to buildings – the first on the effects of the 2010 (and 2013) building codes, and second on energy-use products in Finland. The first involves some estimates for the renovation of existing buildings. In addition, Salminen (2009) provides a limited evaluation of the municipal energy conservation agreements in Finland (1997-2007). The evaluation shows that the rate of participation is modest, as many municipalities lack both personnel and economic resources to implement them. It is also shown that energy audits are central in energy efficiency agreements and the success factors of the programme are the access to subsidies, continuity, active promotion, training of auditors, co-operation and dialogue with

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[9] See e.g. http://www.matinkylanhuolto.fi/

[10] ERA17-action programs of the municipalities and energy-wise strategies. http://era17.fi/osaaminen/kuntien-era17-toimintaohjelmat-ja-energiaviisaat-strategiat/

stakeholders, interlinked policy instruments, flexible and competent implementing agency, long-term political support, and systematic monitoring that generated legitimacy (see in Khan, 2006).

Detailed implementation plans and information tools are key elements to support learning in energy efficient renovations. Strategies, such as Omataloyhtiö.fi, building manuals and the energy expert programmes are good examples for knowledge development and the promotion of learning in the energy renovation arena. Real estate managers are knowledge holders providing potential concentrated learning possibilities and continuity in renovation practices.

3.3.3 Romania

Level of ambition

The ambition of the energy efficiency policies in Romania is to be relatively low when compared to other EU countries. The national target for Romania was set in the first NEEAP: for 2016 it was set at 13.5% of average final energy use (with a baseline taken from the period 2001-2005) (Wade, J., Guertler, P., Croft, D. & Sunderland, L., 2011). Although such reduction may be perceived as a high level of ambition in energy use reduction, in the context of post-1989 declining energy consumption trend, it has been seen as not overly ambitious. Savings potentials are outlined in the Energy Efficiency Strategy (2004) as a reduction in energy intensity of 40% by 2015 against 2003 levels on all economic and social activities[11]. For instance, Romania exceeded its own national energy efficiency intermediate target for 2010. It is estimated that the implementation of extensive energy retrofits in multi-story buildings constructed between 1950 and 1990 could save up to 25% of the energy consumed in the situation before renovation (European Union, 2012).

Since the first NEEAP, only a few policy instruments have been introduced. Efforts in the housing sector are felt to have been consistent. The energy saving potential in residential buildings is commonly recognized, but relies heavily on the identification and allocation of financing. The lack of staff capacity in the public sector and the changes in the institutional framework are considered main challenges for policy implementation. On the positive side, relevant EU legislations were transposed, providing a legislative framework and also some funding mechanisms are available (Wade, et al., 2011). Especially, in the residential sector, some financial programmes are available, including tax reductions as well as financial support for the renovation of multi-family buildings.

Policy initiatives

European legislation is considered as one of the main drivers behind many of the policy measures for energy efficiency in buildings. Important regulations in the field of energy efficiency are Law no. 199/2000, which sets up the legal framework on which to base the development of energy efficiency policies, and Law no. 3/2001, ratifying the Kyoto

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[11] http://www.odyssee-indicators.org/publications/PDF/romania_nr.pdf

protocol and Government Decisions no. 163/2004 which adopts the National Strategy for Energy Efficiency. In addition, energy efficiency of new buildings is regulated by **Code C107/1**, however, the requirements of the code are not mandatory for refurbishments. The technical specifications for new buildings can be used as recommendations in case of energy retrofits (e.g. with regards to the U-values for walls, floors, etc.)[12].

There are some economic incentives in place in Romania, with an ambition level to decrease the energy consumption to 100 kWh/m^2 (BPIE, 2012). Since half of the population of Romania lives in multifamily apartment buildings, the **Multiannual National Programme** addresses energy performance mainly in these building. The level of financial support for the energy renovation of the building envelope is up to 67% under the form of grants (BPIE, 2012). Complementary to this programme, the thermal rehabilitation of the existing building stock (envelope, equipment) is also financed by **preferential bank loans** (up to 90% support). In the context of these initiatives, up to 80% of the cost of renovation is paid by the authorities, with a division of 50% by the central government and 30% by the municipality (Buildup, 2012). Only owner associations, and not the single apartment owner, can apply for this funding. The owner associations apply to the municipality, which assess the application and make a public tender regarding the renovation and decides upon the contractors. Very often municipalities are reported to be slow in deciding on which projects to support. The outcome of this program is a useful example about the shortcomings and unexpected results of renovation projects: many of these programs have incurred in higher costs than expected, and problems with funding from the municipalities (possibly stemming from the economic and financial crisis) were also reported. Amongst the reasons behind the increased costs were the requirements for a more detailed design of the project, thereby needing more engineering work for choosing the solution to the renovation, plus the existence of an official public bidding process. In short, the formalities and the paperwork, as well as certain quality requirements imposed by municipalities, related to the procedure is driving up the prices[13]. Several apartment buildings were renovated using this financing scheme although for a variety of reasons funds are drying up[14].

Other policy measures specifically directed to improve energy efficiency in residential buildings include the improvement of heating and cooling systems in detached houses, the promotion of the adoption of energy efficient light bulbs and household electrical appliances, and the promotion of the development of Energy Service Companies for the implementation of energy retrofits projects (EU, 2012).

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[12] Implementation of EPBD in Romania. Status on November 2010. http://www.epbd-ca.org/Medias/Pdf/country_reports_14-04-2011/Romania.pdf and Implementing nearly Zero-Energy Buildings (nZEB) in Romania –towards a definition and roadmap. http://bpie.eu/documents/BPIE/publications/Romania_nZEB/EN/EN_full_report.pdf

[13] On the positive note, the documents for enrolment in this program are starting to be simplified and already updated on the municipality site: http://www.primariatm.ro/ik/index.php?meniuId=14&viewCat=1704&sectiune=primaria

[14] High percentage of the funding originates from the European Bank for Reconstruction and Development (EBRD), which provides support to the development of market economies, such as Romania, following the widespread collapse of communist regime. However, the EBRD saw it as a difficult business case to invest in building renovation, due to, in part, the need for bundling and because of the difficulty in developing a bankable project that is interesting to investors (BPIE, 2012).

Level of governance

The main government bodies responsible for energy efficiency in Romania are the Ministry of Economy, Commerce and Business Environment, The Ministry of Environment and Forests and The Ministry of Public Works, Transport and Housing. Furthermore, the institutional frame allowing the promotion measures of efficient energy use in Romania was created by setting up the Romanian Agency for Energy Conservation (ARCE) in 1990, which became a department of the Romanian Energy Regulatory Authority now carrying out evaluations and verifications. The key roles, in terms of targets, measures and monitoring (including methods) are not clearly defined between the central and the local governing levels[15] (Wade, et al., 2011).

There are more and more programs at the local level to increase the adoption of energy efficiency measures. Recently municipality has been involved in the energy housing rehabilitation process. It is however acknowledged that many programs lack funding and that customer services for retrofitting solutions (easing the access to energy efficient solutions for house owners), which include building capacity and trust in market operators.

In order to reach the national targets, amongst others, improved cooperation would be essential between the central and local governing levels.

Policy evaluation for learning

Mandatory targets for final energy use are considered to be essential to send a clear message to investors; however it is also noted that target setting shall be strictly monitored coupled with specific measures at sectorial level (Wade, et al., 2011). In 2011, for instance, the Energy Research and Modernizing Institute (ICEMENERG) completed ex-ante and ex-post evaluations on energy saving based on energy saving measures. The example of the National Buildings Rehabilitation Programme was evaluated as a failure, being linked to the changing conditions for co-financing[16] (Wade et al, 2011).

The EU legislation seems to drive changes and promotion of energy efficiency in Romania. Energy auditing, being compulsory when apartments or houses are sold, seems to be an increasingly important tool in the country. The increasing importance is however due to a potential business and occupational opportunity, rather than promoting energy savings. Trainings of auditors are carried out by universities, the quality of energy audits however highly varies. Energy auditing still seems to be a successful tool to promote learning in the renovation arena. Subsidies, on the other hand, seems to support the involvement of different actors in the renovation process, the learning process heavily suffers, however, from their incoherent nature as well as their withdrawal.

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[15] http://www.odyssee-indicators.org/publications/PDF/romania_nr.pdf

[16] http://ec.europa.eu/europe2020/pdf/nrp/nrp_romania_ro.pdf

3.3.4 Sweden

Level of ambition

The Swedish Government, as part of the 16 environmental quality objectives[17], set the targets of energy use in residential buildings and commercial premises as to be reduced by 20% by 2020 and 50% by 2050 in relation to energy use in 1995 (Swedish Ministry of Sustainable Development, 2006). In addition, in 2009 a goal of 20% energy efficiency (i.e. decrease in energy intensity) was introduced until 2020 (Government Bill, 2008).

Since the National Energy Efficiency Action Plan (NEEAP, 2011), only a few energy efficiency policies have been introduced with relatively but not overly ambitious targets. According to Swedish experts, the relative low ambitions are related to the lack of political will and the lack of understanding of the economic benefits of energy efficiency from the side of the building owners as well as the strong belief in market forces alone (Energy Efficiency Watch, 2012).

Policy initiatives

The moderate ambition level is also reflected in the few policy instruments, which have been introduced in the past three years in Sweden. For instance, the **Swedish Building Codes** (BBR) has long been considered to be an effective tool for energy efficient new construction. BBR has both performance and component based requirements. For renovation, although the building code (BBR19, 2011) applies, there are no detailed guidelines for the implementation. In addition, the requirements are low and unclear, Swedish building owners do not perceive it as a driving force for energy efficiency in the existing building stock. In addition, the fact that there is still no clear definition for nearly zero energy buildings, gives contradicting signals to market actors for further actions in the level of stringency for improving energy efficiency in the existing building stock. The Swedish Board of Housing, Building and Planning conducts a project to define more detailed regulations for renovations and to provide guidelines on how to understand the requirements in individual cases.

In terms of **economic incentives**, in addition to grants and tax reduction[18], in the frame of LÅGAN, financial support is provided for demonstration projects and local/regional collaboration initiatives, both with regards to new and existing buildings[19].

Positive developments have been observed with regards to **informative instruments** coupled with the increased commitment and activities of local and regional actors. Local Investment Program (LIP, 2002-2007) and Climate Investment Program (KLIMP, 2003-2007)[20], coupled with technology procurements, are good examples of projects

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[17] Miljömål [Environmental Objectives] Online available: www.miljomal.nu [2012-12-12]

[18] The support level is 25% for grants and euro 5 000/year/buidling (labor cost) for tax reduction.

[19] LÅGAN is a collaborative project between the Swedish Construction Federation, the Swedish Energy Agency, Region Västra Götaland, Formas and others (www.laganbygg.se).

[20] KLIMP, for instance, offered municipalities and companies financial support for reducing GHGs, e.g. installing district heating systems, converting to biofuels, and improving energy efficiency. It had been appropriated for more than 700 measures (SEK 1.5 billion) expected to reduce GHG emissions by 0.9 Mt CO_2-eq. LIP was Sweden's largest single

promoting energy efficiency. The results of these projects have been mixed, in general, characterized by low additionality and high costs (Fransson, 2012). A number of permanent client or buyer groups and professional networks have been reported to be very successful in paving the way for deployment of new technologies and solutions by, for instance, increasing competence of building owners and bringing energy efficient products to the market. BeBo and BeLok[21], administered by the Swedish Energy Agency, are two of these initiatives, also including elements of **technology procurement**. In addition, the network of local energy advisors, supported by the Swedish Energy Agency since 1998, is considered as good support for awareness raising and promoting energy efficiency measures (McCormick, K. & Neij, L. 2009).

The Living-Building Dialogue (2007-2009)[22] is the most recent best practice for improved energy efficiency with the objective of developing networks, improving information channels and knowledge exchange among actors involved in more efficient use of energy in the building sector (Chalmers EnergiCentrum, 2007; Smedby, N. & Neij, L. 2012). The initiative included projects aiming at disseminating experience and technical solutions for developing future best practices through competence development (trainings), environmental building classification (labeling) and constructive dialogues (networking)[23]. The Living-Building Dialogue has been evaluated as a cost-effective measure from a socioeconomic perspective. It has been a good tool for learning, by involving companies which are advanced and stimulate the rest of the sector to follow. A qualitative assessment of Dahlberg (2009) suggests that the experiences of Living-Building Dialogue are mainly positive, with outcomes including the earlier introduction of measures that otherwise would not have taken place and increased export opportunities.

Level of governance

Sweden has a unitary government with active local authorities. Development of energy policy rests with the central government, albeit energy efficiency in buildings is scattered among different authorities. The Ministry of Enterprise, Energy and Communications (Näringsdepartementet) is in charge of co-ordination and planning of energy policy and the Ministry of the Environment (Miljödepartementet) is in charge of climate policy. Swedish Energy Agency (Energimyndigheten), under the Ministry of Enterprise, Energy and Communications, is the main government body responsible for implementing energy policy, including the co-ordination and implementation of the NEEAP. In addition, the National Board of Housing, Building and Planning (Boverket) promotes efficient use of energy in buildings, notably reducing electricity use for space heating.

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environmental initiative, with SEK 6.2 billion earmarked for grants aiming at improving ecological sustainability in the municipalities. For the efficient use of energy SEK 199 million was spent.

[21] See more details on www.bebostad.net and www.belok.se.

[22] Based on the experience of Bygga-Bo Dialogen (Living-Constrauction Dialogue, www.byggabodialogen.se), for instance, Malmö City has started the initiative Bygga-Om Dialogen (Renovation Dialogue) exclusively addressing renovation projects and involved actors.

[23] The competence development targeted different professional groups of the building sector, such as handicrafts, building developers, architects, planners, engineers and building managers. The Swedish labelling scheme (Miljöklassad byggnad) was launched in 2009 and included criteria categories for buildings such as Energy, Indoor climate and Material & chemical substances, with additional requirements for buildings with own sewage systems.

The second NEEAP highlights the role of local and regional actors in realizing the transition to an energy efficiency and sustainable society. Since 2008, Sweden's county administrative boards have to produce regional strategies for energy and climate issues. Municipalities play a significant role in ensuring compliance with BBR as well as the issuance of energy performance certificates. In addition, municipalities play an important role as owner and manager of all the non-profit rented stock[24]. Public authorities are obliged to take a leading role and promoting energy efficiency measures (SFS 2009:893).

Policy evaluation for learning

A number of evaluations have been performed in the energy efficiency field over time and results have been presented in, for example, UNFCCC (2006b) and the IEA (Neij, 2004). At present, however, there is no strategic evaluation either in designing, implementing and applying policy instruments for energy efficiency or a strategic approach on how to improve learning in the building sector (Neij and McCormick, 2009).

It has been recognized that collaboration among actors and networking are essential for further improvement of the quality and quantity of energy efficient renovations in the future. Different types of buyer groups play a significant role in enhancing this development. A number of instruments, such as the Living-Building Dialogue, technology procurement groups (BeBo) and the Local Energy Advisors, are considered as successful tools for promoting knowledge exchange and learning in the renovation arena. The Living-Building Dialogue, for instance, highly contributed to a better understanding for the need of other policy instruments in the field of energy efficiency (Dahlberg, 2009).

3.3.5 Switzerland

Level of ambition

Switzerland has set a *national target* to reduce greenhouse gas emissions by 20% from 1990 to 2020; in order to reach this target, besides the area of transportation, decarbonizing actions are needed in the heating sector. The draft federal "New Energy Policy" for the period up to the year 2050 was published in May 2011 (Bundesamt für Energie, 2011a) together with a draft of an energy strategy action plan (Bundesamt für Energie, 2011b) including a list of specific policy measures (which was complemented in Spring 2012) (Bundesrat, 2012). Efficiency in the building sector is one of the focus areas[25].

In terms of ambitions on the cantonal level, several Swiss cantons declared the notion of the 2000 Watt society as their leitmotif towards a sustainable development in terms of energy. This implies that worldwide, no more than 17 520 kWh of total primary energy and 1 ton CO_2-eq. are to be consumed per capita and year for all services. The intermediate goal (2050) for greenhouse gas emissions lies at 2.0 tons CO_2-eq. per person. This represents a very ambitious venture, since today´s primary energy demand

[24] Almost 60% of Swedish households are rented and more than 20% of these are municipally-owned.

[25] http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=de&msg-id=44187

is approximately 6 300 Watts per person, resulting 8.7 tons CO_2-eq. greenhouse gas emissions per person. Thus, in order to meet the targets of the 2000-Watt society, it is necessary to reduce primary energy demand by 44% and greenhouse gas emissions by 77% (Wallbaum H., Jakob M., Heeren N., 2012).

Policy initiatives

The level of ambition is shown in the stringency of the Swiss **energy standards**. Preceding the strategies of the European Union, the first set of common energy standard requirements for building retrofits for was launched in 2000 and was updated in 2008. The holistic approach (energy demand requirements) is used mainly for new buildings and the single element approach for shallow or deep renovations. When the holistic approach is chosen in deep renovations, the targets are about 20% less ambitious than those for new buildings. The challenge is that only major renovations have to provide evidence of complying with the standards prescribed for renovated buildings.

In order to achieve the ambitious targets several initiatives have been introduced in Switzerland. **"EnergieSchweiz"** (SwissEnergy), a platform for activities to reach energy savings through efficiency and the use of renewable energy[26]. The activities comprise information, motivation, consulting, education and advanced training, quality assurance, networking, promotion and subsidising of advanced projects. The platform is operated by the Swiss Federal Office of Energy (SFOE) in close cooperation with other federal offices, the cantons and municipalities as well as with partners from the economy, environmental and consumer organisations and private agencies. "EnergieSchweiz für Gemeinden" is designed to break down national goals to the local level, specifically for municipalities to support their activities in achieving local energy goals and measures. This programme is implemented with some sixty moderators supporting municipalities in fulfilling the requirements of achieving the Swiss equivalent of the "European energy award" as well as creating products and services to support local energy policy initiatives (Egger K. et al., 2011). 513 Swiss municipalities are member of the Swiss Energy Award Association ("Trägerverein Energiestadt") which offers energy related measures and supports municipalities to reduce their non-renewable energy consumption and to increase renewable energy use. Thereof 284 municipalities with almost half of the Swiss population have acquired the label of the Swiss Energy Award program.

"**Das Gebäudeprogramm**" (Building program)[27] is a national program to subsidize energy efficient building retrofit measures concerning the building envelope[28]. It was launched in 2011 by the cantons and by the Swiss federal government and is designed to run up to 2020. In most of the cantons it is supplemented with cantonal programs to subsidize the use of renewable energies, efficient heating systems and the use of waste heat. The

[26] www.energieschweiz.ch

[27] www.dasgebaeudeprogramm.ch

[28] This programme is a follow-up of a similar programme called "Gebäudeprogramm" which was run by "Stiftung Klimarappen" (Swiss Climate Penny Foundation) between 2008 and 2011 and was endowed by about 180 million CHF for the whole period.

national program is financed by a CO_2 tax on fuels[29]. Furthermore in most of the cantons energy related building renovation costs may be deducted from the taxable income which yields substantial further “indirect subsidies” up to 20-40% of the costs of the retrofit measures, depending on the income of the building owner. It is administered by the cantons and by agencies commissioned by the cantons.

The level of governance

In Switzerland, the level of governance is threefold; responsibilities and competences in energy policy are split between the national (federal), the cantonal, and the municipal level. The federal government and administration are responsible for research, general education and training, as well as the allocation of subsidies for energy efficiency renovations. Based on the national energy law the competence for energy policy regarding buildings is assigned to the cantons. The cantons have agreed on coordinating their policy and on establishing and further developing common requirements for the energy performance of new and renovated buildings. All cantons have their own energy legislation and all cantons and some cities have their own energy concepts, outlining, for instance targets, strategies, measures, action program and allocation of resources. The Swiss association of architects and engineers is identified as a relevant actor in terms of ambitious target setting for energy demand requirements for building retrofits. Some cantons and larger cities have their energy plans supplementing the energy concept and determining spatial aspects and priorities of e.g. energy supply, especially of energy network infrastructures. Municipalities are responsible for local energy planning, and may run education, advising and subsidy programs – the latter often in alignment with cantonal or federal subsidies. Municipalities and large cities, such as Zurich, Basel or Berne often start-up or participate in independent initiatives, such as the 2000 Watt Society. This initiative requires achieving ambitious targets until 2050.

Policy evaluations for learning

Policy evaluations have been plentiful and frequent since the 1990s in Switzerland. From the 2000s, evaluations seem to be more selective focusing on specific programmes rather than taking a holistic approach. In nature, many of them are quantitative. Some good examples of evaluations for future policy learning are listed here below.

The evaluation on the 2000 Watt society programme assessed primary energy demand and greenhouse gas emissions reduction in the Swiss residential building stock (Wallbaum H., Jakob M., Heeren N., 2012). Based on the assessment, policy recommendation was given to federal and local authorities (Wallbaum H., Jakob M., Heeren N., Toloumis Ch., 2010). This evaluation was complemented with the efficiency of electricity use in the Swiss private sector (Jakob, 2012). Other programme specific

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[29] In 2011 180 million CHF (150 million €; this is about one third of the revenue of the CO_2-tax) of which 120 million CHF are allocated for building renovation (building envelope) and 60 million CHF for renewable energies, efficient heating systems and the use of waste heat. Additionally, the cantons provide subsidy programs with cantonal funds of another 80-100 m CHF/year. It is planned to increase the subsidies of the national program to 300 million CHF/year provided the Swiss parliament agrees on the increase of the existing CO_2-tax.

evaluations include the one on CO_2 abatement costs of energy related renovation measures of residential buildings(Walter Ott, Daniel Philippen, Alexander Umbricht; Andreas Baumgartner, Urs Vogel; Martin Jakob; Nadja Grodofzig, 2011) and on the effects of tax deduction for energy related building renovation (Haefeli et al., 2008; Swiss Federal Office of Energy, 2011). In addition, evaluations were made on informative instruments: the free consultation for energy savings (Roshardt, 2007), information activities related to subsidy programmes and technology and market development of energy efficient technologies, such as heat pumps (Kiss, Neij, & Jakob, 2012).

It can be concluded that cantons have a strong role in energy renovations, and cantonal targets set by the building code are strong drivers of retrofitting. In addition, the role of informative instruments is important and influential in Switzerland. Policy programmes, such as "EnergieSchweiz" can play a significant role in terms of knowledge and experience exchange among municipalities. Innovative instruments, such as the 2000 Watt society has a driving role in the implementation of ambitious retrofit targets.

3.4 Role of municipalities in energy efficient renovation projects

Within this section the role of actors in energy-related building retrofits is explored and investigated. The focus is particularly on best practice examples from proactive municipalities in each of the participating countries. The goal of this section is to provide an overview of resent municipal initiatives concerning increased energy efficiency in the residential sector. At the same time, it is considered interesting to highlight the different roles and leverage points that municipalities have in different contexts and countries. However, as also mentioned in Section 3.1, the goal of this overview is not to provide a comprehensive comparative study of the policy instruments and strategies available to local authorities to promote energy retrofits, but rather to put forward some best practice examples that may be taken as source of inspiration and discussion in the future, to delineate the potential role of local authorities and municipalities in this field.

Recent initiatives regarding sustainable cities, sustainable neighborhoods and local energy plans have seen municipalities take a more and more proactive role in the area of energy efficiency (Jensen, 2012). Rather than merely implementing national regulations and standards, municipalities are enacting local and more ambitious strategies. Secondly, in some countries municipalities are, either directly or indirectly, themselves owners of residential buildings. Although municipalities have different competences and different regulatory instruments from country to country, in all countries they are important actors in the context of buildings retrofits. To a certain extent, most policies enacted at regional or national level depend on action at the local level - being it for their application or their enforcement. Thirdly, given the fact that many actors operating in the refurbishment and maintenance industry for residential buildings are often small businesses operating at a local level, local initiatives are best fit to create capacity and knowledge amongst these actors.

In this project, some examples of local initiatives in Denmark, Finland, Romania, Sweden and Switzerland were selected. The examples include initiatives in both small and big municipalities. Data and information regarding such initiatives was collected through interviews with project managers and head of authorities in the municipalities, through analysis of documents concerning the initiatives and through interviews with researchers within the field of energy renovations from each country. The data were collected throughout the INSPIRE project in the years 2011 and 2012. When data has other origins than interviews references are indicated.

In the following sections, examples concerning each country are presented. Each country section includes a background overview to understand the institutional context of the country, a part on the traditional role and instruments of municipalities with regards to buildings and energy, a description of the best practices and initiatives to increase energy efficiency in the local building stock and, finally, the drivers behind these initiatives. Considerations and conclusions regarding the role of municipalities are presented in Section 3.3. The conclusion focuses on what experiences can be derived from these best practice examples and the different roles of the municipalities in the five countries object of this study.

3.4.1 Denmark

Background

Denmark is divided into 98 municipalities (*kommuner*). Municipalities in Denmark have the responsibility for a wide range of areas, from social services to the promotion of employment. Much of the domain related to environmental issues and environmental control is also the municipality’s responsibility. Traditionally, the role of municipalities in promoting energy efficiency among private house owners has been limited. House owners mainly need to comply with the national legislation (especially the building code) when renovating houses. Besides this, a number of more informative means have been introduced regarding energy renovations.

Traditional role of municipalities and traditional instruments

One of the areas in which energy initiatives regarding private housing have been implemented is the enforcement of connection to district heating in specific urban areas. Urban renewal projects that are subsidized by the municipality represent another area in which the municipalities have increased the demands for energy efficiency. Lately, projects have been implemented with the aim to investigate how strict energy demands the municipalities can implement in local planning. Especially regarding social housing, several municipalities have imposed stricter requirements on the building performance, which has initiated a focus on the adaptation of new buildings to the new requirements (Frederikshavn Municipality, 2008; Ministry of Social Affairs and Integration, 2011). Traditionally, local planning has addressed many other parameters than energy efficiency, such as architecture, plot ratio and zoning.

Even though the regulation of energy efficiency issues take place at the national level, some of the utility companies that are obliged to promote energy efficiency are owned by the municipalities. Thereby, the national regulation in this field is actually implemented at the municipal level.

Best practice initiatives

A number of Danish municipalities have initiated activities with the goal of involving the inhabitants and private companies in the development of a common vision for a more energy efficient building stock. Examples are the “energy villages” in the eastern part of Denmark: project zero in Sønderborg which is about the development of a carbon-neutral area and public-private partnerships in Middelfart and Frederikshavn are focused on energy renovations.

In the following, we have chosen to focus on two best practice cases of municipalities in Denmark; one is the municipality of Frederikshavn (with around 60 000 inhabitants) in Northern Denmark and the other is the case of Middelfart municipality in Central Denmark (with 37 500 inhabitants).

These two municipalities have implemented a number of initiatives to promote the energy renovation of existing buildings with different focus points. The introduction of energy efficiency requirements on buildings owned by the municipalities themselves is relatively easy; however, it is much more difficult for the municipalities to intervene in the renovation of privately owned residential buildings. When it comes to new buildings, some municipalities in Denmark have imposed stricter energy efficiency requirements on new buildings, already adopting the standards which are to be implemented at a national level in 2015 or 2020. However, this type of regulation is not as easy to mandate in the context of energy efficiency in existing buildings. Hence municipalities need to adopt and implement a palette of strategies in order to promote energy efficiency in existing buildings.

In the case of Frederikshavn, initiatives for energy efficiency in existing buildings are taken in the context of a wider program for a sustainable energy system called *Energibyen*[30]. According to this program, the energy town of Frederikshavn aims at being 100% fossil fuel free by 2015 (COWI, 2008). The energy renovation of existing buildings was identified as a necessary step to reach the objectives of the program. The municipality did, from 2008, require low energy building class of new houses (Frederikshavn Municipality, 2008). (As Frederikshavn is a small municipality, most of its residential building stock consists of detached houses.) This has required more advanced initiated a stronger knowledge from the building professionals as they have been forced to learn how to apply new technologies in order to fulfil the stricter requirements. Since it was not possible for the municipality to intervene directly or to mandate energy efficient renovations in residential buildings, it was decided to create capacity at a market level, i.e., among energy and built environment professionals.

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30 http://www.energibyen.dk/

In the case of Middelfart, the size of the municipality increased in 2007, as part of a reform of the municipalities in Denmark, in which two smaller municipalities merged with Middelfart (Sørensen, 2012). Previously, none of the three previous municipalities had a focus on energy efficiency, but as a part of the new organization, there was an increased focus on energy and the possibility of linking this to local growth in the municipality. Most of the buildings owned by the municipality of Middelfart had not been renovated for a longer period of time. Due to the large renovation task, it was decided to establish a plan for the renovation of the entire building mass owned by the municipality. Different business models were considered in terms of the possibilities of financing the renovation initiatives; among others, the Energy service company model (ESCO). The ESCO model is, in this case, an example of collaboration between the municipality and an energy service company, where the service company looks into the potential energy saving initiatives in the building mass. The energy service company gives a guaranteed saving on the initiatives and the suggested initiatives are accomplished. At first, a pilot project of energy renovation of nine buildings was made using this model. The result was a total reduction in the energy consumption by 23% (Middelfart Municipality, 2009). After the success, it was chosen to use the ESCO model on all buildings owned by the municipality. Middelfart Municipality was the first municipality in Denmark to use the ESCO model on a large scale (Hansen, U. B., Sørensen T., 2012). The initiatives involved all the buildings owned by the municipality's own buildings and the guarantee of the energy service company secured the investment. The energy consumption was reduced by around 20%, the cost of the renovation was 40 million DKK, and the yearly savings are 4 million DKK.

At the time of the investment, Danish municipalities were not allowed to increase their budget annually, but the state made an exemption to make it possible for the municipality to pay for the investment. A different initiative in Middelfart was the establishment of the network “Grøn Erhvervsvækst” (Green growth of business) of companies focusing on greening the industries through savings of energy consumption and also on growth of green industries within the municipalities which formed the network. A part of the network has focused on energy renovation and made an initiative similar to the one in Frederikshavn involving collaboration between building professionals and a required education of the participating building professionals.

Actors and networking

In Frederikshavn, several actors have been involved in the initiatives taken. A wide collaboration has been established in the network of building professionals. The educational institution EUC Nord has established a new program that the building professionals must complete to be part of the network. The municipality has helped initiating the process and facilitating some meetings. According to the municipality, the building professionals in the network have increased their general awareness of energy efficient initiatives. Another initiative in the goal of becoming independent of fossil fuels has been the collaboration with Aalborg University. The collaboration has especially dealt with locating the potentials of biomass and potentials for changing energy supply. One different initiative has been to hire an energy counsellor paid by the municipality and utility company of Frederikshavn. The purpose has been to perform energy counselling of houses to give incentives for energy renovation of houses. A further objective is, through the savings, to reduce the energy consumption of the town.

In Middelfart, the actors have been the utility companies who have identified potential savings and provided a guarantee on the energy reduction. In collaboration with the municipality, they have looked at the potentials in a number of initiatives. The initiative of Grøn Erhvervsvækst has involved the collaboration between the municipality, an educational center and the local building professionals. The municipality has been the front runner in terms of implementing energy renovations of the entire building mass and has hoped that it would make building owners in the municipality perform energy renovations of their own houses.

Drivers of initiatives

For Frederikshavn, the initiative was driven by the expectations of increased unemployment in the municipality and the expectation that this area in general would decrease. The project is seen as a promotion of local employment, where building professionals, consultants and local industries can benefit from the energy renovations and development of sustainable energy systems; in other words, local development of businesses. One of the other drivers is local investments. Local production of energy secures that the energy expenses are beneficial to the local economy instead of the turnover of large national energy providers. Finally, the city is situated in the far north of the country, where the municipalities experience gradual depopulation. In this context, such initiatives represent a way of putting Frederikshavn on the map and decreasing the depopulation of these areas.

In Middelfart, the driver of the private-public partnerships is a combination of having a building stock with relatively low energy efficiency performance, increasing energy prices and an urgent need for renovating the building mass. On the other hand, the resources for improving the energy efficiency in the municipality are limited and public-private partnerships serve as a good potential for developing energy renovations with limited municipal investments in which the future energy savings finance the investment.

Being the first municipality using the ESCO-model on a large scale, has given Middelfart an advantage, which has led to that both Danish municipalities and other European towns have expressed interest in the use of this model. Middelfart Municipality won the “European energy service award 2011” for the best ESCO project in Europe (Middelfart Municipality, 2011). The ESCO-initiatives has combined energy reduction, the focus on reducing CO_2 emissions and has, at the same time, helped to create and/or to secure jobs locally. Around 100 jobs have been created due to initiatives of the network Grøn Erhvervsvækst through the increased use of building professionals in the municipality (Hansen and Sørensen, 2012).

3.4.2 Finland

Background

The role of municipalities has been investigated through the case of Tampere, as an example for long-term energy-saving initiative. The city of Tampere with 200 000 inhabitants is the third largest city in Finland and one of the forerunners of climate protection on local level. The Climate commitments of the city are in line with the EU targets: decrease greenhouse gas emissions by more than 20% by 2020, increase the share renewable energy to 30% by 2020, in addition, changing city development practices towards sustainability[31]. In addition to these targets, an Energy Efficiency Agreement (period 2008–2016) was signed with The Ministry of Trade and Industry (TEM), whereby the basic goal was set at 9% energy savings in 2008-2016. For instance, the TAPRE project is one tool in achieving this goal. These climate and energy targets are to be implemented through the programme of "Eco-Efficient Tampere 2020" (ECO2)[32] – launched in 2010 – with the aim to be a pioneer in climate policy and to spread good practices by participating in national and international networks. The implementation of the renovation strategy is however until now at an initial stage. In addition, one of the objectives in Tampere Region Climate Strategy of 2030[33] is to prepare a regional plan for repair and new construction. The plan is not yet available because the local advisory services for repair, new construction and energy will be developed in collaboration with other Eco-partners, building inspection authorities and housing offices. In autumn 2012 the service was planned to be offered also for neighboring municipalities.

Traditional role of municipalities and traditional instruments

The City of Tampere has had an energy savings program as early as 1995 and an agreement with the Ministry of Trade and Industry (later TEM). The agreement has resulted in support for energy audits and investments. It has been advocated that municipalities shall be exemplary in this field. Today, the objectives and commitments have become more stringent, in particular because of the EU. Municipalities traditionally following and implementing the requirements set on a higher (national) level; local initiatives traditionally are not common.

Best practice initiatives

ECO2 – Eco-efficient Tampere 2020 implements the climate and energy objectives of the City of Tampere[34]. ECO2 promotes city development through co-operation of actors, creating targets for a carbon-neutral city, creating conditions for environmental business growth (especially in clean technologies), for energy conservation, for renewable energy and for eco-efficient construction. ECO2 coordinates, develops and supports the city's energy waste and climate projects and undertakes studies and project preparation, where

[31] http://www.slideshare.net/ubcenvcom/fin-tampere

[32] http://www.kunnat.net/fi/asiantuntijapalvelut/yty/ilmastonmuutos/tyokaluja/ratkaisuja-2011/Documents/2011-02-01-ilmasto.pdf

[33] http://www.eco2.fi/uploads/Eco%202%20lehti%20eng%20korj.pdf

[34] http://www.eco2.fi/default/en/eco2-programme.html

the partners may be in the city departments as well as companies and other interest groups. Renovation and maintenance is one of the schemes in ECO2[35]. ECO2 renovation targets include the preparation of target levels of energy efficiency, guidelines for different building types (with the aim of achieving energy class A) and operation models for energy efficient project planning, construction and property management. In addition, energy renovations are promoted through the TARMO (Towards energy efficient residential areas in Tampere region) project supported by the SAMPO campaign, which is a new information center for sustainable building and construction and energy use in housing, eco-efficient complementary construction (Tammela project), renovation and energy state grants and innovative energy-saving pilot projects (financed by the housing fund of the city). In general, these activities are commonly applied by municipalities promoting energy efficient building renovations.

Energy efficient renovation is specifically developed in the area of public service buildings. TAPRE-project is a good example for the renovation of public buildings. The initiative is coordinated by Tampere Real Estate services[36] and its goal is to make the service buildings in Tampere area more energy efficient by creating a regional energy market, e.g. uniform energy efficient contracts and policies, to help and to make easier the work of all parties. The market does not develop, if all market participants (both property owners as to the services produced by companies) are not included. The project consists of three working groups which are based on building life-cycle thinking. One focuses on project and implementation planning, the second on contracting and implementation and third on the use of the building. The results, e.g. contract templates and other energy efficient assessment tools, are tested in buildings (schools, day care centers, swimming pools, etc.) chosen by the project cooperation partners from construction and maintenance services[37].

Actors and networks

TAPRE is funded by the city of Tampere, Tampere Central Region, property owners, operators in construction and renovation, Tekes, Motiva and the Ministry of Environment. Co-operative partners use own financing. The main actors in implementation are the coordination body of Tampere Central Region, including eight municipalities (Kangasala, Lempäälä, Nokia, Orivesi, Pirkkala, Tampere, Vesilahti, Ylöjärvi), property owners in the city of Tampere and in other municipalities (such as Kesko, the Pirkanmaa Regional Cooperative Society, the Pirkanmaa Hospital District, the association of Tampere Evangelical Lutheran Churches and the real estate company of Finnish universities), two construction companies (YIT, NCC) and eight maintenance companies, two architectural offices and three engineering consultancies.

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[35] http://www.eco2.fi/uploads/Eco%202%20lehti%20eng%20korj.pdf

[36] http://www.slideshare.net/ubcenvcom/fin-tampere and http://www.eco2.fi/news/86/35/Energiaremontti-ilta/d,muropolku.html (in Finnish)

[37] http://www.eco2.fi/default/fi/hankkeet/tapre.html (in Finnish)

Other important actors on a national level are Motiva and the Real Estate Association. Motiva[38], an affiliated Government agency, plays a relevant role in promoting efficient and sustainable use of energy and materials targeting public administration, businesses, communities, and consumers. The vision of Motiva and its networks is to be decision makers' and end-users' best expert in issues of energy and materials efficiency and renewable energies. Motiva has started in 2010 an area of operation concerning consumer energy advice in Finland[39] with the goal of providing consumers with high quality and reliable energy advice by relevant actors on local, regional and national level cost-effectively. The Real Estate Association[40] has a long tradition in the housing arena, being also actively involved in research and development activities. It consists of housing companies (more than 20 000 with a total population of nearly two million people), property companies, building owners of rental apartments as well as landlords. Real Estate Federation is a supervisor of property owners, real estate expert and industry leader influence. Members have access to the latest information and real estate experts specializing in services. This is reflected in strong communication and information delivery concerning energy efficiency, maintenance, building renovation, renewing building technology, and decision-making process of renovations. The Real Estate Association manages web site Taloyhtio.net[41] which offers useful information, products and services for governments of housing companies and building managers. Registering as a user of Taloyhtio.net is free of charge.

Drivers behind initiative

The most relevant drivers behind the overall ECO2 initiative are a) the EU´s energy commitments promoted by the Covenant of Mayors on local level, b) the draft climate strategy, which has been prepared in cooperation with the municipalities of Tampere region, c) Eurocities Declaration on Climate Change aiming at mitigating climate change, d) Energy Efficiency Agreement with the Ministry of Economic Development, e) Aalborg Commitments (2007), e) governmental financial support in the start-up phase (2010-2012)[42].

Common drivers specifically behind the TAPRE project are a) property owners are more and more interested in energy issues, b) service providers are expected to more energy efficient buildings, and more energy efficient operation and maintenance services, and c) requirements on the individual property owner to define/develop energy efficient procurement principles, which requires resources and expertise.

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38 http://www.motiva.fi/en/areas_of_operation/consumer_advice_on_energy_issues

39 http://www.motiva.fi/en/areas_of_operation/consumer_advice_on_energy_issues

40 http://www.kiinteistoliitto.fi/liitto/

41 http://www.taloyhtio.net/

42http://www.eco2.fi/uploads/liitetiedostot/materiaalipankki/PROJEKTISUUNNITELMA%20_20[1].1._pdf and http://www.sitra.fi/hankkeet/eco2-ekotehokas-tampere-2020

3.4.3 Romania

Background

The role of municipalities with regards to promoting energy efficiency in buildings in Romania is in some way more marginal than the role of municipalities in the four other countries studied in this report. Generally speaking, the role of municipalities in Romania is mainly limited to the application and enforcement of national policies. This means that municipalities in general do not develop policies regarding energy renovations themselves and do not e.g. set local CO_2 reduction targets. Municipalities' action is hence greatly determined by policies developed by the central government, while there are very few examples of proactive local policies implemented by municipalities.

To understand the role of the municipalities regarding energy renovations it is also important to know that municipalities do not own residential buildings, but some historic buildings as well as buildings for public service functions is owned by the municipalities. Most of the residential buildings are not only owned by private housing associations but most of them are also free of real-estate loans.

Traditional role of municipalities and traditional instruments

Among the main tasks of municipalities is to inform about policies for energy efficiency and energy retrofits. When it comes to e.g. subsidies for energy renovations municipalities check the documentation, handle the public bidding process and allocate resources. The thermal rehabilitation program is on the local political agenda by the politicians. Some municipalities make a guide for owner associations and companies on how to do energy renovations. Just to provide an example of the extent of this program, Timisoara has 150 million Euros for retrofitting and 250 000 buildings that are in urgent need for retrofitting[43].

Municipal actions to a certain extent depend on national politics, which can be a factor determining the scope and effectiveness of local actions, behind the formal institutional setting.

Because of these factors, municipalities do not have much room for local initiatives in promoting energy efficiency in buildings. In the context of national and regional policies, they do however act as the final executor of programs regarding renovations, as in the above-mentioned scheme where municipalities have to stand for 30% of the costs of the renovation project. In this scheme the municipalities have more decision-making power manifested by e.g. choosing the contractors for the renovation works, following quality and price criteria.

Besides this kind of tasks, municipalities are not involved in general in renovations. However, there are examples of involvement in energy renovation of buildings in the context of intra-European collaborations.

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[43] http://www.tion.ro/ministrul-dezvoltarii-la-timisoara-avem-150-de-milioane-de-euro-pentru-reabilitare-termica/1113955

Best practice initiatives

The role of municipalities has been investigated through the case of the rehabilitation of historic districts in the city of Timisoara, as an example for long-term energy-saving in historic buildings. The city of Timisoara has 300 000 inhabitants, with a slightly decreasing population over the last 20 years. Timisoara is a social, economic and cultural center situated in the western part of Romania. This city has a historic tradition of being a front-runners when it comes to electrical infrastructure: it was the first European city with electrical lightning and also the first one to have electrified trams[44].

One notable example is the renovation program in the city of Timisoara where historical buildings were renovated by Timisoara City Hall in collaboration with special advisers from the German Society for Technical Corporation (GTZ), who helped by providing funding and expertise. The goals of this project were in the context of the construction of multipurpose buildings (exhibition space, office spaces, workshops and conferences, laboratories, space needed by the park, parking, catering, cafeteria etc.), land with utilities equipment, parceling the "Center for Technology Transfer and Promotion Innovative Alternative technologies"[45]. One of the goals of the investment of GTZ is to provide demonstration and training of activities to introduce rehabilitation. One of the activities is a workshop on participatory process of citizens and entrepreneurs: the focus of the workshop is “measures to improve energy balance in the rehabilitation of historic buildings”[46].

Another example of a new approach in Timisoara is the installation of solar panels in schools, where one project is implemented and feasibility studies of new ones are made[47].

Financing by public-private partnership where municipalities are involved is also common. The financing by public-private partnership may be done in all sectors where it is necessary to achieve energy efficiency improvements. Depending on the types of public-private partnership projects, financing may be ensured either integrally or partially by the investor, together with central and local public authorities. The financial resources made available by the aforementioned may be obtained by allotments from the State or local budget, within the limit of the funds approved annually for this destination in the budget of central or local public authorities concluding public-private partnership contracts.

Drivers of these initiatives

The main driver for the renovation of historic buildings in Timisoara is the foreign funding and expertise for the project. When this is available, local authorities are also ready to

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[44] http://www.citypopulation.de/php/romania-timis.php

[45] http://www.mdrl.ro/index.php?p=592

[46] http://www.gtztm.ro/stiri/workshop

[47] http://e-casaverde.ro/noutati-in-derularea-programului-casa-verde.html

get involved in rehabilitation projects, as it also means more jobs and more cultural tourism[48].

Recently in Timisoara it was announced that the municipality wants to get about eight million Euros of European funding for the thermal rehabilitation of building blocks. Unlike previous years, the municipality's strategic goal is the thermal rehabilitation of the entire blocks of streets: "…we will not rehabilitate disparate blocks. We work at the preparation of this project on all the main streets of the city and, in any case, at all entrances to the city. We hope that from the total amount of 160 million Euros, from which one eights of it, about 20 million Euros return to the Region 5 West, Timişoara will manage to get at least seven, maybe even eight million. With this money we are able to rehabilitate a large numbers of blocks, so that the election commitment to rehabilitate at least 200 units to be achieved. At national level the project will have a total budget of 304 million Euros, of which 150 million from the European Regional Development Fund (ERDF) and 154 million provided from the state budget, local budget and the European Commission's request, contributions of associations. Eligible blocks for this project must have been built between 1950 and 1990."[49]

3.4.4 Sweden

Background

The role of municipalities has been investigated through the case of Malmö in Sweden. Malmö is the third biggest city in Sweden with close to 300 000 inhabitants and with a strong focus on sustainable urban development and improved life quality. The application of sustainability approaches strongly related to the liquidation of the Kockum shipyard and in broader terms the transition of a peripheral industrial city towards a cosmopolitan regional knowledge hub. This vision on urban transition has permeated all actions which have been taken by municipal and private actors in the past 25 years. Today the focus is on supporting businesses with high environmental profile in order to advance the local economy and the international profile of the city in terms of sustainable urban development. Despite the continuous development of the past decades, one of the main challenges remain to be addressed is in the area of energy use in the existing building stock – where 30% of Malmö´s inhabitants are residing.

The new targets set out in the Energy Strategy (2009-2020) and the Environmental Program (2009-2020) of Malmö Municipality is that "by 2020, the City of Malmö will be climate neutral and by 2030 the whole municipality will run on 100 % renewable energy" (Malmö City, 2009). The renewable target is planned to be reached by measures in energy efficiency, local renewable energy production, new transport system, lifecycle-orientated water system in combination with resource-efficient city planning, architecture

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48 http://www.vestul.ro/stiri/2421/proiectul-romano-german-de-reabilitare-a-cladirilor-istorice-din-timisoara-la-final.htm

49 http://www.tion.ro/robu-vrea-opt-milioane-de-euro-pentru-reabilitarea-termica-a-blocurilor-din-timisoara/1173100; http://www.tion.ro/robu-explica-strategia-de-reabilitare-termica-a-blocurilor-din-timisoara/1173898; http://ziuadevest.ro/actualitate/33461-incepe-marea-reabilitare-termic-a-blocurilor-din-timioara.html

and measures improving life quality. One of the main measures to reach these targets is the renovation and integration of the million program housing areas (Malmö City, 2010).

Traditional role of municipalities and traditional instruments

Sweden has a long tradition of local self-government, where municipalities play a relevant role in partly implementing national energy strategies and partly formulating municipal ones (Palm, 2006). Traditionally, municipalities have had a significant role in energy issues. On one hand energy supply systems (gas, electricity and district heating) have been organized in municipally owned companies. On the other hand, since 1977, according to the Swedish law of energy planning Swedish municipalities, they are obliged to have an updated energy plan covering the distribution, production and use of energy (Palm, 2006). It states that the energy use should not be excessive and the supply shall be safe and sufficient. These facts led to further responsibilities in areas of energy planning, energy advice and other energy issues handled by municipally owned energy and building companies. More recently the implementation of Local Agenda 21 has been added to the list of responsibilities (Palm, 2004; Summerton, 1992) and thus providing more “power” and possibilities for municipalities to carry out actions towards sustainable urban development.

Best practice initiatives

Since the 1990s, there have been a couple of sustainability projects running in Malmö, which have served as a good basis and learning for the currently running projects. In terms of new buildings, amongst others “Bo01 Self-Sustaining City District” (see e.g. Larsson, Elmroth and Sandstedt, 2003), “Living Building Dialogue”, a stakeholder management process applied for new buildings (Boverket, 2012) and “Miljöbygg Program Syd”, a Swedish environmental classification tool for new buildings (such as LEED, BREEAM, passive house), have been successful and key tools for sustainable urban development. In terms of building renovations, “Ekostaden Augustenborg”, an eco-friendly development of a 40 years-old, previously labeled as immigrant, city district was one of the first initiatives addressing sustainable betterment of the aging building stock. It was followed by the “ERUF-EKO” project, including the improvement of buildings built in the after-war period (ERUF-EKO, 2011). Currently, for instance, the “Living Building Dialogue” is being redesigned for financing the renovation of the existing building stock (“Bygga-Om-Dialogen”), amongst others, in the area of energy, indoor environment, moisture problems and urban biological diversity and the experience of Augustenborg is being applied in many ongoing renovation projects.

The “Malmö – from East to West” initiative has the focus on the social and economic integration of different parts of Malmö, through innovative transport solutions and environmentally benign technologies. In the past 15 years Malmö has been a guinea pig for new environmentally benign technologies, based on the past experience, this initiative aims at bringing forward the sustainable profile of the city and apply the segregated initiatives to an integrated urban project. The total investment of the initiative is app. SEK 2 000 million, including 14 measures, out of which related to almost 1 500 apartments

(Malmö City, 2010). Some of the overall goals of the initiative relating to energy saving measures (ibid): the climate effects are estimated to be at least 24 500 tons CO_2 yearly, the production of renewables shall be 6 170 MWh and the energy efficiency measures shall reach up to 32 055 MWh.

The initiative includes the renovation of a million program area, Rosengård. There are almost 800 apartments participating in the program owned by one of the biggest housing association, BRF Hilda. In specific for energy efficiency in the existing building stock, the some of the main objectives are formulated as follows (Malmö City, 2010; IEE, 2012). 1) By 2014, an energy saving of 80 GWh shall be reached in the two city districts of this initiative: Rosengård and Western Harbour. 2) The renovation of Rosengård areas shall be the most ambitious sustainable renovation project in Sweden. 3) There shall be a business model and concept created for privately owned housing associations in terms of ecological renovation.

Actors and networks

The main actors implementing ambitious climate and energy saving targets include committed municipal actors, city development managers and environmental or climate departments, climate or sustainability managers who intend to involve businesses and universities for applying advanced technological solutions in the frame of the triple-helix concept.

The Rosengård renovation project, in specific, is considered innovative due to its new approach e.g. towards the application of new technologies and system solutions, long-term economic thinking and the active promotion of this among residents. According to the future plans of Malmö Municipality, based on learning from “Malmö – from East to West” initiative, Malmö can reach 20% energy efficiency in the whole city, the same way it has reached in the two selected demo area: Rosengård and Western Harbour, by transferring lessons learnt from these demo projects. The Rosengård project has a great transferability; during the period of 1965-75, 650 000 similar type of apartments were built in Sweden which all need to be renovated in coming ten years (Malmö City, 2012). These types of apartment buildings have also been popular in other European regions; there is great potential for knowledge transfer in the following years.

Drivers behind the initiatives

The main drivers behind energy efficient renovations are a dynamic business environment and growth, job creation, improving living standard in terms of living quality and healthy business environment as well as learning from sustainable urban networks.

The specific drivers of the initiative “Malmö – from East to West” are very much in line with the more generic drivers of Malmö Municipality creating a cutting-edge livable city after the liquidation of the main industry in Malmö, with an attractive business environment and diverse job opportunities (Malmö City, 2009). These local goals have been supported early on with extensive national funding in the frame of LIP (local investment support) and KLIMP (climate investment support). In addition, these initiatives and goals have been reinforced by objectives set and experience demonstrated by different international networks the municipality is participating in, such as Eurocities, ICLEI, Sustainable Cities and Towns Campaign, Union of Baltic Cities, Klimatkommunerna and Convenant of Mayors.

Financial barriers are often one of the largest hinder to implement advanced solutions, which is why the intention of municipalities is to advance the business environment for growing investments in energy efficiency from the private sphere. In general, municipalities then set earlier targets on their own e.g. building stock to show good examples for the private sector to follow.

3.4.5 Switzerland

Background

The role of municipalities has been investigated through the case of Zurich, as an example for an advanced and forward-looking municipality. Zurich has set more stringent targets in comparison to the federal ones, namely GHG emissions should be reduced to 1 t CO_{2eq}/cap by 2050 (starting from a level of 5.5 t CO_{2eq}/cap in 2005), while investments in nuclear power plants are not to be renewed (Volland B, Gessler R., Püntener T., 2011). In order to give a stimulus for sustainable development and to show best practices, the city council has also decided to set stringent targets for its own buildings, including compliance with energy requirements (set by the Energy Masterplan of Zurich City) and goals of the 2000 Watt Society with consideration to the recommendations on sustainable buildings of the SIA (Swiss Society of Architects and Engineers, SIA-norm 112/1). In addition, public buildings shall meet the needs of future users, principles of economic viability, ecological sustainability and high architectural and urban quality.

Traditional role of municipalities and traditional instruments

Zurich city has had long commitment to energy saving measures; in comparison to ten years ago, the role of the city of Zurich in efficient building renovations has been further expanded. In 2000, the municipal program «Presanz» ended which investigated energy use in municipal buildings and provided a priority list of renovation measures. The experience won in this process led to the introduction of a building management and development strategy for each municipal building, in which the period and the type of upcoming renovations were defined (from simple maintenance and overhauling to renovation and renewal to extensive renovations combined with modernization and sometimes to demolition with new construction). These environmental management systems for municipal buildings acted as drivers for sustainable building activities in the following years also yielding the “7 Milestones initiative” and the first version of the Energy Master Plan.

Best practice initiatives

To implement the ambitious targets of Zurich city and to foster building retrofits, the head of the building department (MBD) of the city of Zurich launched guidelines “7 Milestones to environmentally friendly and energy efficient buildings"(SBS, 2008) referring to the Swiss standards and labels issued by the association MINERGIE[50]. In terms of existing buildings, the first priority is to achieve the minimum requirements of the MINERGIE standard, cover at least 15% of the heat needs with renewables and provide a healthy indoor climate and comfort. Criteria are set for the building process and management as well, including requirements for competitive bidding and continuous follow-up (e.g. measuring and controlling the building performance, carrying out of energy statistic and optimizing the building operation). In addition, according to the guidelines of the city council, financial viability of the renovation shall be assessed accounting for external costs and non-monetary co-benefits. The initiative addresses the city administration and its buildings as well as affiliated organizations like non-profit building associations (which are often provided with city owned building plots at favorable conditions but with the obligation to have cost based rents and to fulfill ecological as well as general standards of the city for building quality).

In 2008, to further support the implementation of the achievement of ambitious targets of Zurich city, the 2000-Watt-society was introduced into the constitution of Zurich. The initiative was supported by the population of Zurich through 76% approval in the municipal voting. This provided a powerful legitimation to the municipal administration and to the executive body to prepare progressive actions. In 2008, the "7 Milestones initiative" together with the "2000 Watt Society initiative" became binding for public administration.

The concept of 2000 Watt Society in Switzerland (Lenzlinger et al., 2012)**:**

- Reduction of primary energy use to 2000 Watt per person whereof at most 500 Watt non-renewable primary energy use until 2100.
- Reduction of carbon emissions to 2t CO_{2eq} per person per year until 2050 and 1t CO_{2eq} per person until 2100.
- Sustainable development of the city of Zurich

The "7 Milestones initiative" was a result of the city councilor's political agenda in 2001 striving for new achievements at the end of a legislative period. This coincided with political initiatives from certain parties, e.g. the Green Party of Zurich demanding for sustainability and abolishment of nuclear electricity production. The development and update of the "7 Milestones initiative" has been driven by the "Energy Masterplan" of the city. Very sound support of the voting population and the commitment of the city council to the 2000 Watt Society and to sustainable development of the city are strong factors supporting the administration by implementing the initiative. Additionally the activities of

50 www.minergie.ch, www.minergie.com

the administration are watched by an alert part of the parliament and further supported by supplementary budgets to implement the targets in the building sector

In 2011, Zurich city established a municipal research program in the energy sector for the next ten years. The research program was initiated by the parliament, in which parties with a certain preference for sustainability and energy issues succeeded to have a majority for the necessary budget of 1 million CHF (about 830 000 € in 2012). One subprogram promotes research to accelerate building renovation and to improve the standards achieved by building renovations. The other subprogram establishes a panel with 3 000 – 5 000 building users to explore the effects of different behavioral measures and measures to reduce energy use compared to control groups with no measures.

Actors and networks

The "7 Milestones initiative" was prepared by the Municipal Building Office partly in cooperation with other offices of the building department (e.g. the office of urban design Zurich) whereupon the draft program was given in a consultation process to all the offices of the municipal administration affected by the program. The Municipal Building Office was also contacting other building administrations of active Swiss cities as well as of active Swiss cantons. On one hand the choice was a result of existing cooperation procedures and networks within the municipal administration and on the other hand of existing contacts and expert networks among progressive cities and cantons.

In the case of the city of Zurich there are three actor groups identified to be relevant. The head of the building department of the city of Zurich, being committed to the initiative, the council of the city by backing the initiatives and the parliament of the city supporting the decisions. Experts and professionals in the municipal administration who have a preference and personal commitment for energy and sustainability issues and who pursue energy and sustainability approaches with a long term perspective.

Drivers behind the initiatives

The main drivers of these initiatives are energy security, economic and long-term commitment to different European and national schemes, such as the 2 000 Watt Society and the Minergie standard. It has also been observed that municipalities are more active today than previously; R&D plays an important role triggering commitments also on a municipal level.

We have found finances as the main barriers of the implementation of these initiatives. Ambitious energy renovations require higher investments in the short run and often with a life cycle perspective; the economic viability was often not clear-cut positive. Additionally in a city like Zurich with many historical buildings or buildings representative for a certain style of architecture there are sometimes conflicts between ecological sustainability and social and cultural demands.

3.5 Discussion

In the discussion, a summary of the most relevant policy initiatives (3.5.1) and similarities and differences in the role of municipalities (3.5.2) in the five countries is provided. In addition, the role of different actors and network in energy renovations is discussed (3.5.3), and policy initiatives are highlighted which support knowledge development, learning and networking among involved actors in energy efficient renovation projects (3.5.4).

3.5.1 Good examples of policy instruments for energy efficient renovation

Energy renovations, in principle, take place on market terms. However, it has long been known that, due to market and other barriers, they require the development of policy instruments and initiatives at a local level. Beside barriers at the market level, it has also been pointed out how the value of energy saving in people's mind competes with other non-energy related needs and wishes. In blocks of flats, for instance, residents have difficulties accepting the investments related to renovations, thus compromising the adoption and effective implementation of energy renovations in this kind of buildings. Therefore, policy measures are important to promote and support energy renovations. Economic instruments can be either a strong differentiation of property tax based on energy consumption, or financial support of the renovation, for example by tax deductions. However, financial support may have only catalytic effect, as the sums necessary to implement extensive renovations are much bigger than what governments may be able to provide for. Therefore there is a strong need for new financial solutions or development of existing models, such as energy conservation service, that can work around the problem of building owners' access to capital. Also, innovative instruments promoting this kind of solutions as well as learning and networking among actors to implement them are needed. The incoming regulations for renovation and the guidelines for its application will provide a good basis for new policy instruments to implement energy renovations.

	Denmark	Finland	Romania	Sweden	Switzerland
National climate targets					
Reduction of energy use (2020)	7.6%[51]	9%[52]	13.5%[53]	20%[54]	20%[55] (CO2)
Reduction of energy use (2050)	Zero carbon	30%		50%	
Requirements for renovations in building codes	Component based	Voluntary	Voluntary	Performance and component based	Performance and component based
Economic incentives for renovations	Grants, Energy obligations of utilities	Grants, Tax incentives, Energy Audit Programme	Grants, preferential loans	Grants, Tax incentives, Technology procurement (BeBo, BeLok)	Grants, Tax incentives
Information tools	Energy labeling, Knowledge Center for Buildings	Energy Environment Expert Programme, Building Service Manual, Web-based information sharing system	Education of energy auditors	Local energy advisors	EnergieSchweiz

Table 26: Goals and incentives for energy renovations in Denmark, Finland, Romania, Sweden and Switzerland

The requirements of building standards for renovations do not always reflect the ambitious national energy efficiency targets. Both component and performance based requirements for renovations exist only in Sweden and Switzerland. In Denmark, component based requirements are set for renovations and in Finland and Romania, requirements set by the building codes are voluntary and of indicative nature.

51 Denmark set a target of 100% renewable energy in the energy and transport sector by 2050. It has an implication of the energy efficiency targets, which was set as a reduction of energy use of almost 7.6% in 2020 relative to 2010 (Danish Government 2012).

52 Finland set an improvement of 9% in energy efficiency by 2016 (NEEAP, 2007). Finland has a non-binding target of a reduction in final energy demand by 11% below the projected baseline in 2020. In improving the use of energy in buildings, the goal is for consumption to be at least 30% lower in 2030 and at least 60% lower in 2050 than the present level. Beyond this, the objective is to reduce final energy demand by a further 30% below 2020 levels by 2050. In addition, Finland aims to be a pioneer in energy-smartness by 2017. The long-term goal is to make the Finnish built environment the best in the world by 2050. More specifically, the implementation of EPBD intends to reduce energy use in existing buildings by about 25% and CO2 emissions by about 45% by 2050.

53 Romania set the target for 2016 at 13.5% of the average final energy use (with a baseline taken from the period 2001-2005) (NEEAP, 2004).

54 Sweden has a long-term target of 20% energy efficiency improvement by 2020. In addition, mid-term targets for reduced final energy use were set for 2010 (6.5%) and 2016 (9%). Another target is within Sweden's 16 objectives for a sustainable environment (set in 1999), whereby one objective outlines the total energy use per unit area heated in dwellings and public/commercial premises: it should be reduced by 20% by 2020 and by 50% 2050 on 1995 levels.

55 Switzerland set the target to reduce greenhouse gas emissions by 20% from 1990 to 2020; in order to reach this target, the energy efficiency action plan (approved in 2008) aims to cut the consumption of fossil fuels by 10% compared with the 2010 level and to cap the electricity consumption growth at 5% between 2010 and 2020.

	Energy demand [$kWh/m^2/year$]		Component U-values [W/m^2K]				Overall U-values[3]	
	Residential	Residential (electric)	Ceiling	Wall	Floor	Windows	Overall	Average
Sweden	110-150 (90-130)[4] (55-75)[5]	55-95 (30-50)[5]	0.13 (0.08)[2]	0.18 (0.1)[2]	0.15 (0.1)[2]	1.3 (1.1)[2]	0.72 (0.4)	0.72 (0.4)
Denmark[1]	52.5+1650/area		0.15	0.20	0.12	1.5	0.77	0.77
Finland	130–180[7] -23-30%[8]		<0.09[6]	<0.17[6]	0.16-017	1.0[6]	-50%[6]	
Romania	125-150[9]		0.2	0.56	0.22	1.3	1.24	1.24
Switzerland	49-68[10, 11] (39-54)[10, 11]	22-28[10]	0.2-0.28[10]	0.2-0.30[10]	0.2-0.30[10]	1.3-1.6[10]	n.a.	n.a.

[1] The values correspond to requirements for renovations; new buildings have lower component U-values, but a more stringent energy performance standard.
[2] The two sets of values correspond to two different ways to calculate compliance, either based on U-values alone or an overall frame value with some maximum U-values.
[3] Overall U-value sums the U-values from the ceiling, walls and floor, and then adds 20% of the window U-value.
[4] Swedish National Board of Housing, Building and Planning - Proposal for revised regulation 2011.
[5] Nearly zero energy buildings, Swedish Energy agency Proposal.
[6] Either the U-value (overall coefficient of heat transfer) of walls and roofs shall decreased 50% or it shall comply with the component-based requirements. Requirements for efficiency of technical systems comprise ventilation and heating, e.g. the heat recovery from exhaust air shall be at least 45% of the heat required for heating the ventilation, new water and sewer systems shall fulfill the requirements of new construction.
[7] The limit for energy consumption depends on the type and use of the building; in the case of hospitals e.g. the value is higher (370 $kWh/m^2/year$). The calculation can be made according to the calculation guidelines given for new buildings in the National Building Code of Finland (Ministry of the Environment, 2012).
[8] The calculation can be made according to the calculation guidelines given for new buildings. The decrease depends on the type and use of the building.
[9] Regarding the energy certification system, classes in EPC are from A (the most efficient) to G (the most energy consuming). Class A in the energy performance certificate (EPC) ranges from 125 kWh/m2yr (heating, domestic hot water -DHW- and lighting) to 150 kWh/m2yr (all energy uses). EPC covers heating, cooling, ventilation, DHW and lighting (these are the "utilities", i.e. energy uses). For a building which has no cooling system and no mechanical ventilation system, the energy use class A is below 125 kWh/m2/yr. These values are not actually imposed as a minimum requirement for new buildings since there is no requirement for final and primary energy in Romania.
[10] SIA 380/1 (2009) Thermische Energie im Hochbau (range for U-value requirements)
[11] INSPIRE-tool

Table 27: Building standards in Denmark, Finland, Romania, Sweden and Switzerland

Economic incentives are present in all five countries: grants, subsidies and funds are available in each country, albeit only in Denmark and Romania with special focus on existing buildings. In addition, with the exception of Romania, each country has additional economic instruments to support energy renovations. Successful economic instruments are the energy utilities' obligation (Denmark), the Energy Audit Programme (Finland), the technology procurement (Sweden) and the former Climate Cent Foundation, now Buildings Programme (Switzerland). The National Buildings Rehabilitation Programme (Romania), due to the changing co-financing conditions, was assessed to be a failure.

Among the informative instruments, the web-based information sharing system (Omataloyhtiö.fi) among housing association managers in Finland seems to be a successful strategy for overcoming the lack of experience of housing associations in renovation measures, lack of information and workmanship, and the different values on energy efficient and cost-effective renovation measures. In addition, the further improvement and enforcement of Building Service Manuals (Finland) has a great potential to contribute to continuity in learning in energy renovations.

In terms of voluntary initiatives and agreements, buyer groups of housing associations, for instance Bebo (Sweden) and technology procurements are considered to be successful tools for learning and networking among different actors involved in energy renovation processes.

3.5.2 Similarities and differences in the role of municipalities

The roles of municipalities differ from one country to another. In the following, these differences are discussed, not as much in terms of traditional roles as in terms of how best practice examples and experiences can serve as inspiration and a source of learning to other municipalities.

In the five countries included, the municipalities only have a limited tradition of influencing energy efficient renovations in private housing. In all the countries involved, the authorities have less power when it comes to introducing energy renovations compared to setting demands for new buildings. Due to the climate challenges and the increasing energy prices, and social responsibilities (e.g. job creation) the roles of the more proactive municipalities are now changing. When the municipalities do not have the normative regulation to secure energy renovations, which means do they then apply?

Strategic climate goals

In Zürich, Tampere, and Frederikshavn, the municipality has set a strategic target for reducing the CO_2-emissions of the entire municipality, and these targets go beyond the national or federal targets. Energy renovations are one of the means of reaching these targets. In Tampere, the energy saving program started in 1995; thus, it has been going on for quite some time, whereas the initiatives in the other countries are more recent. In Sweden, the role of municipalities in the energy area has been present for a longer period and has increased, which is seen in case of the example of Malmö. In Zürich, the Minergie standard of both new houses and retrofit of houses gives guideline for the required level of renovation needed to fulfil the standard. The Minergie standard gives guidance and milestones to reduce energy consumption.

“Getting on the map”

For some municipalities, energy renovations have a more strategic meaning than “just” saved energy. Being an attractive municipality is another driver for, e.g., Frederikshavn, which is situated in an area experiencing a general depopulation. Malmö also finds that energy renovations can be a driver to support business with an environmental profile advancing the local economy and the international profile of the city. The municipality of Middelfart has placed green growth high on the agenda and sees it as a very important aspect of the initiatives in reducing the energy consumption. These municipalities emphasize putting the city on the map by promoting pioneering initiatives.

Promoting local investments and securing jobs

In Sweden and Denmark, one driver behind the increased energy renovation is the creation of a dynamic business environment that can help to promote economic growth and job creation. For Malmö in Sweden and for Frederikshavn and Middelfart in Denmark, energy renovations are also a matter of local employment. Since energy renovations are often done by local manpower, an extensive renovation program has the capacity of reducing the unemployment rate in the municipality. In the context of the recent financial crisis, energy renovations have also helped to counteract the increasing unemployment rate in the built environment sector.

Good examples

To facilitate the promotion of energy renovations in general, in Zurich stringent targets have been set for the municipality's own buildings. Similarly in Tampere, Frederikshavn and Middelfart, the idea is that, through the renovation of the municipality's own building stock, the municipality provides a practical example inspiring the private building owners to apply energy renovations as well. At the same time, the municipalities invest in capacity building on energy renovations among built environment professionals and other craftsmen in the local area, and secure the possibilities of further education on energy renovation among the building professionals. Malmö, for example, has started a large renovation project of 800 apartments from the Swedish "million-program" the project aims to explore a new financing mechanism for renovations ("Bygga-Om-Dialogen") by involving various stakeholders, such as insurance companies and unemployment services.

Information and Research

Both in Zürich and Tampere, initiatives are taken in informing the inhabitants how to do energy renovations, and the municipalities administrate funds for renovation processes that can help to speed up the renovation of buildings.

Zürich and Frederikshavn have both initiated research programs to accelerate building renovation. Frederikshavn has also initiated a research program involving, e.g., Aalborg University in order to develop the local energy systems, but also to discuss potentials and local possibilities of energy production and saving. The municipality has also contributed to draft a booklet describing important aspects of energy renovations for households, which is diffused through the internet. Research and development, as well as learning from previous experiences, are hence important aspects in the municipal level helping to create better solutions and knowledge on the potential initiatives. Malmö has made different types of renovation projects that involve huge areas of privately owned apartments. One of the outcomes of this big initiative is a business model and a concept for ecological renovations in privately owned housing. Timisoara has made initiatives in the renovation of historical buildings, focusing on long-term savings in these buildings.

Barriers to the promotion of energy renovations

Some of the main barriers experienced by these proactive municipalities are related to economy. Even though the life cycle cost is often reduced through the energy renovations, the short-term costs increase and the longer payback time can be a barrier to energy renovation. Often shorter payback time initiatives are chosen instead. It's generally easier to put demand on new buildings compared to renovation of private buildings.

Another common barrier is historical buildings, in which the energy renovations can become very expensive, if not impossible, due to the architectural demands of the historical buildings, which, especially in Zurich, is an issue.

Table 28 provides a brief summary of the differences and similarities of the municipal actions investigated in the frame of this project.

	Denmark	Finland	Romania	Sweden	Switzerland
Strategic climate goals	More ambitious targets than the national ones	More ambitious targets than the national ones			More ambitious targets than the national ones
Getting on the map	Driving force (national)	Driving force (international)		Driving force (international)	
Promoting local investments and securing jobs	Main target of renovations			Main target of renovations	
Good examples	- Targets for municipal buildings - Capacity building of professionals	- Targets for municipal buildings - Capacity building of professionals	Long-term savings in historical buildings	Business model development for renovations	Targets for municipal buildings
Information and research	- Educating inhabitants - University involvement	Educating inhabitants	Long-term savings in historical buildings	Business model development for renovations	- Educating inhabitants - University involvement
Barriers to the promotion of energy renovations	Economic (long payback periods)	Economic (long payback periods)	- Economic (long payback periods) - Historical building stock	Economic (long payback periods)	- Economic (long payback periods) - Historical building stock

Table 28: Municipal initiatives in Denmark, Finland, Romania, Sweden and Switzerland

3.5.3 The role of actors and networking in energy retrofits of buildings

The fragmentation of roles and of a lack of coordination in the value chain and processes behind energy retrofits are important issues for the initiation and implementation of retrofits projects. For example, in order to facilitate access to energy saving solutions, there have been suggestions about the need (and opportunity) for new market players to offer a single point of access or function as “system integrators” in renovation projects and of potential business models for "one-stop-shops" which may offer house owners a single point of entrance into renovation projects (World Business Council on Sustainable Development (WBCSD), 2009; Tommerup *et al*., 2010; Vanhoutteghem *et al*., 2011). Such one-stop-shops are supposedly aimed at facilitating the adoption of retrofits project by building owners. What is sure is that the extensive energy retrofits of the building stock according to EU and national goals is a societal challenge and as such needs the involvement of all actors which are part of the renovations value chain and processes (Killip, 2011).

In Denmark for example, as part of the process to create a more active involvement in the society and markets, in some municipalities there have been instances witnessing the creation of networks to address the fragmentation among different actors involved with retrofitting. These networks are mainly composed by built environment professionals, sometimes on the impulse of municipalities, and among their aims is the facilitation of the adoption and implementation of energy retrofits project by house owners.

The complex and long value chain requires the involvement of many actors and it is important that each actor carries out renovations (both from the point of view of physical changes and from the point of view of managing the process) in a correct way. Retrofitting projects carried out improperly not only increase costs but also create lock-in effects that make further retrofit more expensive and less efficient (Killip, 2011). For example, once households invest in suboptimal energy efficiency technology they will feel hindered to change it before a long period of time. Conversely, the replacement of technological solutions before the end of their life-time destroys capital and is cost-inefficient from both a private and a societal point of view. Furthermore, energy retrofits vary according to building typology and climate conditions, thus capacity needs to be created at local level, according to amongst others weather conditions, financing, policies institutional frameworks and construction practices.

Actors in the value chain can also influence the rate of adoption of energy retrofits as well as the nature of the solutions adopted. There is also an on-going discussion regarding the drivers behind the possible involvement of financial actors (Lützkendorf et al., 2011) as well as about financial guarantees to avoid the risk of energy retrofits. In Denmark, there are instances where banks begin to act as a coordinating actor putting together different players in the market to promote the uptake of energy retrofits projects to their client, although such example is apparently not followed in the other countries examined in this study (Maneschi, 2012).

However, while investigations about institutional and economic factors, determinants of decision making, as well as evaluations of regulatory and economic policy instruments are relatively common (see, e.g. Beerepoot and Beerepoot, 2007; International Energy Agency, 2008; Ryghaug and Sørensen, 2009; Nicol, 2011; Weiss *et al*., 2012), there seems to have been less research regarding how actors' initiatives and creativity may contribute to policy goals as well as their drivers and motivations behind their activity. It is on the other side increasingly recognized that the organizations and individuals taking part in the renovation process are pivotal in achieving energy efficiency policy goals. Beside this, the importance of spreading knowledge and best practice also depends on the fact that knowledge and practices are shared and spread among actors operating in the same sector. From this perspective, actors' networking and involvement can be seen as a way to raise performance standards.

This not only descends logically from the fact that supply side actors are often in charge of the practical implementation of new technical solutions. The role of these actors comes to importance with relation to their capacity of influencing practices of other professionals they relate with, thus contributing to the diffusion of new practices which can favor sustainability in the built environment (Howells, 2006). These actors have also a positive impact on the determination of consumers' demand for sustainable solutions, either by identifying intervention points, by championing certain approaches or by diffusing knowledge about measures to reduce environmental impact (Bessant and Rush, 1995; Howells, 2006). When relating to users, it emerges from the case studies in this report that consideration of users' needs, practices and requirements is increasingly becoming a focus point in the action of municipalities and seems to go hand-in-hand with innovative approaches. This applies not only to the implementation and utilization phases but also and more importantly to the phases preceding implementation, especially persuasion and decision, like in the cases of Frederikshavn and Zurich. Shortly put, there is an increasing need to understand all aspects of buildings, from the technical aspects to how users and customers use and perceive the building. In relation to this, the Danish case studies show two examples of practical initiative aimed at brokering knowledge among actors and marketing.

Another important aspect, beside the increasing relevance of non-technical skills (e.g. "soft" skills such as negotiation and marketing) is also the fact that several initiatives originate from local communities, in a context where the local authorities play a leading role. It is also a further instance of built environment professionals orientating their attention to users' requirements and needs, not only regarding the type of services offered but also how such services are delivered, i.e. by increasing the quality of the supply. Especially in the Danish context, the impulse of municipalities is an important driving force to many programs for the reduction of energy consumption in buildings, together with a focus on creating local jobs through increasing the training and coordination of professionals. In these cases, the local policy goals of employment and energy use reduction or climate change mitigation are both drivers behind this kind of initiatives. The role of the municipalities in the networks consists mainly in giving guidance for the building's owners to gain trust in connection to the planning and execution of energy retrofits. It has been pointed out that there is more trust in initiatives with the municipality supporting the networks (Strandgaard, 2012; Maneschi et al., 2013).

According to the program managers in Frederiskhavn, the interdisciplinary collaboration among various craftsmen has helped to widen their horizon and to be more aware of other discipline's focus points in energy retrofits and not just about the domain of their single specialty, thus aligning skills and practices with the local and national policy goals.

In other countries there have also been similar initiatives to coordinate the action of value chain actors involved in the planning and execution of energy retrofits. In Sweden the Swedish Passive house network is an example, as well as the network of Finnish real estate managers. This kind of programs can be considered as innovative solutions to promote energy retrofits that go beyond traditional policy instruments and also try to address the barriers regarding retrofits as a whole, and not focusing on a single barrier.

In the Romanian case there was a wide use of information initiatives like workshops and training for capacity building. The goals of these initiatives included the rehabilitation of urban infrastructure and improving urban services, including urban public transport, increasing the focus on sustainable development for business and the rehabilitation of social infrastructure, including multi-family housing and / or social and improvement of social services.

From a policy point of view, it can be noted how policy-making has been mainly focused on programmes to promote sustainable consumption in the built environment (especially with regard to energy efficiency). The case studies hint the importance and the potential of more focus on practices in the supply side. This insights call for an increased focus on the role and practices of actors, both in research and in policy programmes, especially with regard to communication, marketing, follow up and monitoring. It is also interesting to note instances of inclusion of education and research institutions as part of the networks to promote energy renovations.

3.5.4 The role of policies in knowledge development and learning

Actors and networking and the knowledge development and learning among them are the key components of innovation processes and thus the dissemination of good renovation practices. Hereby, we have highlighted some policy initiatives which support innovation in energy renovations.

Policy initiatives and strategies for learning

The number of policy initiatives promoting knowledge development and learning is increasing in all five countries. To support the progressive building codes, the Knowledge Centre for Energy Savings in Buildings was established and has been highlighted as a good platform providing trainings and information to building professionals, i.e. tradesmen, advisors, enterprises in the building sector (Denmark). Another tool supporting building codes are the building service manuals (Finland) managed by real estate companies; these manuals and the responsible actor group are considered to be of high importance as knowledge holders establishing the base for continuity in learning. On a local level, network of craftsmen, supported by municipalities has been noted as very effective tool to intensify learning in renovation processes (Denmark). In addition, the network of Local Energy Advisors (Sweden), supported by the Swedish Energy Agency, contributes to moderately increasing awareness raising on energy efficiency issues. Web-based information sharing tools, such as Omataloyhtiö.fi, have been shown to be successfully and increasingly supporting learning among housing associations (Finland). These tools might require upfront investments (e.g. governmental funding) before gaining independency and starting to be business-interest driven. Voluntary programmes, such as the Energy Environment Expert Programme (Finland) - whereby residents are educated as and educate each other to be energy experts - show modest success without additional funding involved. Other voluntary programmes, such as the Living Building Dialogue (Sweden) or the EnergieSchweiz (Switzerland) have reached learning on a broader level among more and more various actors involved in the construction process. Technology procurement programmes (BeBo, BeLok), pulling together buyers and other actors, further contribute to network building and knowledge dissemination in the renovation arena (Sweden).

Policy evaluations for learning

Policy evaluations, in general, do not have a long history and strategic approach on how to improve learning in these countries. Typically, evaluations are sporadic with focus on single policy instruments. Denmark, for instance, has a somewhat stronger tradition in evaluations (e.g. Bach et al., 2004; Dyhr-Mikkelsen et al., 2005) and also a more holistic approach including multiple policy instruments and overall climate mitigation efforts at a time (Energy Analysis, Niras, RUC and 4-Fact, 2008a and 2008b). Finland has also recently carried out in-depth evaluations related to buildings; one focuses on possible energy savings and GHG emission reductions of the 2010 and anticipated reductions of the 2013 building regulations, including estimates for the renovation of existing buildings (McCormick, Neij, 2009). In Sweden, there is no strategic evaluation approach in place with a holistic view focusing on the promotion of learning in renovation processes. In Switzerland, both quantitative and qualitative policy evaluations exist, albeit more focus on specific programmes than policy mixes. In general, it can be concluded that the focus of evaluations is on cost-effectiveness and economic efficiency and less focus is given to innovation effects and learning. A holistic view, and a regular and comprehensive approach is needed in policy evaluations in order to improve the policy-making process.

3.6 Concluding remarks for the chapter

Policy intervention has got an increasingly important role in energy efficient renovations. Recent building codes are gradually including binding requirements for renovations and besides the traditional grant and tax incentive schemes, additional economic instruments appear in the policy landscape, such as energy utility obligations, to further support energy renovations. Information tools and voluntary agreements, although with varying results, but seem to be commonly used instruments.

The role of municipalities regarding sustainable development and climate mitigation as well as energy efficiency and sustainable buildings is gradually increasing; the selected best practices show various municipal commitments and ambitious targets towards “a better future”. The main drivers are highly context-dependent, some drivers, however, common to the selected cases, include climate mitigation, energy and cost saving, energy security, forerunner position, promoting local economies and job creation. These municipal best practices often serve as a source of inspiration and intense learning processes among municipalities both on a national and international level, for exploring and expanding the potential roles of local authorities in the field of energy efficient renovations.

The complexity of energy renovations, including multiple factors and actors, calls for strategies and policies promoting learning and networking for advanced knowledge and knowledge exchange as well as improved processes and interaction. Over the long term these processes require different types of policy instruments promoting learning at different stages. In addition, the choice of instruments and strategies also requires knowledge and constant evaluation. Evaluations are presently scarce; more and more strategic evaluations are needed to understand how to improve learning and the dissemination of best practices in energy renovation.

4 Case studies of sustainable renovation

In this Chapter 4 selected case studies are presented, which are thought to be relevant for the building stock of the countries where they are located. The cases were selected to exemplify the constraints faced by professionals when renovating buildings designed with different priorities and requirements than the ones used today.

Overview on the selected cases

All the buildings types are mostly used as residential buildings in the countries where they are located, but the Danish case study functions as a hotel. In all cases, the owners of the projects started the renovation with more general focus in mind than energy saving targets, but quite advanced energy renovation measures have been implemented during the process. Table 29 summarizes the main functional parameters of the buildings before the renovation started.

	Area (m^2)	Use & Ownership	Heating method	Annual (standard) HDD (18.3°C baseline) [56]	Building envelope	Energy consumption ($kWh/m^2/a$)	Est. cost of heating ($Euro/m^2$)
Romania	1 427	Residential Owner occupied	District heating	2 924	Prefabricated reinforced concrete	339	13 / 21[57]
Denmark	1 271	Hotel Private	Oil & direct electric	3 653	Timber framed cavity walls	317	
Sweden	14 860	Residential Municipality owned Rental	District heating	4 193	In-situ reinforced concrete & timber framed infill walls	216	19.5
Switzer-land	2 0971	Residential, City of Zurich	Two gas heating systems	2 976	Plastered 32 cm brick massive construction wall, not insulated	117	30

Table 29 Situation of the buildings before retrofit.

4.1 Methods

The selection of examples and data collected on each case study was aiming to form a holistic view on the retrofit process in the target countries. The case studies are intend for

[56] For Timisoara, Copenhagen, Goteborg & Geneva; US Dep. of Energy Weather data - http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm

[57] http://www.anrsc.ro/ - Sometimes subsidized price to customer was between 160-338 Lei/GCal (weighted average 202 Lei/GCal). Agreed price at delivery point weighted average 329 Lei/GCal (244-519 Lei/GCal). The values lead to costs of 13 or 21 Euro/m^2/Year, depending on considering or not the subsidies.

scrutinizing the suitability in real life applications of conclusions from Chapters 2 on cost-optimal choices of retrofit, and Chapter 3 on the expected impact of actors and policy instruments. Hence, it was important to select case studies independent of the project itself, and grounded in everyday industrial practice in the targeted countries. The intention was to observe the retrofit case from outside, not to be part of it.

The criteria to select the cases were:

- Represent a statistically relevant building typology in the country of question;
- The retrofit aims should focus at improving the energy efficiency of the buildings;
- The retrofit should be considered ambitious and forward looking, in its own country setting;
- The renovation should be at least started, but better finished, so that not only design plans but also post renovation monitoring results are available;
- The project team should have access to data on the case study, but also possibility to conduct interviews with the key stakeholder;

The core data collected on the case studies were focused around:

- A detailed technical description, and a description of the conditions of current use for the building (including conditions of ownership);
- An inventory, and technical details of the work carried out in the renovation process;
- Details about costs of the different renovation interventions, including cost benefit estimates by the developer;
- A discussion on the drivers for the renovation and the targets set by the investor/owner, based on interviews/discussions or published material on the case study;
- The future renovation plans of the owners;
- The type of benefits other than targets of energy efficiency and their relative importance in the decision process of the case;

It is worth mentioning that, in all cases the trigger for the renovation was something else than energy savings. Usual reasons were some technical deficiency, degraded state of the building envelope, inadequate indoor comfort or accessibility needs of the occupants. The Danish case is focused mostly on energy improvements, but the other cases heavily involve improvements of social targets related to the occupants' wellbeing. Hence, in some of the cases calling non-energy saving targets “co-benefits”, as is done in this work, may be questionable. They are instead the main drivers of the renovation, and once they kicked-off the process, the projects are geared towards energy efficiency targets by the stakeholders.

The case studies are not intended to be compared with each other. Such comparison would yield no benefits because of the diversity of building configurations, uses, ownership models and country settings. The only valid evaluation can be done by comparing the case study as realized in reality, with the more abstract considerations of Chapters 2 and 3.

4.2 Energy renovation of Hotel Sanden Bjerggaard, North Jutland

This case is an energy renovation process at the Hotel Sanden Bjerggaard in the Northern part of Jutland.[58] The hotel is a former private mansion and was initially built in 1918 and expanded in 1968 and 1985. The hotel has 23 rooms of different sizes, a restaurant and several other meeting rooms and conference facilities for 80 persons. There are 7 employees including the hotel manager. The building was originally a summer residence, and was later converted into a hotel. It has been used as a conference facility since 1994.

The hotel is a typical example of a Danish building from the beginning of the 20st century (Danish Statistics, 2011). Like most of the Danish buildings, it is a detached house; around 7 out of 10 Danes live in detached housing, and the same applies to most hotels and restaurants. In Denmark more than 90% of the detached houses are owned by those using them (Danish Statistics, 2011). Although it makes sense to take into consideration this building with regards to the Danish building stock, the only caveat is that this is not an owner-occupied building but a small commercial building. Beside this, and to some degree the size of the house, the house can be reasonably considered as an average detached residential building in Denmark.

Figure 13: Entrance of the hotel

[58] The case description builds on data from interview and data provided by the building owners and other involved partners.

The building is a brick construction with a tile roof which is typical for Danish houses and, before the energy renovation, the windows were double-glazed. The walls are cavity walls and, like many cases from this period, the cavity wall insulation has decomposed and is not efficient anymore.

No thorough renovation has been made for more than 30 years, as only the most needed renovation has been implemented. This means that the buildings, like a big part of the Danish building stock, need renovation within the next decade (Bygherreforeningen, 2012). The huge need for renovations has two main explanations. First, the relative old buildings, constructed before 1960, are made from materials with a long lifespan. At the same time, buildings built more recently, after 1960, are made from materials with a shorter lifespan (Bygherreforeningen, 2012). Thereby, the need for renovations in general and the potential for also doing energy renovations are large in the decades to come.

Parameter	Amount
Number of floors	1-2 (a smaller part of the hotel only have one floor)
Ground floor	771 m^2
Total size of hotel	1271 m^2
Estimated area of windows	150 m^2
Energy consumption of electricity in 2007	204 507 kWh ~ 147 245 DKK (19 738 €)
Energy consumption of fuel oil in 2007	17 167 liters ~ 171 670 kWh ~ 120 179 DKK (16 110 €)
Consumption of hot utility water	42 442 kWh /year
Occupancy	1949 rebuild in 1968 and 1985

Table 30: Technical data for the hotel.

The energy renovation performed at Hotel Sanden Bjerggaard involves a wide variety of initiatives and serves as a good example of energy renovations of old houses which have not had thorough renovation for a longer period. The example is, however, more wide-ranging than most energy renovations in this type of buildings, as the investment costs are high. One of the new installation initiatives is the test of a Danfoss Link CC controller giving the possibility of individual temperature regulation in each room of the hotel (Danfoss 2012). This technology has not been implemented in a building of this size before, which means that the producer is interested in following the consumption after the installation of this technology in which several systems work together.

Figure 14: Ground floor of the hotel.

The renovation was initiated in 2008 when it was observed that the electrical water boiler that provides hot water to most of the hotel was leaking and needed to be replaced. At this point, the hotel manager considered to implement a new electrical water boiler. However, the manager and the board decided that a more thorough energy optimization of the whole hotel was needed. An entrepreneur was contacted to suggest initiatives in order to optimize the overall energy efficiency. The goal of the energy renovation is two-fold, both to reduce the environmental impact from the use of energy and to achieve economic savings caused by the increased energy efficiency. The old oil burner was installed in 1953; it produced heat and hot water to the part of the hotel not heated by electricity. The yearly oil consumption was around 15 500 liters. The system was relatively inefficient and, e.g., the cellar with the old burner always had a room temperature around 35 degrees Celsius. In 2007 (which was not a special cold year), the energy consumption of the hotel was 317 kWh/m^2. Of this, around 60% was provided by electricity and 40% from the oil burner. This level is higher than an average consumption of a hotel from this period (Möller 2010). The annual expenditures on energy of the hotel are 400 000 DKK, around 53 600 EUR.

Work carried out in the renovation process

The process of the energy renovation of the hotel has been divided into 6 larger investments. The following describes each of the initiatives and the estimated savings.

The first focus area is the building envelope involving both cavity insulation and the replacement of old windows:

- Cavity wall insulation was renewed for 270 m^2 of the buildings, giving an estimated total energy reduction of 14 850 kWh/year (55 kWh/m^2).
- 16.9 m^2 of double-glazed windows were replaced with new class triple-glazed with a U-value of 0.85 W/m^2*K.
- 3 m^2 of double-glazed windows were replaced with new double-glazed with a U-value of 1.23 W/m^2*K.

— 1.8 m^2 of single-glazed windows were replaced with new double-glazed with a U-value of 1.23 W/m^2*K.

The total annual saving achieved by these initiatives in the building envelope is estimated at 19 151 kWh.

The second focus area is the control of hot water circulation according to the needs. The control of the water flow for the bathroom facilities is implemented. Motion sensors have been installed in the bathrooms. The control is timed and stops the water flow to the room 5 minutes after the room is left, which has reduced the previous constant flow of water to only flow in use. The water flow is 50 °C and the return temperature is 40 °C. Estimations are made on the potential savings. In the assessments, it is assumed that 35 % of the rooms are occupied in average and that there is detection activity in each room 5 hours a day. On these assumptions, the expected reduction in the energy consumption for hot water is around 90 %; this means that the energy use for heating hot water is reduced to 10% of the initial use, only due to the huge reduction in pipe losses. However, there will still be energy consumption due to cleaning and this gives a slightly higher consumption than the above. The previous consumption was 42 442 kWh/year. The consumption of hot utility water is based on assumption that it accounts for around 25 % of the former energy consumption from the oil boiler. In the part of the building heated by electricity the hot utility water accounts for around 20 % of the total electricity consumption (measured data). The new system is expected to give a reduction of 85 % of the energy consumption, reducing it to 6 480 kWh/year.

The third investment is changes in the ventilation of the rooms. New exhaust devices were installed in 13 bathrooms. The exhaustion ventilator has been changed from a 350 W ventilation unit to a 200 W unit. The previous working time was 17.5 hours/day, as it was only turned off when the hotel was not in use at all. This is now reduced to 2 hours a day, since it is coupled to the motion sensors described in the previous section.

The fourth initiative is a replacement of the oil boiler with a new smaller condensing oil boiler and a 16kW heat pump. The previous consumption was 15 500 liters of oil estimated at 155 000 kWh. The installation of the first 16 kW Queen VV DC heat pumps together with installation of a new 35 kW oil boiler will give an expected saving of 81 132 kWh in total. These savings requires that investment on the building envelope and changes in the circulation pump.

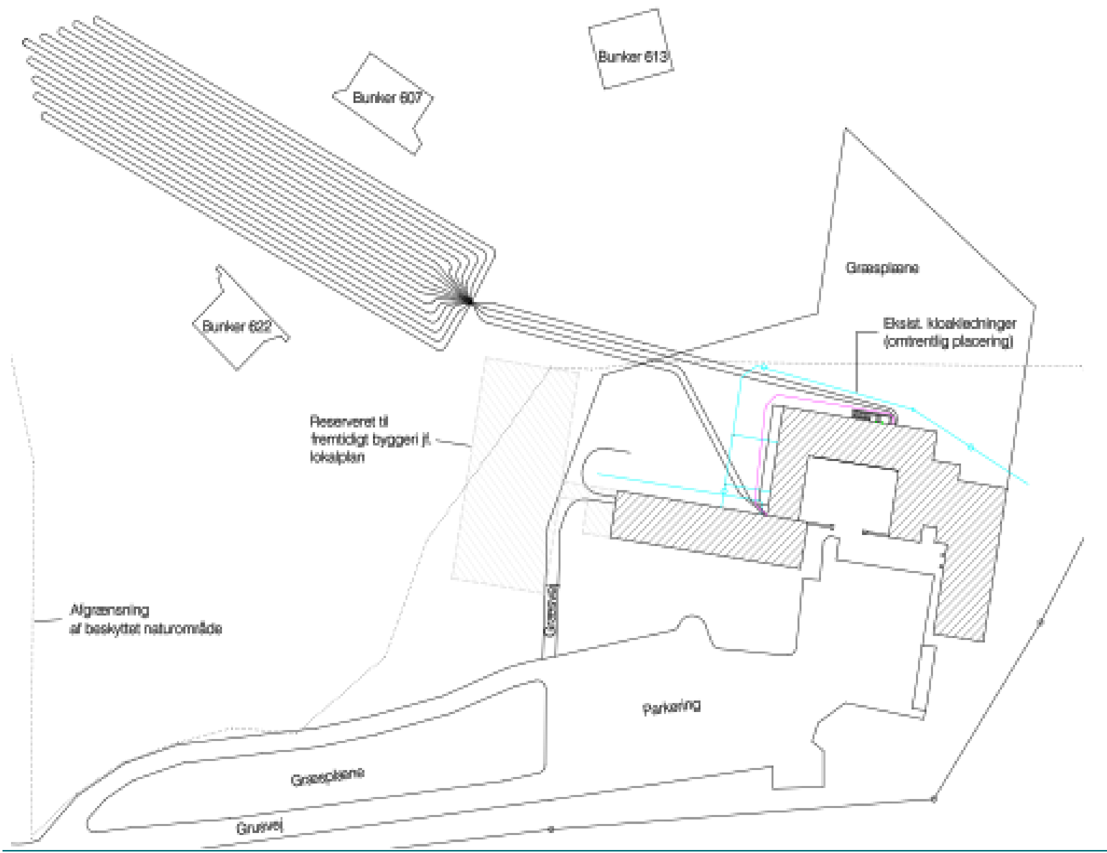


Figure 15: Plan for the pipes of the heat pump (Pretzmann 2011).

The fifth initiative is the installation of a ground source heat pump. The heat pump is a 16 kW Queen VV DC. 13 of the rooms that previously had electric heating are now heated by the heat pumps. The energy consumption for the heat pump is estimated to be 38 397 kWh. Through the change of heat supply and the other initiatives, the future consumption for heating is expected to be 26 932 kWh. This initiative was one of the hardest to implement, both due to the lack of experiences with this types of (quite large) heat pumps among the workmen, but also due to the municipality rejecting the project several times as the Hotel is situated in a protected area. Putting the pipes for the heat pump into the ground constitutes a potential risk of environmental hazards. In the end, a solution was made in which the pipes were placed under a grass lawn and a parking area, and the municipality approved the project (Figure 15).

The last initiative is a control system that monitors and controls the heat consumption in 90% of the area of the hotel. The control system gives the possibility of setting the temperature in each individual room for two weeks at the time (changes in room temperature can be changed several times a day in this period). By having remote control of the temperature in the rooms, it is possible to reduce the temperature when the individual room is vacant, but still allowing it to have a comfort temperature before the next guest arrives. This is done through remote control of thermostats. The investment is expected to give savings of 5 417 kWh/year. The total savings in the different initiatives are shown in Table 31..

Initiative	Energy savings (kWh/year)	Investment costs (DKK)	Investment costs (kEuros)
Improved building envelope	19.2	188 860	25.3
Operation of utility water circulation	36.0	84 728	11.4
Changed ventilation in bathrooms	13.6	63 665	8.5
New oil boiler and heat pump	81.1	367 923	49.3
Converting from electrical heat to heat pump in part of the building	11.6	443 943	59.5
Remote control of the heat installations	5.4	60 932	8.2
Total	166.9	1 210 051	162.2

Table 31: Savings of the initiatives

As the heat pump was installed in the spring of 2012, there are no measured data on the energy consumption in a Danish winter; therefore, the figures are estimates. Since the installation in the spring, the estimated savings for the summer months have been met. The valuation of the house is 4 150 000 DKK (556 330 €) (Skat, 2012) giving 29.16 % cost of the total value.

Costs

The financial investment of the project was one of the main obstacles to initiating the energy renovation. At first, it was a problem to get a loan for investing in the energy renovation, as the hotel industry in Denmark has been influenced by the economic crisis To reduce the risk for the local bank, the hotel applied for a guarantee for the investment through "Vækstfonden", a Danish fund helping to support growth in companies and local areas. The growth fund gives guarantee for up to 75% losses of companies (Vækstfonden, 2012). This made it possible to increase the mortgage provider loan for the hotel. The new loan is a 20-year loan with a low interest rate of less than 2%. The guarantee made it possible for the local bank to finance the loan for the total energy renovation investment of 1.5 million DKK. The assessed annual saving of the energy renovation initiatives is 166 000 DKK at a price of 1 DKK/kWh. This gives a simple payback time of 8.4 years without taking interest and changes in energy prices into account. Because of the 20-year loan with a low interest rate and the simple payback time of 8.4 years, the increased repayment including interests of the hotel is lower than the saving achieved due to the reduced energy consumption.

Drivers for the initiatives and targets

The hotel previously invested in and introduced new initiatives in green investments such as using eco-labeled detergents, sorting waste and introducing good housekeeping among the employees. The hotel manager is interested in having a greener profile of the hotel by investing in energy renovation initiatives. One of the main reasons to have energy renovation is the economic aspect. The investment has a relatively short payback time and can, from an early stage, reduce the total expenditures of the hotel. The reduction in the energy consumption makes the expenditures of the hotel less dependent on changes in the energy prices.

Since the total investment was decided to be maximum 1.5 million DKK, no specific energy performance targets were set, such as specific energy consumption per square meter per year. Instead, calculations were made for a large number of possible initiatives and the combination of technologies with the shortest expected pay-back time was chosen.

Future plans for improving the energy efficiency

The hotel is situated far from other buildings and has several roof surfaces faced towards south and south-east. Due to the installed heat pumps, the electricity consumption of the hotel is relatively high. Calculations show that, with the current electricity prices in Denmark and the current subsidies for producing renewable energy, it is feasible to implement solar panels as a next step in the process. For now, however, it is not possible to get the loan for the investment.

Co-benefits due to the energy renovations

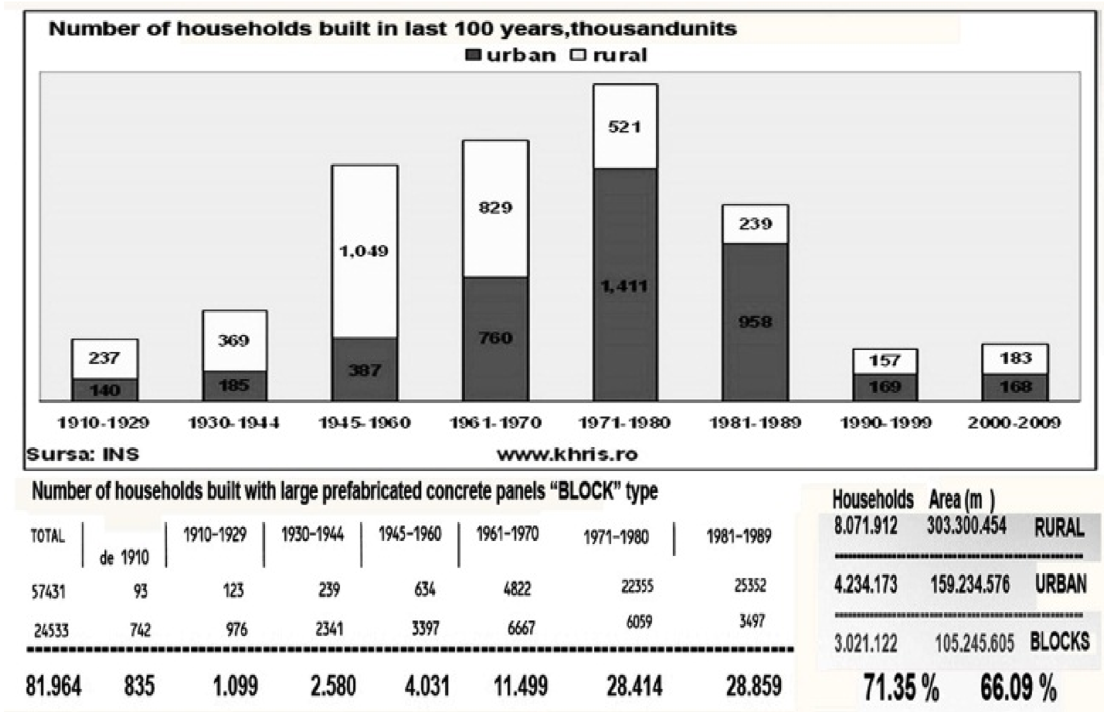
The employees of the hotel have become very aware of the energy consumption of the hotel due to the projects implemented, and this has motivated further savings in, e.g., the kitchen due to changes in practices. Another positive outcome of the investment is the response from both tourist and conference participants living at the hotel. The comfort in the rooms is expected to improve during the winter, as the previous heating system was not always sufficient during the coldest winter months.

Concluding remarks

The energy renovation process has been a lengthy process both in terms of the amount of planning hours put into the process but also due to the number of obstacles. The energy renovation was mainly implemented due to a very determined and engaged hotel manager.

4.3 Sustainable renovation options for the T744R prefabricated concrete panel buildings, Timisoara

According to the Census of Population and Housing of 2011, Romania had about 19.0 million inhabitants. They were living in 8.5 million dwellings with 22.7 million rooms. 52.8% of the population was urban with most multi-apartment buildings concentrated in the urban areas. The number of apartment buildings was around 84000, with 2.5 million apartments. According to the census, over 71% of the existing urban housings were multi-dwellings, covering an inhabitable area of 66% from the total inhabitable area, as shown in Figure 16 (INNSE, 2003).



TOTAL	de 1910	1910-1929	1930-1944	1945-1960	1961-1970	1971-1980	1981-1989
57431	93	123	239	634	4822	22355	25352
24533	742	976	2341	3397	6667	6059	3497
81.964	835	1.099	2.580	4.031	11.499	28.414	28.859

Households	Area (m)	
8.071.912	303.300.454	RURAL
4.234.173	159.234.576	URBAN
3.021.122	105.245.605	BLOCKS
71.35 %	66.09 %	

Figure 16: Statistical data regarding the building stock according to the 2002 census (INSSE, 2003)

From the 57431 prefabricated panel buildings, most have been built between 1960 and 1990. During 1965-1989, 4 million dwellings were built; more than 150 000 each year. The overwhelming majority, 41 540 buildings have 5 floors.

A second group of important typologies are the 9, 10 and 11 floors totaling 9180 buildings. All other configurations total only 7440 buildings, 300 taller than 11 floors, 4920 buildings lower than 5 floors and 2220 buildings having 6, 7 or 8 floors. Practically the two most widely used configurations in Romania are the 5 floors and the tower (9, 10, 11 floors) typologies, with very few other configurations.

Currently, home ownership rate in Romania is close to 95%; dwellings are owner occupied with no outstanding loan. ("…At the same time, Romania has many homes occupied by their owners, with an overwhelming percentage, 98% of total residential space...". Percentage of 98% means that are rented only about 170 000 homes out of almost 8.5 million in Romania. These data show very low flexibility of the labor force in Romania".). The situation in Romania is explainable considering the measures adopted after 1989, of selling the state-owned apartments to the tenants at low prices, including many of the buildings nationalized. The two figures combined show a significant demand for housing coming from young people[59].

[59] http://www.tudorestates.ro/news.php?id=54

Buying with credit is not common or desired choice. Only the young generation is open to enter credit schemes, and even there the reluctance has strengthened, following the hard lessons learned in the 2008-2009 economic crises, when property prices dropped.

As result, a 5 floor prefabricated panel building typology (T744R) is used as case study located in urban areas in Romania. Apartments are privately owned in these buildings, with building being in condominium type ownership. The building is administrated in the typical Home Owner Association (HOA) system.

Description of the T744R block of flats

As shown in previous studies (Botici et al., 2012), the communist period collective buildings were executed in 3 main stages using different typologies of standard projects, due to design improvements, cost efficiency and new state secretes regarding usable area of flats. The collective building housing program stopped suddenly in the 90's, but only after covering significant parts of cities.

The studies conducted on the existing building stock for the city of Timisoara, confirmed the fact that in the period 1962-1990, three different types of projects were mainly used (Botici et al., 2012). In the first period of this urban development, between 1962 and 1975, the most used standard project was "T744R-IPCT" (see Figure.17). It had a densification of 70 buildings/10.000m^2; with distance between buildings approximately 60 meters. Individual flats had relative small living areas and they are simple oriented. Usually, neighborhoods were built near de center of the city. The building is a 5 storey, with a height reaching nearly 14 meters and having internal storey height of 2.60m. The units accommodate 20 apartments, 4 on each floor with a built area of 54 square meters per apartment. Units were usually built attached to each other and they often form continuous street fronts.

Figure.17: ''IPCT" project type T744 R

The structure of these units is entirely made of precast concrete panels assembled on site. These panels were executed on specialized construction sites and transported to the building site. Unit T744R has a longitudinal internal wall made of precast concrete panels, and 6 transversal interior walls. Precast panels in these walls are single layered, using 14 cm thick B250 class reinforced concrete. The staircase is positioned at the middle of the building (see Figure 18).

Figure 18: Current floor of T744R 5 storey block of flats

The exterior enclosure was also from prefabricated concrete panels composed of layers with different functions: the load bearing layer, the thermal insulating layer and protection layer. The thermal insulation layer is placed on the exterior face of the panel and has around 6 cm. The protection layer is made of reinforced concrete of 5 cm thick. ’’T744 IPCT” project type was realized using two mainly types of exterior panels (see Figure 19). Both of the panels had the structural layer of 11 cm thick, made of B250 concrete class. The difference is made on the thermal insulation layer which was changed in the second period from one layer of mineral wool 6 cm thick, to a thermal insulation layer composed of 2.5 cm thick BCA layer and 2.5 cm tick polystyrene layer.

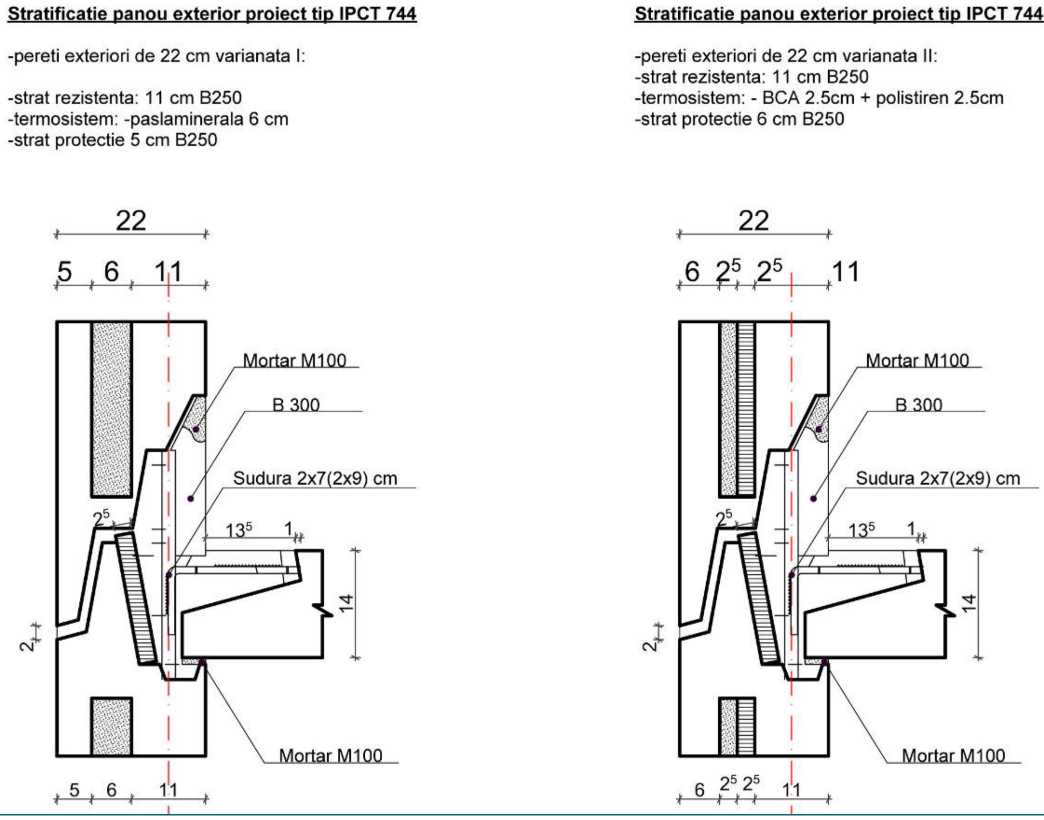


Figure 19: Facade panels of T744R 5 storey block of flats

The roofing was in most cases executed with no special attention for the thermal insulation layer. In most of the cases an 8-14 cm dross/GNB layer was applied. Slab over the basement has no thermal insulation either.

Retrofitting targeting social sustainability by interior space partitioning

The inhabitable areas in the units built before 1975-1982 are fairly small (27-33m^2/apartment) and are built with rigid partitioning walls. From this point of view buildings may require special attention in the reorganization of the interior spaces to fulfill social sustainability expectations (BIT 4/1971 Residential buildings constructions. Technical Informational Journal – in Romanian).

Two possible interventions are presented on typology T744R-IPCT for reconfiguring the areas separated by vertical surfaces. The necessity of making large openings in floors is highlighted from the architectural point of view that allows for the re-design of the interior rigid partitions and also provides multiple options in terms of interior furnishing. Reconfiguring through practicing large openings in the load bearing elements must be done in a coherent way for a whole building, so as not to affect the ability of the structure to bear loads. The final purpose of the study is the analysis of different types of apartment repartitioning, in order to obtain cost-effective, structural and functional solutions that could be integrated into a reliable 3D building matrix (see Figure 20).

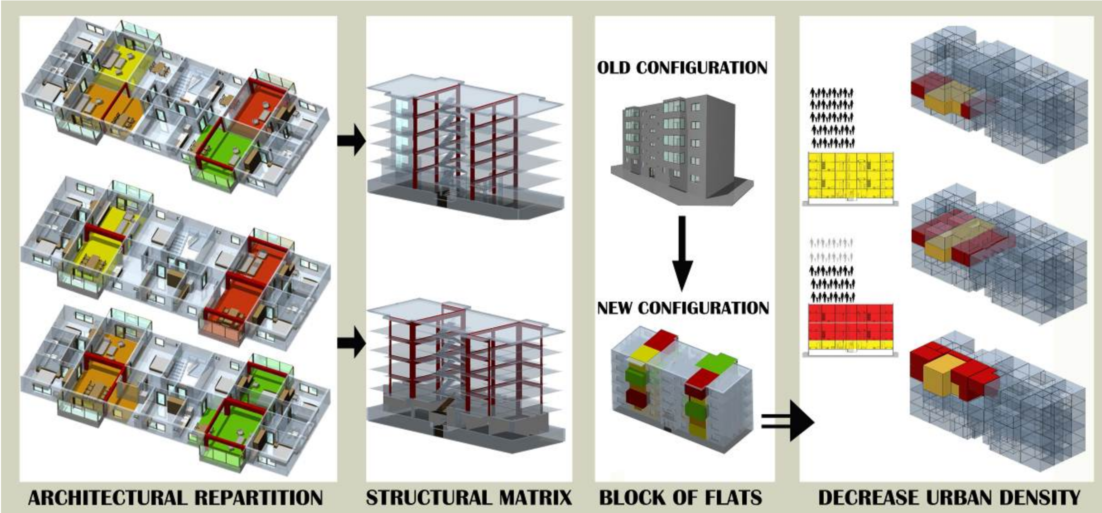


Figure 20: Example of interior partition reconfiguration (Botici et al., 2012)

Besides providing more attractive living spaces in apartments, this type of intervention can rebalance urban areas in terms of density, green zones for residents and can help decongest traffic routes. The possibility of practicing openings in the walls is influenced by the way in which the panels were built. Practically, the creation of openings in the existing walls improves the habitation comfort of the interior space (see Figure 21).

In some cases, by creating openings in the walls and floors, existing apartments can also be coupled, e.g. existing flats expanding through horizontal unification (see Figure 22) or existing flats expanding through vertical unification (see Figure 23).

The pairing of two apartments at the same storey and turning them into one apartment can be considered one of the most efficient methods for creating flats with larger living areas and increased comfort. This kind of intervention needs to be done carefully because it implies the reorganization of interior areas through major interventions on the vertical structural diaphragm walls. A second alternative to create flats with extended living areas on different storey heights and a diverse volumetric interior is by coupling apartments from different levels.

Figure 21: Reconfiguration through replacing walls with steel frames (Botici et al, 2012)

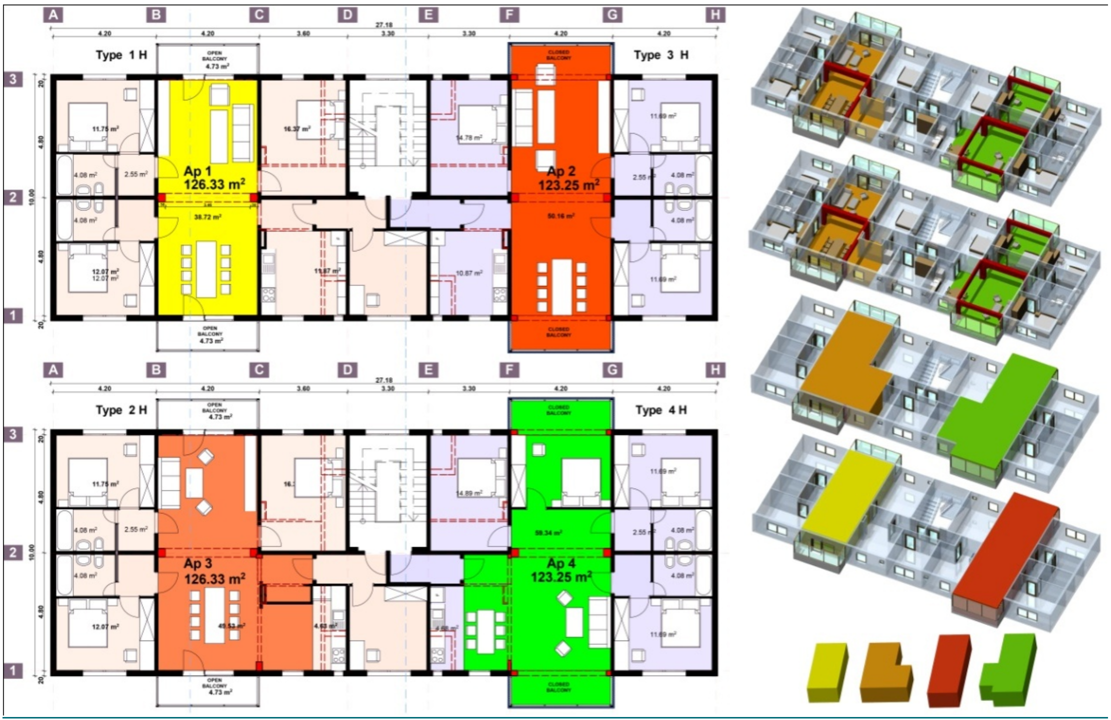


Figure 22: Horizontal reconfiguration – apartment coupling by creating openings in walls (Botici et al., 2012)

Figure 23: Vertical reconfiguration – creating openings in floors

Energy performance of the T744R block of flats

The heat in the form of hot water for domestic purposes and heating, passes through several stages from the moment in which is produced and delivered to the final consumer (flats). Thermal energy, thermal heat, is produced in thermal plants, and transported long distances by transport networks to the consumers home / business address (distribution). Centralized district heating is the cleanest, safest and most efficient heat supply of high density areas with great population. As shown in the “National strategy regarding the supply with thermal power of the municipalities” approved by H.G. 882/2004: "For crowded urban areas with high density of habitation, all national and international studies concluded that in terms of energy efficiency and environment, centralized supply heat is advantageous".

These centralized systems have the same composition as those of high capacity, but have an installed capacity between 20 to 100 MWt, so are at a smaller scale but contain the same number of components of the technological chain. Heat sources generally equipped with hot water boilers and rarely with cogeneration plant with backpressure turbine, which of course work in basic operating system. They are commonly named, centralized systems of thermal power plants of the area.

Timisoara district heating company (DHC), also referred to as SC Colterm SA, is a municipally owned company supplying warm water to residential, commercial and industrial consumers and process steam to some small industrial consumers. It was established in 2003 by merging the two different companies operating on the heat market in Timisoara: SC TermoCET 2002 SA (the heat producer — created by transfer from Termoelectrica to the municipality in 2002) and SC Calor SA (the heat transport and distribution system operator) and it have started to operate from the 1st of January 2004. SC Colterm SA is the operator of the entire district heating system chain in Timisoara: production (CET Timisoara Sud and CET Timisoara Centru), transport and distribution. The district heating system in Timisoara supplies 87 000 apartments, i.e. 70% of total heat demand. The distribution network has been partially refurbished and modernization works are on-going; losses along the network are reasonable (compared to other district heating systems in the country).

The 2000-2007 strategy for Timisoara shows as energy-related priorities the modernization of primary and secondary thermal energy networks, interior installations, thermal plants and units, through the improvement of insulation and fitting of high performance equipment, with a focus on cogeneration. A 30% reduction target is set regarding water and thermal energy losses.

CET Colterm S.A., the district heating company owned by the City of Timisoara, has applied for a loan from the European Bank for Reconstruction and Development for the modernization of the municipal district heating system. The Company completed in 2008 the installation of new gas and steam turbines with hot water recovery boilers for cogeneration of heat and electricity of 19.7 MW gross electricity production and installation of two other units of gas engines for cogeneration.

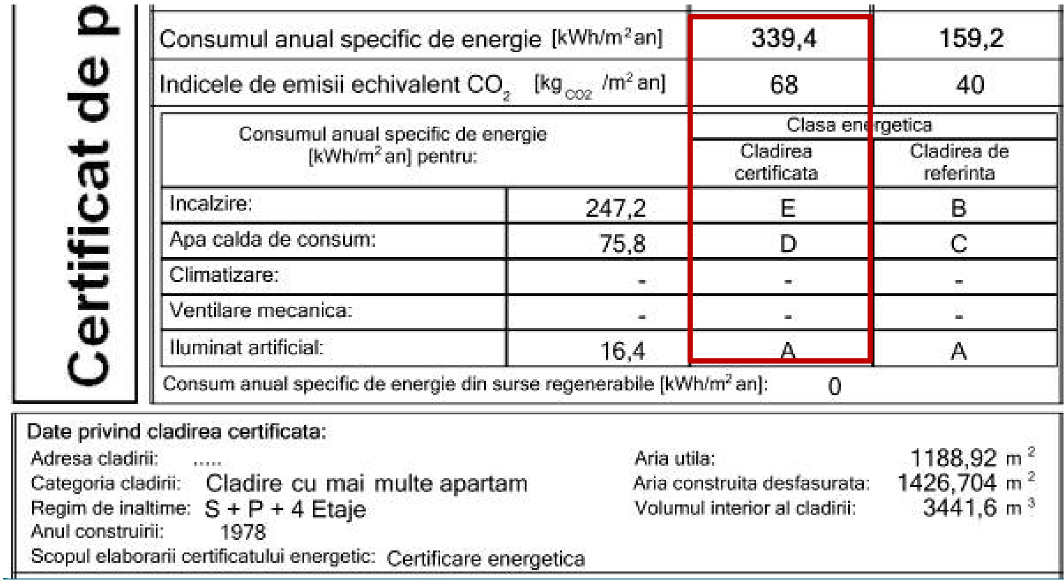
Also in recent years, SC COLTERM SA Timisoara was constantly concerned with rehabilitation of thermal transmission, distribution and supply of heat, so the city heat network in the next years, of a total length of 73 kilometers, will be completely modernized leading to significant reduction in heat loss from the system.

For project type T744R, three energy performance (EP) target levels were studies, each one of them analyzing one of the conditions (Botici et al., 2013):

- EPI – analysis of the existent building as designed, located in Timisoara and having the most disadvantageous orientation considering natural lighting;
- EP II – analysis of the existent building as designed, located in Timisoara and having advantageous orientation considering natural lighting;
- EP III – analysis conducted on the existent building as designed, located in Timisoara, using thermal rehabilitation as used currently in Romania; in accordance to minimal requirements of the design code C-107-2005 (revised in 2010);

The results are completed in order to observe the capacity of reductions for the primary energy demand and greenhouse gas emissions, and how external factors influence the reduction.

Figure 24 presents EP I case. With an annual consumption of 339.4kWh/m^2/year for heating, hot water, and electricity, the basic building is in energy class D. The same building, but in case EP II, advantageous orientation, resulted in 331.7kWh/m^2/year consumption, with all saving sun heating consumption. EP II was computed in order to compare differences for the energy consumption of the same unit in different external conditions. Comparing the energy consumption, it can be observed it is not modified significantly, the difference being approximately 8 kWh/m^2/year.



Certificat de p

Consumul anual specific de energie [kWh/m²an]		339,4	159,2
Indicele de emisii echivalent CO_2 [kg_{CO2} /m² an]		68	40
Consumul anual specific de energie [kWh/m² an] pentru:		Clasa energetica: Cladirea certificata	Cladirea de referinta
Incalzire:	247,2	E	B
Apa calda de consum:	75,8	D	C
Climatizare:	-	-	-
Ventilare mecanica:	-	-	-
Iluminat artificial:	16,4	A	A
Consum anual specific de energie din surse regenerabile [kWh/m² an]: 0			

Date privind cladirea certificata:
Adresa cladirii: .....
Categoria cladirii: Cladire cu mai multe apartam
Regim de inaltime: S + P + 4 Etaje
Anul construirii: 1978
Scopul elaborarii certificatului energetic: Certificare energetica
Aria utila: 1188,92 m²
Aria construita desfasurata: 1426,704 m²
Volumul interior al cladirii: 3441,6 m³

Figure 24: T744R block of flats– EP I case

In Table 32 are shown the values of thermal resistance transfer elements of the building envelope studied and the minimum thermal resistances prescribed by C107/2005 code (revised in 2010).

Building envelope element	Actual thermal resistance (m^2K/W)	Minimum thermal resistance according to C107/2005, updated in 2010 (m^2K/W)
Exterior wall	1,1521	1,80
Basement floor slab	0,398	2,90
Roof terrace	0,596	5,00
Window	0,19	0,77

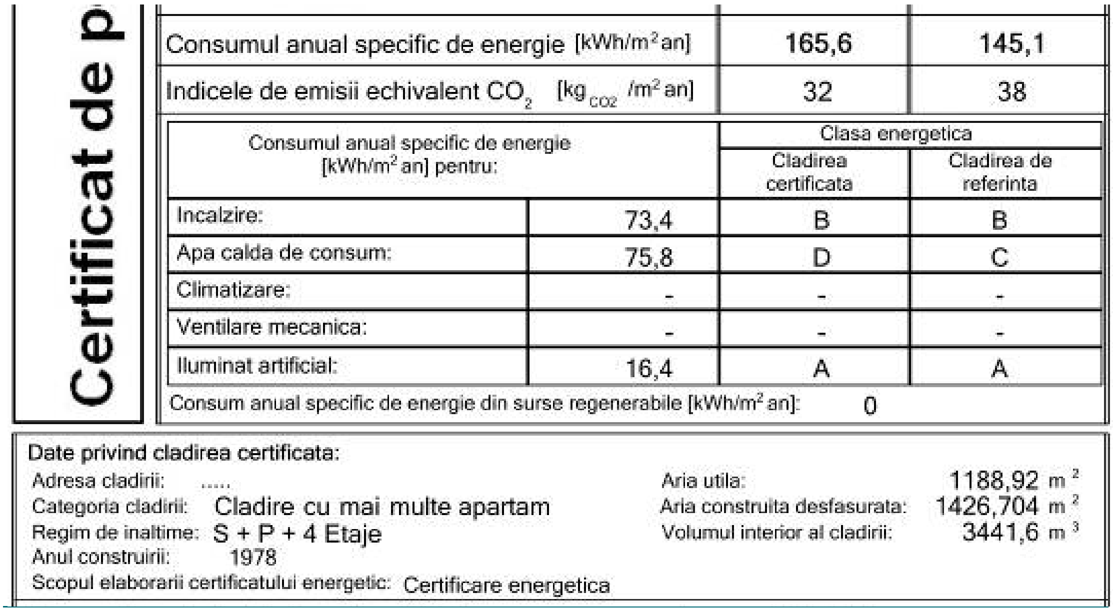
Table 32: Heat transfer resistances

In order to fulfill the minimum heat resistance, according to C107-2005 code, three different solutions of thermal insulation are proposed, and for each of these solutions different thicknesses of insulation layer were analyzed, as shown in Table 33. For the required thicknesses the design code C107-2005 was used.

Polystyrene		Mineral wool		Polyurethane foam	
Required thickness (cm)	Thermal resistance (m^2K/W)	Required thickness (cm)	Thermal resistance (m^2K/W)	Required thickness (cm)	Thermal resistance (m^2K/W)
3	1,833	2	1,827	2	1,985
12	3,125	10	3,1	6	2,898
23	5,3	18	4,974	12	5,096

Table 33: Insulation solutions for minimal of heat transfer requirements

Figure 25 confirms that, after the thermal rehabilitation, the energy-efficiency class is „B" with a consumption of 165.6 kWh/m^2/year], approximately 50% less than in EP I case.



Certificat de p

Consumul anual specific de energie [kWh/m^{2}an]	165,6	145,1
Indicele de emisii echivalent CO_2 [kg_{CO2} /m^2 an]	32	38

Consumul anual specific de energie [kWh/m^2 an] pentru:		Clasa energetica	
		Cladirea certificata	Cladirea de referinta
Incalzire:	73,4	B	B
Apa calda de consum:	75,8	D	C
Climatizare:	-	-	-
Ventilare mecanica:	-	-	-
Iluminat artificial:	16,4	A	A

Consum anual specific de energie din surse regenerabile [kWh/m^2 an]: 0

Date privind cladirea certificata:
Adresa cladirii: .....
Categoria cladirii: Cladire cu mai multe apartam
Regim de inaltime: S + P + 4 Etaje
Anul construirii: 1978
Scopul elaborarii certificatului energetic: Certificare energetica
Aria utila: 1188,92 m^2
Aria construita desfasurata: 1426,704 m^2
Volumul interior al cladirii: 3441,6 m^3

Figure 25: T744R block of flats– EP III case

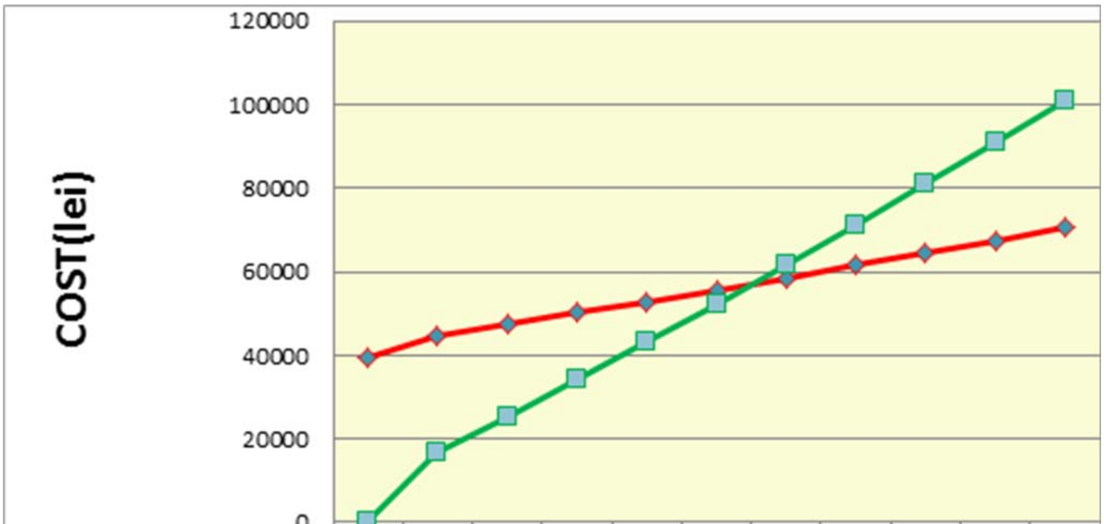
Costs

Figure 4.14 presents a survey and an evaluation of the overall cost for a period of 20 years, a discount rate of 2% and an interest rate of 2% for a rehabilitated block of flats (EP III case). It can be underlined the following differences:

- in the idea that nothing will be invested in thermal rehabilitation, we start from an original cost of 0 lei, but due to big heating consumptions subsequent monthly building costs are much higher than in the case of thermal rehabilitation

- secondly, in case of rehabilitated building, an initial cost of 39 600 lei (8 800 euro) is necessarily, amount which can be amortized in 11 years, as can be seen from Figure 26.

After 20 years it can be noticed that 100 979 lei (22 440 euro) are spent for the building not rehabilitated (expenses only for building heating) and only 70 556 lei (15 680 euro) for the rehabilitated building (including regular rehabilitation costs).



TIME(years)	0	2	4	6	8	10	12	14	16	18	20
clădirea reabilitaă	39600	44748	47397	50099	52854	55663	58527	61446	64425	67461	70556
clădirea nereabilitată	0	16793	25437	34250	43237	52399	61742	71267	80980	90882	100979

Figure 26: Overall cost chart

Drivers for the initiatives and targets

In the recent years, in Romania, the renovation and rehabilitation of prefabricated blocks built before 1990 were simple actions led by the necessity and requirement of holding an energy audit for apartment's sale (The law 372/2005: "Mandatory energy performance certificate is in force starting from 1 January 2011 if sales contracts to buy or rent apartments in blocks of flats and residential buildings"). Starting with January 1, 2011 is mandatory to get energy-efficiency certificates, available to potential buyers or tenants by owners, and is one of the drivers behind this renovation/rehabilitation process.

Also, in the idea of reducing energy consumption, the apartment' owners push the association administrator to find rehabilitation/renovation companies, in exchange of the block's roof terrace. Usually, these companies are building an additional storey, and instead of new volume are doing the thermal rehabilitation of the block's facades, remake common installations, painting the staircase, change the entrance door and windows etc. This type of exchange proved to be very profitable, and therefore in recent years many companies arise on the market for this type of activities.

Recently the municipality was heavily involved and wants to obtain EU projects for funding these rehabilitation actions ("Nearly 150 buildings could be rehabilitated with

European money in the Timisoara City. The amount of the funding is over eight million, which will be accessed by the municipality. The project will start on 15 November 2012, and Timisoara municipality representatives must submit the necessary documentation to obtain the funds. Then, the process continues with a rigorous analysis of those who entered the competition”[60].

Co-benefits due to the energy renovations

The main advantages of these neighborhoods rehabilitation is the social aspects. The rehabilitation and retrofitting of these urban structures in decay, revival of community spirit have to be the premises of these projects. The ability to respond accurately and fairly the current needs and trends (interior surfaces, light, greenery, necessary functions, and efficient use of space) should be the main topic of research regarding these urban structures. Engaging the inhabitants in the rehabilitation, maintenance and life of their neighborhood can and should become one of the main ideas regarding these projects.
The process of defining the problem, finding solutions, understanding long term consequences, ensuring the monitoring and feedback, constantly educating people so that they understand the solutions offered are of great importance in success of these interventions.

4.4 Brogården passive house retrofit, Alingsås

The Brogården passive house retrofit case study is a sustainability renovation project in Alingsås, Sweden. This case has been chosen, because it represents a relevant part of the Swedish building stock in terms of (1) technology, (2) construction period, (3) maintenance, (4) climatic and (5) ownership perspective.

Brogården is a residential area located 40 km outside Gothenburg (latitude 57°55’48 N), consisting of 300 apartments in 16 two-to-four-floor buildings placed in slab blocks around yards.

The apartments in Brogården are owned by Alingsåshem, a municipally-owned housing company. The company has around 30 employees and owns app. 3300 apartments in the neighboring communities (Alingsåshem, 2012). The annual turnover is approximately 19 million Euros, and the level of new developments is about 50 new apartments per annum (ibid).

The buildings in Brogården were built in 1971-73, in the frame of the “Million Program”. During this program, between 1965 and 1975, in order to address the housing shortage in Sweden, one million new homes were built; out of which 600 000 dwellings in multi-family houses (Hall & Vidén, 2005). Today, about one sixth of the Swedish population lives in these multi-family dwellings (ibid). Out of the total number of apartments, public residential buildings account for approximately 60%.

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[60] http://www.romanialibera.ro/actualitate/locale/incepe-reabilitarea-termica-la-timisoara-283367.html

These buildings are mostly prefabricated concrete, and were built focusing on a rationalized building process rather than high quality. Buildings are characterized by a certain type of loadbearing structure, called book shelf shell or lamella shell, whereby the gables and apartment dividing walls were used as the loadbearing structure (SP, 2010). It was the most common construction system during the period 1960 – 1975. Many of the apartments are in poor state today and need to be renovated in the coming ten years. The renovation of the entire Brogården area began in February 2008 and it is expected to finish by 2013. The experience yielding from this case study is applicable for an additional 350 000 apartments having been constructed with similar design in several cities in Sweden (Berggren, Janson & Sundqvist, 2008).

Before renovation

The renovation of Brogården spans between 2008 and 2013. Skanska is the main contractor of the refurbishment project. The project involves the extensive renovation of the buildings with passive house techniques, and includes the installation of new façades and roofing, thicker insulation and new ventilation systems (Skanska, 2012).

The buildings were built using in situ concrete as gables, while interior shear walls and infill walls have a wood frame with insulation and gypsum boards. The loadbearing gable walls were concrete (150 mm) covered with insulation (100 mm) and brick (60 mm) on the outside. The outer walls on the long sides consisted of a wooden construction with insulation (130 mm) and brick (120 mm) (SP, 2010; Skanska, 2012). There are three different foundation systems: concrete slab without insulation, cellar with shelter and crawlspace. The façade material is yellow brick. The roof is low tilted with short shoulders, covered by under-felt, insulated with mineral wool and cellulose insulation (180 mm) (SP, 2010). The original double-glazed windows were renovated in 1985; after this replacement, the U-value of the triple-pane windows were 2.0 W/m^{2}K; the U-value of the doors was 2.5 W/m^{2}K. The balcony slabs are an extension of the load bearing concrete frame creating thermal bridges in the floor inside the apartments (ibid). The buildings are heated with a traditional district heating system with hydronic radiators; the ventilation system is centrally operated without heat recovery (Skanska, 2012).

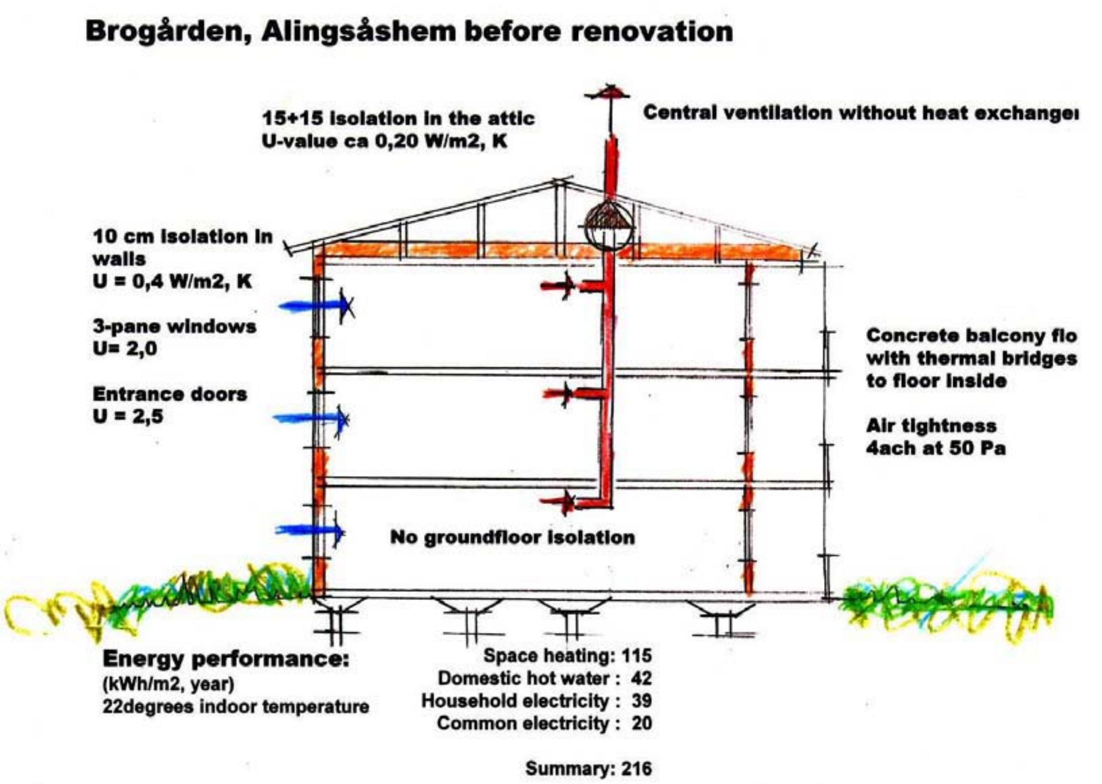

Figure 27: Energy balance before renovation (by Hans Eek in SP, 2010)

Drivers for the renovation

The main reasons for renovation in Brogården were the severely damaged crumbling brick facades and the tenants´ complaints about drafts and uneven indoor temperatures (Janson, 2010; SP, 2010). Before the renovation started, the board of Alingsåshem decided to have the tenants´ comfort as the starting point of the renovation. It included high quality indoor environment and improved accessibility for elderly and disabled people. Early on in the planning process, the application of passive house technology was brought up by Hans Eek, architect who has been living in Alingsås and working with low energy building since the 1970s. The passive house concept was discussed as a feasible approach to address these deficiencies, amongst others to increase indoor comfort, lower energy use for space heating and improve the ventilation system.

The major targets of the renovation followed the overall policy and the directives of Alingsåshem, which include i) the provision of a wide range of dwellings in an attractive, safe and pleasant environment, ii) accessibility and integration of different groups and iii) the development of energy efficient solutions for housing in order to contribute to the realization of the local governments' vision for Alingsås (Alingsåshem, 2012). In the light of these directives, specific targets were formulated for the Brogården renovation process, including a) enhanced indoor comfort, b) lower total energy use, c) active tenant participation in the renovation process, d) the possibility for tenants to influence indoor climate and energy use, e) the technology, which is easy to use and maintain, f) 60% accessibility and g) long-term and stable rent levels (Janson, 2010; SP, 2010).

The demanding energy use targets of Alingsåshem – to keep total energy demand at 92 kWh/m^2 - were inspired by the voluntary passive house standard, which was in the process of adaptation from the German Passivhaus Standard requirements when the renovation started. In terms of indoor environment, Alingsåshem chose to follow the requirements of the P-label developed by SP, the Technical Research Institute of Sweden (SPCR 114), which includes thermal comfort, air quality, moisture control, acoustic environment, air exchange rates, low emission construction materials, surface finish, paints, etc. (SP, 2009).

Considerations of accessibility have received high priority due to the residents of the area and the coming recommendation from National Board of Housing and Planning (Boverket, 2012). The majority of individual requirements Alingsåshem set in this project are stricter than the Swedish legally binding requirements.

	U-value before renovation (W/m^2 °C)	U-value after renovation (W/m2 °C)		Energy demand before renovation (kWh/m^2/y)	Energy demand after renovation (kWh/m^2/y)
External wall	0.4	0.15	Space heating	115	27
Windows	2.0	0.85	Water heating	42	18
Roof	0.3	0.12	Domestic electricity	39	28
Floor	NA	0.25	Electric appliances	20	21
			TOTAL	216	94

Table 34: Initial and target U values; energy demands in Brogården (based on SP, 2010)

After renovation - Technical measures improving energy efficiency

After renovation, the layout of some apartments has changed; in order to have larger apartments, some were merged. In addition, the height of the ceiling was lowered so that the ventilation ducts could be mounted (2.20 m).

Building envelope

In terms of the slab, a layer of EPDM rubber was laid on the existing ground slab against moisture. On top of that is 100-120 mm expanded cellular plastics board, a screed and fiber board floor was laid; the cellar vault is insulated with cellar (SP, 2010).

The concrete load bearing structure has been preserved but the old infill walls were replaced with new walls using steel-stud frame and in total 440 mm insulation, which gives a total thickness of 520 mm (Skanska, 2012). The infill walls are covered by fiber cement panel boards. The existing low tilted roof has been preserved, the beams of the roof have been extended to cover the new thicker façade, and new loose wool insulation was added in the attic (app. 500 mm). The old balconies became part of the living room and new self-supporting balconies were placed outside the façade. The windows were replaced with new triple-paned ones (outer panes with low-emissivity coating, gaps are filled with krypton gas) with a U-value of 0.9 W/m^{2}K (opening windows) and 0.8 W/m^{2}K (non-opening window).

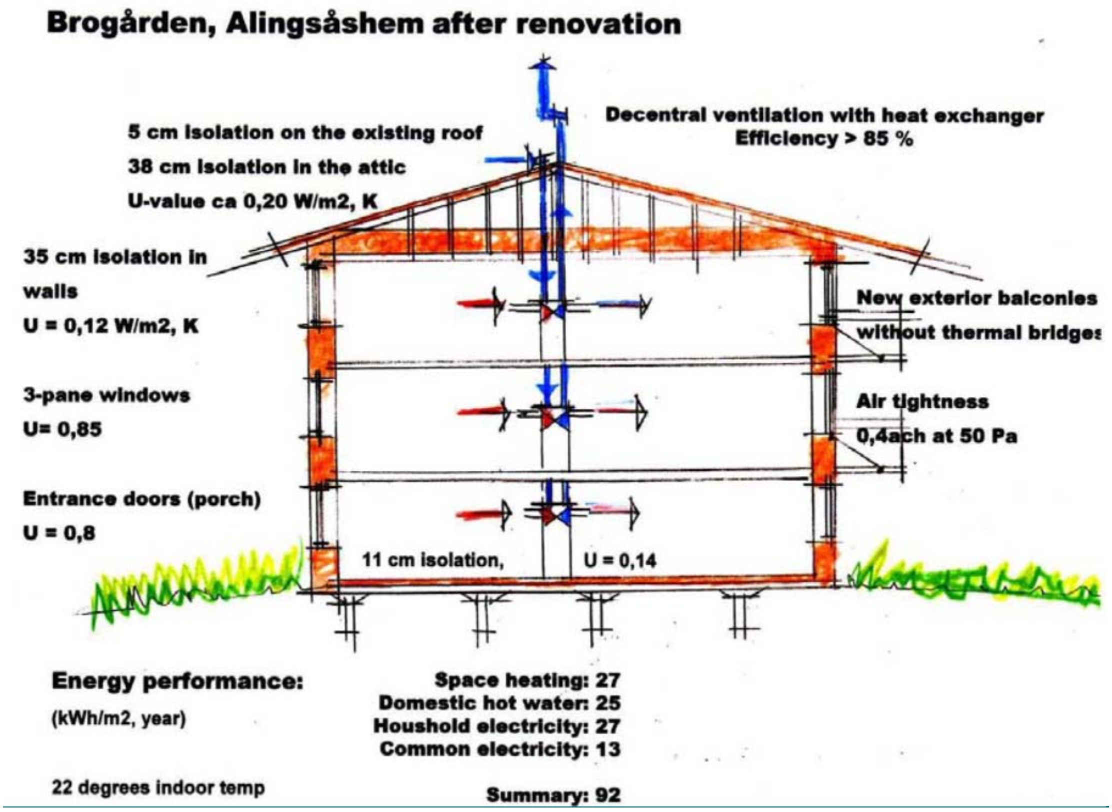

Figure 28: Energy balance after renovation (by Hans Eekin SP, 2010)

Building service technology

The buildings do not use conventional heating systems and require very little energy for space heating; the buildings are equipped with highly efficient heat recovery ventilation systems. After renovation, the apartments were heated by preheated supply air. In the demonstration building, separate ventilation units were installed in each apartment (REC Temovex 250S-EC) (SP, 2010). The system was complemented with heating coils for very low outdoor temperatures, which had capacities of 1.2 kW or 1.77 kW depending on the size of the apartments (ibid). The tenants were able to increase the output from the heating coil to increase the indoor air temperature, using a display in the ventilation unit. The filters are change by the care takers. The district heating connection was kept for the waterborne heating coil in the ventilation units. Alingsåshem decided to have central ventilation systems in the rest of buildings. The original district heating supply system was kept for distribution of domestic hot water. Since Alingsåshem and the local energy company are part of the same corporation, thus sharing the directives and policies of the Municipality of Alingsås, it is in both parties' interests to decrease energy demand in the community. According to the plans, in summer, the tap water will be heated by solar panels and in the wintertime the tap water will be heated by district heating. To make sure of the appropriate maintenance of the solar panels, the heating company will be in charge and the new solar panels will be added to the district heating system.

Economic context

Due to the very strict requirements and targets, the estimated renovation cost was very high. As a first step, Alingsåshem had considered demolition and rebuilding before the decision on renovation was taken. As demolition in this case was more expensive, than renovation, Brogården was decided to be retrofitted.

According to rough estimates, mainly due to the passive house techniques, the project cost around 25% more than a conventional renovation project (Skanska, 2012). In return, the retrofitted apartments use over 50% less energy than prior to the redevelopment (ibid). Based on the renovation of the first building block, Alingsåshem calculated the total investment (including maintenance and rent shortfall) is around SEK 380 million with a payback period of 20 years; SEK 1 280 000 per apartment, SEK 19 800 per m^2 (Personal Communication, Ulf Alexandersson, Alingsåshem AB, April 2012). The financial calculations assume an energy price increase of 5%; the calculation is done for 40 years. Alingsåshem is a municipally owned housing company having no profit on this renovation project. The energy saving investment is estimated to take up 30% of the total renovation investment cost. The energy saving investment was assumed to be paid back within 10 years, depending on the energy price development (Janson, 2010). Also it is assumed that as the time for renovating the following building blocks will decrease, the cost of renovation will decrease too. As the renovation was not energy efficiency focused, but also targeted other sustainability measures for the improved comfort of residents, the renovation costs are presented in six categories.

1	extension (e.g. balcony)	12.1%
2	accessibility (e.g. elevators)	4.8%
3	improved standard (e.g. renovated bathrooms)	28.9%
4	energy saving measures (e.g. insulation of the building envelop)	30.1%
5	maintenance (e.g. kitchen renovation)	22.2%
6	apartment structures (e.g. 5 m2 larger living rooms)	1.9%

Table 35: Approximated distribution of investment cost in Brogården (based on interviews with Alingsåshem)

After the renovation, Brogården will have 264 apartments for rent, all together on 19 513 m^2 living space (Beem-Up, 2012). The apartments vary between 1.5 to 5 rooms however more than 70% of the apartments has two or three rooms. The average area of an apartment is 74 m^2. Rough estimates show the following distribution of costs per apartment.

	SEK/apartment	kEuro/apartment
High standard	600 000	69
Energy saving measures	360 000	42
Maintenance type	240 000	28
Rent shortfall	80 000	9
Total investment cost	1 280 000	148

Table 36: Cost per apartment of the renovation interventions (Personal Communication, Ulf Alexandersson, Alingsåshem AB, April, 2012)

The apartments in Brogården are rental apartments, the table below shows the rental costs before and after the renovation. The negotiated rents will not be changed in the following five years (Janson, 2010).

	Before renovation		After renovation		After renovation with elevator	
	SEK/m^2	Euro/m^2	SEK/m^2	Euro/m^2	SEK/m^2	Euro/m^2
Second / third floor	734	85	893	103	917	106
Ground floor (new build standard)			1101	127		

Table 37: Rental prices negotiated with tenants for the next 5 years, (based on Janson, 2010)

The Brogården project is a pilot project, the first extensive passive house renovation project in Sweden, which enabled the use of different research and development financial sources, both for the building owner (e.g. Swedish Energy Agency funding) and the building developer (e.g. Swedish Research Council funding). The largest part of the renovation project, however, was funded by bank loan from a regional bank. No favorable conditions were provided due to sustainability issues or energy renovation considerations. In addition, other financial sources were used to finance the project, such as the subsidies provided by the Swedish National Housing Board for elderly people being able to stay in their apartments (Boverket, 2010).

Concluding remarks

Brogården passive house renovation project has been a long process in terms of planning, negotiating and implementing a new concept. There has been a lot of learning during the process which presumably will facilitate the following renovation processes Alingsåshem facing. It also offers a market niche for Skanska, the general contractor, whose competence in low-energy building constructions has been immensely increased. This renovation process not only needed extensive man hours and finances, but also a lot of commitments of different actors in the process, such as the general manager of the housing company, a local architect, committed building engineers and enthusiastic and supportive municipal actors (see more details on additional project costs in Kiss, 2013).

4.5 The settlement Paradies in Zurich, Switzerland

Situation

The settlement "Paradies" (see Figure 29) is located in the hilly green area at the city border of Zurich. It consists of the five buildings that are detached buildings consisting mainly of small apartments. Each building includes four to eight floors and total heated floor area amounts 20 971 m^2. The total number of apartments is 220 and their size ranges from 1.5 to 4.5 room apartments. Underneath the settlement there is an underground parking. The settlement was built in 1970 to 1972 and it is really in need of rehabilitation in terms of architectural and energy-efficiency aspects. Since its construction 40 years ago no significant renovation measure has been undertaken. The thermo-technical aspects of the building do not correspond to today's requirements and there are significant thermal bridges. The windows and doors have not been renovated since the construction phase and are in poor condition. The buildings have cubic outside appearance, which has 32 cm brick walls with a plastered surface and without insulation. The flat roof is insulated with 12 cm cork insulation. The living area is supported by the main and kitchen balconies that are integrated to the surface. The windows are double glazed and have wooden frameworks.

The settlement is heated by two gas heating systems that were renovated in 1990 and are at the end of their lifetime and thus renovation is required. The temperature range of the heating distribution system is 90/70 °C and tubular radiators are used with thermostatic valves.

Figure 29: The settlement Paradies just after the construction phase (1972). The settlement consists of the five buildings.

With the renovation of the settlement the owner of the buildings, city of Zurich, pursues three main goals:

- To come close to the level of Minergie-standards of the building envelope from energy-efficiency point of view
- To achieve architectural reassessment
- To reduce the number of small apartment by merging the apartments

Drivers for the initiatives and targets

The rehabilitation of the settlement is not only driven by energy related considerations but also from an architectural point of view. The “Paradies” settlement was built in 1970/72 and nowadays is in a state of urgent need of a comprehensive renovation. On the one hand side the outer wall has started to crumble and there is no thermal insulation and on the other hand, the apartments are not state of the art and do not fulfill the requirements of today’s needs.

Thus the energy related goal of the owner of the settlement is that the standards of these four buildings should be close to the requirements of “Minergie”. The building envelope should be retrofitted in order to reach this goal.

Further on, a new and more efficient heating should be installed. Additionally, the air quality is increased by adding a housing ventilation system into the moist rooms (showers etc.) and by manual window ventilation in the remainder of the rooms. Building technologies should be added and renewed as well. Additionally, the kitchen balconies are removed, primarily to reduce the costs during the renovation but also to remove huge thermal bridge into the building.

Moreover the architectural aspect of the renovation is an important driver too. The main target is to retain the character of the original settlement with gentle changes on the in- and outside but it will be adjusted to the new standards of nowadays living and it should last for the next 30 to 40 years. Also the social aspects of the settlement have changed over the last decades, therefore the mixture of the apartment sizes will be changed to a more family friendly size and all apartments will be disabled-friendly. The number of the small apartments are reduced from 1.5 to 2.5 room apartments to have a higher share (almost 40%) of 4.5 to 5.5 room family apartments. Due to merging of small apartments the total number of flats is reduced from 220 to 194.

There is need for some further reinforcement of the building in view of earthquake security and also in general static manners. The changes in the distribution of the apartments entailed a replacement of some load bearing walls with newer steel-reinforced walls.

Examination of different renovation scenarios

Different renovation variants were investigated in a case study before the final renovation decision was made. The impacts of different renovation measures on the costs, PE use and GHG emissions were generally compared with a reference case, in which basically no energy related renovation measures were undertaken. In the reference case, which served as a basis for comparison, the renovation measures, such as cleaning, painting and replacing the existing heating system by a new one of the same type, were included.

Seven different variants were investigated, in which energy related renovation measures, such as wall insulation, replacement of the windows and new heating system with ground source heat pump, were undertaken. U-Values of the wall and windows are shown in Table 38. The roof and the cellar were renovated in none of the seven variants and the U-Value stays at 0.33 W/m^2*K for the roof and 1.6 W/m^2*K for the cellar and they are therefore not shown in the table.

U-Value W/m^2*K	Ref.	GT	GT +IW	GT +IW+IWa	IWa	IW	IW+IWa	GT+IWa
Wall	1	1	1	0.2	0.2	1	0.2	0.2
Windows	2.5	2.5	1	1	2.5	1	1	2.5

Table 38: U-values of the “Paradise” settlement in case of seven different scenarios. The roof and cellar are not renovated in this case study (Ref: Reference scenario, GT: geothermal heating system implemented, IW: insulation windows, IWa: insulation walls)

The replacement of the windows with new and better (energy-wise) windows (triple glass and sealed) is economical in all cases due to the fact that in the reference scenario the costs of the restoration of the windows are already high (1.2 Mio CHF). Together with these windows the primary energy demand decreases drastically with the installation of the new insulated façade and windows (see Table 39). The GHG reduction is mainly driven by the replacement of the heating system and there is only a small difference between the two scenarios with the new windows or new façade combined with the geothermal heat pump. The replacement and insulation of the façade is more expensive and the benefit of the GHG reduction over 20 years is rather small. The costs in this case are high as the assumed construction form of a ventilated facade is highly complex. Regarding GHG reduction it is to mention that if the embodied energy is taken into account that the façade renovation is not the best option. In Table 39 all the important model results are shown for the different scenarios.

	Ref.	GT	GT +IW	GT +IW+IWa	IWa	IW	IW +IWa	GT+IWa
Space heating energy-demand (kWh/m^2)	117	117	92	50	74	92	50	74
Primary energy demand (MJ/m^2)	678	562	416	282	506	501	417	353
CO_2- reduction (t/a)	---	683	732	779	233	257	361	753
Investment-costs (Mio CHF)	1.8	4.3	4.8	7.1	4.7	2.7	5.5	6.8
Operating costs (Mio CHF/a)	0.450	0.244	0.177	0.110	0.323	0.320	0.253	0.150

Table 39: The Energy demand for space heating (kWh/m2) and the CO2-reduction (t) compared to the reference scenario (Ref: Reference scenario, GT: geothermal heating system implemented, IW: insulation windows, IWa: insulation walls) (TEP-Energy, 2012)

The results for space heating energy demand refer only to the space heating, while warm water demand will remain the same for all the different scenarios (21 kWh/m^2). The impact of replacing the fossil heating system with a heat pump, replacing windows and insulating the façade is most distinct in terms of CO_2-reductions.

Work carried out in the renovation process

The owner of the settlement requires this settlement's energy-efficiency to come close to the "Minergie"-standard and therefore a combination of replacing the heating system, the windows and the installation of wall insulation is finally chosen (Scenario: GT+IW+IWa).

Different to the scenario calculation there won't be a geothermal heat pump installed. The reason for this change is the underground parking garage and the railway tunnel underneath the settlement which would have made the installation too complicated and too expensive for this project. Therefore the close seawater work "Moos" will be used as the energy source for the settlement. The new heating system will be implemented into the former heating central in the settlement. For improving the lifespan of the thermal heat pump a heat buffer system will be installed directly on-site in each building as well. There will be an emergency heating system still on site to bridge the energy need in case of small maintenance work. The whole system will be installed by the local energy utility EWZ in an energy supply contracting framework. Also building and maintenance of the heating system will be carried out by the contractor.

The new façade is planned as a compound façade with a 14 cm EPS-Graphite insulation. The reason for choosing graphite insulation is to keep the embodied energy as low as possible. On the insulation there will be a thick layer of plaster (15 mm) to insure that the insulation will be especially durable and reliable. Fibre-reinforced concrete panels will be installed to protect the façade in the base area. These panels are highly resistant against both mechanical load and varying climate conditions.

The new windows will be triple glassed and sealed for a better insulation as compared to the old windows. Also in terms of acoustic insulation some of the buildings will need specific noise protection insulating windows, due to the nearby highway, which is a considerable source for noise.

The balconies of the kitchen side are damaged and some of them have started to lower down. The renovation costs would be too high, therefore they will be removed. The large balcony door will be kept and guardrails will be installed instead of the balcony. A further advantage of removing the balcony is that the kitchens will be brighter and will get more sunlight from the outside, due to the missing shade of the balcony above. And a big thermal bridge will be removed as well.

Further on, the ventilation system of the bathrooms will be replaced with an integrated heat recovery system. In every building there will be one monobloc with a plate heat exchanger installed and another 26 monobloc heat exchangers will be installed in the basement close to the vertical shafts, 6 monoblocs will be installed on the roof where there is no space in the basement. Due to the fact that the ventilation system will be only installed in the bathrooms and not in every room, the official Minergie label won’t be applied for these buildings.

Investments

The total costs of the rehabilitation are estimated at about 51.0 Mio CHF. It does split up into construction costs (44.4 Mio CHF) and reserves (6.6 Mio CHF). The main matter of expense is the replacement and renovation of the windows and the insulation (9.8 Mio CHF) and the heating and sanitary-installations (8.6 Mio CHF). Compared to the calculated scenarios these numbers are slightly higher due to the fact, that the façade renovation is more complicated than estimated in the model calculations. Compared to other similar projects in Zurich the cost per flat are rather low (181 000 CHF/flat to roughly 230000 CHF in other projects) but the overall project costs are more or less comparable to other projects. There is a possibility for applying to the “Gebäudeprogram” to subsidize the renovation and further a credit over 10 Mio. CHF has been requested and granted from the city of Zurich for social housing projects in Zurich. The Paradies Project is subsidizes by 0.86 Mio CHF for the use of alternative energy source for heating.

Future plans for improving energy efficiency

After the renovation will be completed no further plans are known for improving the energy efficiency due to the fact that after the building phase the settlement is compliant with the “Minergie”-standard and close to the 2000W-society-standard in Zurich.

Co-benefits due to the energy renovations

Beside the savings in energy consumption also architectural aspect are taken into account when defining the renovation project. Small changes will give the settlement a new and contemporary look, while it will maintain the original charm of the buildings. The whole kitchen and bathroom section are replaced as well with new and modern furnishings. In an overall look the whole settlement is revaluated to the today's standards. Also parts of the electrical installation are replaced during the renovation due to the fact that they are outdated and not conform anymore to today's standards. The park inside the settlement remains as it was, only small measures are taken (renewing of the playground, installation of new bike racks with space for 435 bikes, some new bushes and trees). Even though all the above mentioned changes and improvements the rent of the apartments stays low (from 850 CHF before and 1310 CHF after the renovation for a 4.5 room flat) which was achieved also due to subsidies from the Canton Zurich.

4.6 Discussion and Conclusion

Effective energy renovation measures can range from the simplest to the very complex – e.g. in the Danish case the most cost effective saving measures were to stop the needless ventilation and flow of hot water to bathrooms. These measures account for 8% and 22% of the savings, but only 5% and 7% of the cost. They are the most common sense measures too.

On the other hand, in the Swedish case, in order to limit heat losses on the façade, a very complex and costly set of measures have been implemented by integrating former balconies inside the building envelope and building new external balconies. In this way, the previous losses due to thermal bridges in slab are eliminated. However, the cost effectiveness of such energy saving measure is very hard to estimate, since the intervention also resulted in 5 m^2 additional living space for each apparent, and some remodeling of the internal space.

Without the intention is not to directly contrast the case studies with each other, a summarizing Table 40 is presented more as a map for the targets and cost of the interventions in the different countries.

With reference to the classification of the retrofit measures presented in Table 1, it can be noted that the case studies used almost the full range of retrofit measures according to Table 40. The choices seem to have been based on the (1) typology of the building and the (2) budget targets for investment.

The Danish and Swedish retrofit cases are quite similar in being very ambitious and by using a wider portfolio of interventions, ranging from improving thermal protection (S1), change of the heating system (S2), implementing heat recovery (S3), efficient electricity services (S4) up to control and regulation measures (S7). However, there are also important differences.

The Hotel Sanden Bjerggaard in Denmark has the character of a historic building so the retrofit concentrated to efficiency of HVAC systems, compared to improving thermal protection of the building. The residential building is Alingsås both the HVAC systems and the thermal protection were improved.

The hotel is privately owned, and even if the retrofit was co-financed by public programs, the focus of the interventions has been more strictly on cost efficiency. In the Alingsås case an interplay of more considerations can be observed – social sustainability of the neighborhood, shared interest of the district heating supplier and the city, the ability attract R&D funding to this pilot project, the interest of the contractor to participate in such a pilot. These considerations gave momentum to a very ambitious project. The outcomes are reflected in both the costs and performance targets (Table 40).

	Energy renovation measures	Other targets	Classes of retrofit measures	Energy demand (kWh/m^2/y)	Cost of energy renovation (Euro/m^2)	Cost of other renovation (Euro/m^2)
Romania	Wall insulation only	Internal space distribution	S1, S4	165.6	27.3	NA
Denmark	Wall insulation, upgrading windows, replacing heating system to heat pump, active control of environment	None	S1, S2, S4, S7,	NA	128	0
Sweden	Wall, floor and ceiling insulation, windows, heating system	Internal space distribution, accessibility	S1, S2, S3, S4, S6, S7	94	600	375
Switzer-land	Wall insulation, windows, heating system replacement	Internal space distribution, architectural renewing	S1, S2, S3, S4	117	430	1600

Table 40: Situation after retrofitting

The Romanian and the Danish case studies are offering the possibility to compare results on cost optimality (Chapter 3) with the actual retrofit measures taken or proposed, since in these two cases the building typologies analyzed in Chapter 3 are similar to the one in the case studies.

For the Danish case a series of common sense interventions were implemented just to make energy usage more efficient, and eliminate wasting of energy. These were the reducing of water circulation and ventilation of unoccupied bathrooms. Besides these measures, the change from oil heating to ground source heat pump has been implemented. This measure was shown to be cost effective by the calculations reported in Chapter 2 (Figure 2). Once ground source heat pump is installed, the measures improving thermal performance of the walls, floors and the roofs are cost effective (Figure 2) but were not used in the study case. The upgrade of the windows, done by the hotel is shown to not be cost effective only from the point of view of energy savings. Other benefits, like comfort, may have been considered. In the case of the Romanian MFH building, the proposed retrofit measures are exclusively concentrating on improving thermal performance of the building. Interestingly, the calculations (Chapter 3, Figure 7) highlight the effectiveness of changing the replacement of the heating system, form district heating to gas based or to water source heat pump. Such change, especially to gas heating, has been undertaken in many smaller cities in Romania. Hence, it seems that the cost effectiveness of the measure is supported by empirical observations. In larger cities (e.g. Timisoara) disconnecting from the district heating is actively resisted by the city authorizes and the central government, Therefore, the local authority may be not only be the catalyst of sustainable retrofitting, as in the Swedish study case, or take the role of integrator providing the planning and coordination of the renovation, the role which findings of Chapter 5 would suggest to suit them, but they can also oppose cost efficient retrofit measures.

Another observation concerning the Romanian case is that while calculations show window upgrading not to be cost effective, there is a very widespread tendency on the market to implement this measure. It appear that the co-benefits (indoor comfort, noise reduction, dust reduction, etc.) clearly outweigh the economic arguments in this case.

The case study examples highlight two other aspects of recent renovation trends: (i) the impact of high-tech to renovations by deployment of active control for optimizing resource use and (ii) the unavoidable complexity and multidisciplinary of profound renovation interventions. The reshaping of the building façade in Sweden implied, in the technical design phase alone, the (i) architectural design for the space modification proposed (ii) re-evaluation of the buildings structural safety and redesign of the load paths (iii) design of new foundations and structure for the added balconies (iv) thermal and moisture calculations for the new infill walls and (v) energy calculations for the newly created space. One should add to this the many professionals needed to carry out the involved construction task.

The role of the stakeholders in the renovation process is also crucially highlighted in the Swedish case study. The profound effects of different ownership on the ambitions of the renovation are clear by comparing the Romanian and the Swedish cases. In Sweden, the fact that the buildings were owned by the municipality and only rented to occupants, gave a strong impulse to carry out profound renovation. The detail that the energy utility company was also owned by the municipality was also helping the project’s energy focus. Therefore strong synergies could develop along common goals with all stakeholders. Even so, tenants had to be reassured with a 5 year freeze on rental prices. In the Romanian case, a very similar building can realistically target less ambitious renovation goals, not lastly because of the fractured ownership. In the Romanian case, the building is owned as a condominium and renovation measures have to be agreed by the Home

Owners Association (HOA's). This means that the proposed renovation have to appeal to most co-owners, as they have to pay their share of the bill at the end. So, while in Sweden the fears and reluctance of the occupants was a marginal inconvenience in implementing the project, in the Romanian case the same fearful and reluctant occupants are supposed to be the drivers of the renovation. Also not negligibly, a HOA has no ability to mobilize the technical know-how and financing opportunities accessed by a municipal administration. These two, technically very similar yet very different cases highlight the imperative need to develop instruments tailored to the market situation in each country. While in the Nordic countries a relevant part of the building stock is owned by municipalities, major share (>80%) of apartments in East-Europe are owned in the condominium scheme, so the "Alingsås-model" may be technologically an example, but implementation instruments have to be locally tailored.

And this brings the discussion to financing and co-financing instruments. From the presented case studies, they do seem to play an important role in implementing energy renovation. The Danish renovation case started as the usual way of replacing an oil heater was financially impossible. Therefore the owner started looking for alternatives, becoming enthusiastic and recognizing the potential benefits to his business. In Sweden the Alingsås case is a pioneering project, (financially) supported by the Swedish Energy Agency, the Swedish Research Council and the Swedish National Housing Board. As it had very ambitious goals, budget constraints were not the primary driver. In Romania, energy renovation of building topologies like the one presented here can be supported 20% by owners, 30% by municipalities and 50% by the government. These financial instruments are very important: in addition, two improvements are suggested with relation to their applications. Firstly, the focus of financial support has to be broadened from strictly energy focus, to also include aspects of material (and/or resource) efficiency and social sustainability. The Alingsås case is the model to follow to ensure long term sustainability of the old building stock. Secondly, financial support should be directed more pointedly to areas of best cost to benefit ratios; these are already attractive to owners.

5 Conclusions and recommendations

5.1 Conclusions

The building sector accounts for 40% to 50% of the final energy consumption in the countries participating in this project. While in the European Union (EU) energy-related requirements for new buildings are constantly increasing (e.g. EPBD; nearly zero energy buildings up to 2020), the improvement of energy performance of the existing building stock constitutes a major challenge for the future, especially with relation to the greenhouse gas emissions reduction goals of 2050. Mastering of this challenge requires the identification of cost optimal retrofit strategies to achieve maximal reduction of energy consumption and carbon emissions through and within building renovations.

Building owners are missing holistic and integrated strategies for various building types and thus there is an identified need for ready-to-use recommendations and standard solutions. Although, from previous policy analysis it can be derived that the understanding of cost-benefit curves and the knowledge of ready-to-use recommendations and standard solutions are necessary, they are not sufficient to foster the rehabilitation of the building stock and to reduce its PE and GHG intensity. Particularly, a better understanding of the way of thinking and of the decision pattern of the actors that facilitate and actually implement PE and GHG mitigation measures is needed. Ultimately, framework conditions, barriers and enabling factors have to be understood and to possibly be adjusted to tap existing potentials.

In order to provide holistic and integrated strategies for various building types, and ready-to-use recommendations the INSPIRE project is constructed based on the following three fields.

a) Techno-economic assessment of energy efficient building retrofit strategies

b) Assessment of actors and policy instruments for energy efficient renovations

c) Case studies of sustainable renovations

First the techno-economic assessment of energy efficient building retrofit strategies is conducted in the Chapter 2 in order to investigate the influence of different renovation packages on primary energy use, GHG emissions, and life cycle costs of different residential buildings in different countries.

In order to conduct the generic techno-economic evaluations a calculation tool was developed, which can be used by energy actors to carry out their own calculations to evaluate environmental impacts and cost-effectiveness of different renovation strategies for buildings. The tool includes a database of empirical techno-economic characteristics of several types of measures from the following categories: (i) building envelope insulation, (ii) heating systems, (iii) ventilation system with heat recovery, (iv) electricity based services (lighting, cooling, and appliances), (v) energy supply mix, (vi) building automation control and regulation, and (vii) onsite energy production.

Based on the calculations, conclusions can be drawn from the Chapter 2. (Additional calculations carried out with the tool specifically for Switzerland and related conclusions are documented in a separate report.) Underlying boundary conditions (e.g. life cycle cost methodology, future energy price increases are assumed) need to be taken into account when assessing the results.

The results indicate that:

- Energy efficiency measures on the building envelope reduce particularly primary energy use.
- Renewable energy systems reduce particularly GHG emissions.
- It is difficult to reduce significantly GHG emissions only with efficiency measures.
- The importance of using renewable energies within building renovation also arises from the fact that with increasing energy-efficiency performance of the building envelope the share of energy needs for domestic hot water and for electricity is increasing. The related energy need is difficult to reduce with efficiency measures. Renewable energy sources can lower its environmental impact significantly, though.
- The choice of the heating system dominates the results regarding costs and greenhouse gas emissions.
- To some extent renovation measures on the building envelope are cost effective, for most reference buildings investigated regardless of the choice of the heating system.
- The effect on costs or environmental impact of increasing the energy performance of a single building element is small compared to the effect of involving more building elements in an energy-efficiency renovation.
- In the case of the multi-family reference examples investigated from Romania and Switzerland, the energy-efficiency renovation of the wall is the most cost effective renovation measure of the building envelope.
- For the single-family reference buildings investigated in Denmark, Sweden and Switzerland, energy-efficiency renovation measures on the wall and the roof are the most cost effective measures.
- For the single-family buildings from Denmark and Switzerland, and the multi-family buildings from Romania and Switzerland, the trade-offs between renewable energy measures and energy efficiency measures are rather small, in the sense that a renovation package, which is the most cost effective with one heating system, is also close to the cost optimum with other heating systems.

- Implementing both envelope insulation measures and a switch to a renewable energy system to reduce primary energy use and GHG emissions effectively is economically attractive.

- Synergies are created between envelope insulation measures and switching to a renewable energy system, as the former reduces the required peak capacity of the renewable energy system. The reduction of the required peak capacity of the renewable energy system is a key driver for making many renovation measures of the building envelope cost effective also when renewable energies are used as the main source for heating.

- The moment of replacement of the heating system is a good opportunity to combine a switch to renewable energies with energy efficiency measures on the building envelope. As the energy need of the building is reduced, peak capacity of the heating system can be reduced as well, which is a key driver for making many renovation measures of the building envelope cost effective also when a new heating system using renewable energies is installed as the main source for heating. If this opportunity is missed, and the dimensions of the heating system are determined without taking into account renovations on the building envelope, subsequent energy-efficiency renovation of the building envelope will be less cost effective.

Secondly, the role of different actors involved in energy efficient building retrofits, in particular municipalities, as well as the role of policy instruments in energy related building retrofitting are investigated in the Chapter 3. This investigation is made in order to get another point of view about factors that have an effect on the building retrofitting projects and energy renovations.

The lack of knowledge has been previously identified on how actors and policy instruments can intensify the quantity and quality of energy efficient retrofit processes (Heiskanen et al., 2010; Kiss and Neij, 2011). This study (Chapter 3) investigates the current role of actors and policy instruments in order to provide a better understanding of renovation processes and to contribute to the dissemination of energy efficient retrofit practices in the different countries considered in the INSPIRE project.

Beside barriers of energy renovations at the market level, it has been also pointed out earlier how the value of energy savings in people’s minds competes with other non-energy related needs (e.g. a new kitchen), which in turn creates another barrier to energy renovations. Therefore, policy measures are important to promote and support energy renovations. Additionally, there is a strong need for new financial solutions or development of existing models, such as energy conservation service, that can work around the problem of building owners’ access to capital.

The main barriers to the promotion of energy renovation are related to economy. Even though the life cycle cost is often reduced through the energy renovations, the short-term costs increase and the longer payback time can be a barrier to energy renovation. Often shorter payback time initiatives are chosen instead. Another common barrier is related to historical buildings, in which the energy renovations can become very expensive, if not impossible, due to architectural aspects of the historical buildings.

To overcome some of these barriers, policy instruments play an important role. The following policy instruments are found to foster efficient and effective building renovation strategies and portfolios of retrofit measures.

- Stringent building standards would have the potential to guide and improve energy renovations. The lack of ambitious building standards for energy renovations creates confusion in the building sector.
- Economic incentives are important to overcome the initial investment costs and to level out barriers related to the long payback periods. Strong differentiation in property tax based on energy consumption can lead to higher awareness about the inclusion of energy considerations when investing in properties. In addition, financial support through tax deductions has shown to be favored in the investigated contexts. However, financial support may have only catalytic effect, as the sums necessary to implement extensive renovations are much bigger than what governments may be able to provide for.
- Therefore the role of innovative instruments, amongst others informative ones, such as the web-based information sharing system Omataloyhtiö.fi among housing association managers in Finland are needed to overcome the lack of experience of housing associations in renovation measures, lack of information and workmanship, and the different values on energy efficient and cost-effective renovation measures.

Voluntary initiatives and agreements are also an important element of the policy mix supporting energy renovations; e.g. buyer groups of housing associations, for instance Bebo (Sweden) and technology procurements are considered to be successful tools for learning and networking among different actors involved in energy renovation processes.

As suggested above, different actors have very important role in promoting energy renovations. Municipalities have a limited tradition of influencing energy efficient renovations in private housing. Due to the climate challenges increasing energy prices, and increasing social responsibilities (e.g. job creation) the roles of the more proactive municipalities are now changing. To involve active financial actors and guarantees into energy renovations is an on-going discussion. In Denmark the banks begin to act as a coordinating actors by pulling together different players of building renovation processes and organize the retrofitting into a package and so offer it to their clients.

In summary, policy intervention has got an increasingly important role in energy efficiency renovations. The study shows that energy renovations are supported by building codes, which include requirements for renovations, the traditional grant and tax incentive schemes and additional economic incentives, partly with the involvement of the private sectors, such as energy utility obligations, as well as information tools and voluntary agreements. The role of municipalities, under the challenges of climate change and sustainable development, is gradually increasing in energy efficiency renovations and sustainable buildings. The main drivers for building renovations are highly context-dependent. However, some drivers are common and include climate mitigation, energy and cost saving, energy security, forerunner position, promoting local economies and job creation. These municipal best practices serve as a source of inspiration and intense learning processes.

Due to the complexity of energy renovations, strategies and policies promoting learning and networking for advanced knowledge are required. Over the long term different types of policy instruments promoting learning at different stages are required. In addition to this more strategic evaluations are needed to understand how to improve learning and the dissemination of best practices in energy renovation.

The third main part of the report includes the selected case studies that are intended for scrutinizing the suitability in real life applications of conclusions from Chapters 2 on cost-optimal choices of retrofit, and Chapter 3 on the expected impact of actors and policy instruments. The case studies are meant to exemplify the constraints faced by professionals when renovating buildings. The case buildings are selected to be relevant for the building stock of the countries where they are located and they are mostly used as residential buildings excluding the Danish case study of a hotel. The intention of the cases was to observe the retrofit case from outside, not to be part of it.

The case studies are not intended to be compared with each other. Such comparison would yield no benefits because of the diversity of building configurations, uses, ownership models and country settings. The only valid evaluation can be done by comparing the case study as realized in reality, with the more abstract consideration of Chapters 2 and 3.

Two tendencies are recognized from the case studies. High-tech control systems are more and more used in the business of energy retrofitting due to their low cost and high impact, especially to limit unnecessary use of energy. These smart sensors will become more sophisticated, and certainly will be used on wider scale in the future. The other tendency is to implement complex interventions, instead of just upgrading a single building element at once. Often the renovation is targeted to improve social sustainability also, not only energy efficiency. These type of complex measures, shown to be more efficient also by calculations, require more sophisticated planning and coordination, technical, legal, economical, etc.

In the most of the cases the “integrator”, required to do this sophisticated planning, is not well defined. In the Danish study case the owner, supported by a research group from the local University, played the role of integrator. In Sweden the city, at the same time owner, investor, and energy supplier, took the role of integrator. However, in the Romanian case this role is missing from the picture. It is important to create or delegate the integrator role to one stakeholder in each country context. E.g. in Romania the cities could very well take the integrator role by opening renovation advisory centers to encourage more renovation activity. This would be in line with the tendencies highlighted in Chapter 4, with cities taking more active roles. Certainly, if the intention is to encourage owners to start thinking about complex renovations in large numbers, then expert advice is needed on a much more organized level.

As a conclusion of the cases studied and their connection to the Chapter 2 and 3 the following points can be recognized

- In the Danish case study the most effective saving measures were to stop the needless ventilation and flow of hot water to bathrooms. These are the most common sense measures as well.
- In the case studies there are two main drivers for the choices of retrofit measures (1) typology of the building and the (2) budget targets for investment.
- An interplay of more considerations can be observed in the retrofitting case studies, such as
  - Social sustainability of the neighborhood
  - Shared interest of the district heating supplier and the city
  - The ability to attract R&D funding to a pilot project
  - The interest of the contractor to participate in a pilot project
- The change from oil heating to ground source heat pump was shown to be cost effective by the calculations reported in Chapter 2 (Figure 5). This measure was also implemented in the Danish case. The calculations show also that if this measure is followed by improving thermal performance of the walls, floors and the roofs, then the later measure would be cost effective as well. However, the later measure was not implemented in the case study.
- The upgrade of the windows is shown to not be costs effective only from the point of view of energy savings. This means that co-benefits, such as indoor comfort, noise reduction, dust reduction etc., influence also to the decision to implement this measure. This was proved in practice within the Romanian case.
- The calculations in Chapter 2 highlight the effectiveness of changing the replacement of the heating system, from district heating to natural gas based or to water source heat pump. Such change, especially to gas heating, has been undertaken in many smaller cities in Romania. This means that the cost effectiveness of the measure is supported by empirical observations.
- By the case studies two aspects of recent renovation trends are highlighted
  - the impact of high-tech to renovations by deployment of active control for optimizing resource use, and
  - the unavoidable complexity and multidisciplinary of profound renovation interventions

- The role of the stakeholders is crucially highlighted in the case studies and has a strong influence to ambitious of realistic renovation targets. This is, especially, shown in the Swedish and Romanian cases where the ownership is arranged by different ways. In the Swedish case the municipality was the owner of the buildings and the energy utility company that creates strong synergies along common goals with all stakeholders in the project. In the Romanian case the ownerships are more fractured when the synergies and common goals are more difficult to create.
- The example above of the impact of the stakeholders' role in the renovation project shows the imperative need to develop instruments tailored to the market situation in each country in order to create synergies and common goal easier between the stakeholders and avoid a negative impact of different ownership structures.
- The case studies raise the discussion about financing and co-financing instruments that seem to play an important role in implementing energy renovation. Two improvements for the financial instruments are suggested.
  - The focus of financial support has to be broadened from strictly energy focus, to also include aspects of material efficiency and social sustainability.
  - Financial support should be directed more pointedly to areas of best cost to benefit ratios; these are already attractive to owners.

In all, the results of the case studies show similar outcomes and behaviors as the generic calculations in the Chapter 2 and the actor analysis in the Chapter 3.

5.2 Recommendations

Based on the above mentioned conclusions and the general experience derived from the international collaboration in the INSPIRE project, some general recommendations are highlighted. These recommendations relate to the direction of both future research and policymaking.

- The results found in this study indicate that from a perspective of reducing greenhouse gas emissions at least costs, it can be recommended to focus particularly on promoting a shift to renewable energies.
- Promoting retrofitting measures of the building envelope is also important for both primary energy and GHG emissions reduction, and are in many cases cost effective. They also reduce the required capacity and costs of (renewable) energy system in the building and thus, these measures should be implemented as a first step.
- From a perspective of reducing GHG emissions or primary energy at least costs it is advisable to promote in particular the renovation of as many building elements as possible, rather than setting high energy performance levels of single elements.

- In order to use the full potential of renewable energies and energy efficiency measures to reduce greenhouse gas emissions and primary energy use, it is furthermore important to combine a switch to a renewable energy system with energy efficiency measures of the building envelope to make use of related synergies. This approach also contributes to finding the renovation package with the lowest possible costs.
- It is important that policy interventions to promote sustainable building renovations specifically target at the moment of the replacement of the heating system for a given building, in order to make sure that energy efficiency measures are combined with or carried out before the replacement of the heating system, in order to make use of synergies.
- Besides barriers of energy renovations at the market level, the value of energy savings in people's minds competes with other non-energy related needs (e.g. a new kitchen) and this creates another barrier for energy renovations. Therefore, policy measures are important to promote and support energy renovations. Additionally, there is a strong need for new financial solutions or development of existing models, such as energy conservation service, that can work around the problem of building owners' access to capital.
- The complexity of energy renovations, including multiple factors and actors, calls for strategies and policies promoting learning, networking for advanced knowledge and knowledge exchange as well as improved processes and interaction. Over the long term these processes require different types of policy instruments promoting learning at different stages. In addition, the choice of instruments and strategies also requires knowledge and constant evaluation. Evaluations are presently scarce; more and more strategic evaluations are needed to understand how to improve learning and the dissemination of best practices in energy renovation.
- The focus of financial support has to be broadened from strictly energy focus, to also include aspects of material and resource efficiency and social sustainability.
- The financial support should be directed more pointedly to areas of best cost to benefit ratios; these are already attractive to owners.
- As renovations are becoming increasingly complex, more sophisticated planning and coordination of technical, legal and economic aspects are required. There is a need for appropriate "integrators" to do the related planning and coordination. It is important to create or delegate the integrator role to one stakeholder in each country context. E.g. in Romania the cities could very well take the integrator role by opening renovation advisory centers to encourage more renovation activity. This would be in line with the tendencies highlighted in Chapter 4, with cities taking more active roles. Certainly, if the intention is to encourage owners to start

thinking about complex renovations in large numbers, then expert advice is needed on a much more organized level.

Furthermore, at a more general level the following conclusions, recommendations and suggestions for further research are formulated:

1. **The solutions are available, but implementation is slow**: The core focus of INSPIRE has been how to improve the energy efficiency of buildings. A general conclusion is that the technological solutions are available, so the main challenges are related to the organizational and institutional side of the implementation. Retrofit solutions are especially needed, since existing buildings are the overwhelming part of the total numbers of buildings. Building constructors, banks and social housing associations are increasingly becoming aware of the potentials of energy efficiency, but still several institutional barriers are dominant e.g. the tariff structure for district heating in the Nordic countries (section 3.2.1).

2. **From energy to resource efficiency:** Since the technologies are available for making passive houses and even energy-producing buildings, then the importance of energy consumption during the phase of use will not be the main environmental concern in the long run. The main environmental impacts related to buildings will move to other life cycle phases such as embedded energy in materials in the future. *Resource efficiency* is in this way becoming the key focus, and more attention has to be given to the choice of materials and to the end-of-life of buildings. In order to save energy in the phase of use, then more energy is embedded in the materials as in the case of insulation. Besides, increasing recycled content in materials will in most cases contribute to the reduction of CO_2 emissions, and closing the material cycles are also a way forward. Life cycle thinking including all phases of the building and the creation of closed loop are important ingredients in the future policies towards buildings.

3. **Integrated solutions**: The main focus in the solutions to energy efficiency in buildings is on heating and the building envelope. Standard solutions and pre-fab renovation solutions can also be a way forward to lower the costs of making more resource efficient renovations of existing buildings.4. Much more attention has to be given to all environmental aspects of buildings such as the use of water, electricity, heating, waste, etc. and solutions are emerging that combine smart meters with user interfaces that increases the awareness of the users and offer easy options for managing the resource use in households – efficiently and sufficiently (section 4.1).

4. **Social practices of users**: The role of users is significant for the use of heating, electricity, etc. in the households. Energy renovation is not just about technical solutions, and in order to avoid the rebound effect: more efficient = more use, then more attention has to be given to social practices of different user groups in order to expand the knowledge and capacity building of user within this field.

5. **Total cost of ownership and new business models**: One important barrier to energy renovation is the fact that current decision patterns compare initial investment cost, but mostly ignore later running cost of heating and electricity in the planning of renovations and new buildings. In order to increase the standards and levels of ambitions total cost of ownership/life cycle costing has to be an integral part of the decision-making processes. Besides, new business models in social housing associations, ESCO systems, etc. are also ways forward to “move” the running costs to a resource efficient, long-term investment (section 3.2.1).

6. **From energy efficient buildings to sustainable communities**: In the near future buildings will become an active part of the energy system. For this reason, the traditional linear thinking of energy supply and consumption has to be changed to a dynamic and interactive understanding. A smart and sustainable energy system is cross-cutting all energy carriers: electricity, heating, gas, waste, etc. as well as the different sectors: buildings, industry, transport and communication.

7. **Intermediaries matter**: To what extent the good intentions in European and national policies on energy efficiency in buildings actually are implemented at the ground level is to a high degree dependent on which role the different intermediaries are playing. The competences of the craftsmen, the advice of the banks, the procedures of the building officials in the municipality, etc. are all crucial for the choices and behaviour of the users. In order to facilitate the up-take of new resource efficient and renewable energies in buildings the competences and procedures of the different intermediaries have to support the sustainable solutions. Smart solutions require smart people and smart partnerships.

8. **Policy mixes**: One shoe size does not fit all. A broad spectrum of policy instruments has to be available in the toolbox in order to increase the energy renovation of buildings. A mix of policies can require and facilitate this development. A strict building code for major renovations, pre-fab solutions, up-dated training of craftsmen planners and buildings owners and operators , special conditions for loans to energy renovations, awareness campaigns, etc. are all part of the solutions to a higher uptake of resource efficient renovations of existing buildings (Section 3.1).

Annexes

A-1 Literature

Aalborg Kommune (2011). Klimastrategi - Forebyggelse 2012-2015, Aalborg Kommune, August 2011.

Alkhatib, M. (2012). Optimering för kostnadse ektivenergie ektivisering vid ombyggnad. Kungliga tekniska högskolan Samhällsbyggnad Byggnadsteknik.

Alingsåshem (2012). The official homepage of Alingsåshem AB Housing Association. Online available: http://www.alingsashem.se/index.php?page=om-alingsashem [2012-12-12]

Andersen, H. S. (2007). Hvorfor er der behov for en social boligsektor i Danmark. Statens Byggeforskningsinstitut, marts 2007.

BBR19 (2011). Byggregler [Building Regulations]. Online available: http://www.boverket.se/Om-Boverket/Webbokhandel/Publikationer/2008/Building-Regulations-BBR/ [2012-12-12].

Beem-Up (2012) Building Energy Efficiency for Massive Market Uptake. Beem-Up Project report of the EU 7th Framework Programme. Online available: http://www.alingsashem.se/uploads/pdf/BEEM%20UP_sv_low.pdf [2013-12-12]

Berggren, B., Janson, U. & Sundqvist, H. (2008). Energieffektivisering vid renovering av rekordårens flerbostadshus [Energy efficiency renovations of the millionprogramme houses] , Lund University and Skanska Teknik. Report EBD-R—08/22.

Bertoldi, P., Rezessy, S., Lees, E., Baudry, P., Jeander, A. & Labanca, N. (2010). Energy supplier obligations and white certificate schemes: Comparative analysis of experiences in the European Union. Energy Policy 38, 1455-1469.

Bill 958 (2012). Bill to Parliament of amending the Land Use and Building Act. 2012; http://www.finlex.fi/fi/laki/alkup/2012/20120958

Botici, A. A., Ungureanu, V., Ciutina, A., Botici, A., Dubină, D., Fülöp, L. A. (2013), Sustainable retrofitting solutions for precast concrete residential buildings. Architectural and structural aspects. In: Ungureanu V., L Fülöp (editors). Opportunities in sustainably retrofitting the large panel reinforced concrete building stock. Editura Orizonturi Universitare, 2013, ISBN: 978-973-638-537-7.

Botici A. (2011), Current issues and approaches for retrofitting of large prefabricated concrete residential buildings, Seventh International PhD & DLA Symposium, 24-25 Oct. 2011, Pecs, Hungary, ISSN 1788 1994

Botici, A. A., Ungureanu, V., Botici, A. M., Dubină D. (2011), Interventii structurale pentru reabilitarea functionala a blocurilor de locuinte din panouri mari prefabricate (Structural Interventions for functional rehabilitation of apartments in panel buildings), Journal of the Association of Structural Engineers – AICPS; vol.3/2011, pag.53-67 (in Romanian)

Botici, A. A., Ungureanu, V., Ciutina, A., Botici, A. M., Dubină D. (2012), Sustainable retrofitting solutions for precast concrete residential buildings, Proceedings of the Third International Symposium on Life-Cycle Civil Engineering (IALCCE'12), Vienna, Austria, October 3-6.

Botici, A. A., Ungureanu, V., Ciutina, A., Botici, A., Dubina, D., Nagy, Zs., Fülöp, L. A., Riihimäki, M.J., Talja A. (2013), Sustainably challenges of residential reinforced-concrete panel buildings. Perspectives from Eastern and Northern Europe, The 6th edition of the research conference on constructions, economy of constructions, architecture, urbanism and territorial development "Challenges for Romania within Horizon 2020 - The EU framework program for research and innovation 2014-2020: Preparing European partnering in research and technological development for sustainable constructions and built environment", 18.10.2013, Bucharest, Romania

Botici, A. A., Ungureanu, V., Ciutina, A., Botici, A., Dubina, D., Nagy, Zs, Riihimäki, M.J., Talja, A., Fülöp L. A. (2014), Sustainability Challenges of residential Reinforced-Concrete Panel Buildings, Urbanism. Architecture. Constructions, Vol. 5 Issue. 2, 1.4.2014, pp. 83-98

Boverket (2009). Så mår våra hus. Redovisning av regeringsuppdrag beträffande byggnaders tekniska utformning m.m. [This is how our buildings are. Revision on the technical features of buildings]. Online available: www.boverket.se

Boverket (2010). Teknisk status i den svenska bebyggelsen– resultat från projektet BETSI. [The technical status of the Swedish building stock – results of the BETSI project]. Online available: http://www.boverket.se/Global/Webbokhandel/Dokument/2011/BETST-Teknisk-status.pdf

Boverket (2012). The dialogue project Building-Living and Property Management for a sustainable building and property management sector. Online available: http://www.boverket.se and www.byggabodialogen.se (30 October 2012)

BPIE (Buildings Performance Institute Europe) (2010). Cost Optimality – Discussing methodology and challenges within the recast Energy Performance of Buildings Directive

BPIE (Buildings Performance Institute Europe) (2011). Europe's buildings under the microscope - A country-by-country review of the energy performance of buildings. Buildings Performance Institute Europe: Brussels.

BPIE (Buildings Performance Institute Europe) (2012). Energy Efficiency Policies in Buildings – the use of financial instruments at Member State level. Buildings Performance Institute Europe: Brussels.

Buildup (2012). Romania: Romania: Second National Energy Efficiency Action Plan and Separate Listings for Article 10 of Directive 2010/31/EU, Online available http://www.buildup.eu/publications/20829on October 16, 2012.

Bundesamt für Energie (2011a). Grundlagen für die Energiestrategie des Bundesrates; Frühjahr 2011. Aktualisierung der Energieperspektiven 2035 (energiewirtschaftliche Modelle). Bern, Mai.

Bundesamt für Energie (2011b). Skizze des Aktionsplans Energiestrategie 2050 (in German). Bern, Mai

Bundesrat (2012). Faktenblatt 1 - Erste Massnahmen Energiestrategie 2050 (in German). Bern, April.

Chalmers EnergiCentrum. (2007). Uppvärmning av byggnader. Stockholm: Naturvårdsverket.

COWI (2008). Energibyen Frederikshavn - forretningsplan Analyse og plan. Frederikshavn Municipality, December.

Dahlberg, Å. (2009). Bygga-Bo Dialogen - Samlad slutbedömning 2007-2009 [Living-Building Dialogue - Final assessment 2007-2009] Online available: http://www.boverket.se/Global/Bygga_o_forvalta/Dokument/Bygga-Bo-Dialogen/Dokument-lankar/samlad_slutbedomning_2007-2009.pdf [2012-12-12]

Danfoss (2012) Danfoss Link™ CC - Central Controller, http://dk.varme.danfoss.com/PCMPDF/DanfossLink-CC_X002585_VDFZC201.pdf. May, 2012. Accessed December 23, 2014.

Danish Energy Agency (2010a). Lokalplansbestemmelser om energiklasser og bebyggelsesprocenter, http://www.ebst.dk/file/133399/Lokalplaner_energibestemmelser_og_BR10.pdf, 17.11.2012.

Danish Energy Agency (2010b). Bygningsreglementet Bygningsreglementet.dk, http://www.ebst.dk/file/131479/bygningsreglementet_br10.html, 14.11.2012.

Danish Energy Agency (2011a). Energistatistik 2011, Available at:http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Aarsstatistik/Documents/Energistatistik%202011.pdf.

Danish Energy Agency (2011b). Bygningsreglementet 7.4.1 Generelt Bygningsreglementet.dk, http://www.bygningsreglementet.dk/br10_02_id116/0/42, 14.11.2012.

Danish Energy Agency (2011c). Energiramme for nye bygninger, http://www.bygningsreglementet.dk/br10_02_id106/0/42, 24th October, 2012

Danish Energy Agency (2011d). Fælles bestemmelser for bygninger omfattet af bygningsklasse 2020, http://www.bygningsreglementet.dk/br10_02_id106/0/42, 24th October, 2012

Danish Enterprise and Construction Authorities (2011). Bygningsklasse 2020, Online available: http://www.ens.dk/da-DK/ForbrugOgBesparelser/IndsatsIBygninger/lavenergiklasser/Documents/baggrundsnotat_for_tyvetyve.pdf (24 October, 2012).

Danish Government (2011). Energy strategy 2050. Online available: http://www.ens.dk/Documents/Netboghandel%20-%20publikationer/2011/Energy_Strategy_2050.pdf, (February, 2011)

Danish Government (2012). Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti om den danske energipolitik 2012-2020, March, 2012

Danish Metrologic Institute (2012). Vejret i Danmark 2011. Available at: http://www.dmi.dk/dmi/vejret_i_danmark_-_aret_2011

Danish Ministry for Economic and Business Affairs & Danish Enterprise and Construction Authority (2010). Building Regulations. Online available: http://www.ebst.dk/

Danmark Statistics (2011). Website of the Danish Statistics Office, http://www.dst.dk

Decree (2012). Decree of the Ministry concerning the building energy efficiency in repair and construction work. 2012. http://www.ymparisto.fi/download.asp?contentid=136855&lan=fi

Department for municipal buildings of Zurich (Ed.) (2008). Sustainable Building – Standards for environmentally friendly and energy efficient buildings City Council resolution Nr. 1094, Zurich, September.

DOE – Weather Data: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

Dyhr-Mikkelsen K., Larsen, A. & Bach, P. (2005). Evaluation of Free-of-Charge Energy Audits. Proceedings of the ECEEE Summer Study Conference, 30 May - 4 June 2005, Mandelieu La Napoule, France.

Egger, K. et al. (2011). EnergieSchweiz für Gemeinden - Jahresbericht 2010 (Annual report of SEM, in German), Ettenhausen, Switzerland, March.

Energy Analysis, Niras, RUC & 4-Fact. (2008). En vej til flere og billigere energibesparelser: Evaluering af samtlige danske energispareaktiviteter, Rapport [A way to more and cheaper energy: Evaluation of all Danish energy saving activities]. Online availabel: http://www.ens.dk/

Energy Efficiency Watch. (2012). Survey Report: Progress in energy efficiency policies in the EU Member States – the experts perspective. Findings from the Energy Efficiency Watch Project. Online available: http://www.energy-efficiency-watch.org/fileadmin/eew_documents/EEW2/EEW_Survey_Report.pdf [2012-12-12]

Energy statistics for one-and two-dwelling buildings in 2005, p.11 (2005). Swedish Official Statistics; Statens energimyndiget och SCB, EN 16 SM 0601

ERUF-EKO (2011). Ekologisk omställning av efterkrigtidens bebyggelse [Ecological conversion of the housing areas built in the afterwar period]. Malmö stad: Holmbergs Tryckeri.

European Union (2010). DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings, Online available: http://www.energy.eu/directives/2010-31-EU.pdf (19th May 2010)

European Union (2012). First National Action Plan for Energy Efficiency (2007-2010), Online available: http://ec.europa.eu/energy/demand/legislation/doc/neeap/romania_en.pdf (October 16, 2012)

Feist, W. (2006). Factor 10 is a reality. Presented at the 15th Anniversary of the Darmstadt - Kranichstein Passive House.

Fülöp, L. A., Riihimäki, M. J. (2013). Opportunities in sustainably retrofitting of the large panel reinforced concrete building stock in East Europe, in Ungureanu V., L Fülöp (editors). Opportunities in sustainably retrofitting the large panel reinforced concrete building stock. Editura Orizonturi Universitare, 2013, ISBN: 978-973-638-537-7.

Fülöp, L.A., Ungureanu V., Ott, W., Bolliger, R., Jakob, M. (2013). Cost effectiveness of energy retrofit solutions – Results from generic calculations with a reference building in Romania, in Ungureanu V., L Fülöp (editors). Opportunities in sustainably retrofitting the large panel reinforced concrete building stock. Editura Orizonturi Universitare, 2013, ISBN: 978-973-638-537-7.

Fransson, S. (2012). Styrmedel för energieffektivisering av befintliga flerbostadshus [Policy instruments for improving energy efficiency of existing apartment buildings]. Thesis. LTH:Lund.

Frederikshavn Municipality (2008). Bosætning. Online available: http://frederikshavn.odeum.com/dk/fokusomraader/bosaetning/, 2008.

GI & Bygherreforeningen (2012) Bygningsgenerationer og renoveringsbehov – Scenarier

Government Bill. (2008). An Integrated Climate and Energy Policy (2008/09:163) Online available: http://www.regeringen.se/sb/d/108/a/126679 [2012-12-12]

Gram-Hanssen and Christensen (2011). Energy efficiency in existing detached housing. Danish experiences with different policy instruments, Hørsholm: Statens Byggeforskningsinstitut, SBI. 21 s. (SBi 2011:01). ISBN 978-87-563-1494-7

Gross, Nadja (2009). Die Bedeutung der Architekten für die energetische Erneuerung von Wohngebäuden. Masterthesis ETH Zürich, October.

Hall, T., and Vidén, S. (2005). The Million Homes Programme: a review of the great Swedish planning project. Planning Perspectives, 20(3), 301-328.

Hansen, U. B., Sørensen T. (2012). Håndbog om Grøn Lov og Praksis, Online available: http://www.energimidt.dk/Offentlig/Udelys/Artikler-om-udelys/Documents/haandbog-om-groen-lov-og-praksis.pdf, July.

Harvey, L. D. D. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. Energy Efficiency (special issue): How Far Does it Get Us in Controlling Climate Change?, 2(2), 139–163.

Heiskanen, E., Brohmann, B., Fritsche, U., Schönherr, N. & Aalto, K. (2010). Policies to Promote Sustainable Consumption: Framework For a Future-Oriented Evaluation. Pre-print version (Nov. 2009) - final version published at PIE, Vol 6 No 4, 2009.

Hiller C. (2003). Sustainable energy use in houses, Will the energy use increase with time?, Study of literature and computer estimations, Report TVBH-3041 Department of Building Physics, Lund Institute of Technology, Lund University.

IEE (2012). Energy Planning in Malmö (Sweden). PEPESEC PROJECT, Contract No. EIE-07-179-S12.466281, Deliverable No. 4.1. Online available: http://www.pepesec.eu, October.

Implementation plan for the Strategy for Renovation 2009–2017. Reports of the Ministry of the Environment 7/2009 (YMra 7/2009 Korjausrakentamisen strategian toimeenpanosuunnitelma 2009-2017, ISBN:978-952-11-3401-2. ISBN 978-952-11-3401-2 (PDF)) Online: http://www.ym.fi/download/noname/%7B095471F5-B20E-4ECC-AB9A-90B2E5C5AEC0%7D/31965

INNSE (2003). – Recensamantul populatiei si a locuintelor 18-27.03.2002 (Population and buildings census 2003).

International Energy Agency (IEA). (2007) Energy Policies of IEA Countries: Finland 2007 Review. Online available: http://www.iea.org/

International Energy Agency (IEA) (2008). Database of Energy Efficiency Policy Measures for Finland. Online available: http://www.iea.org/textbase/pm/

Jakob M., Kallio, S., Nägeli, B., Ott, W., Bolliger, R., von Grünigen, S..(2014). Integrated strategies and policy instruments for retrofitting buildings to reduce primary energy use and GHG emissions (INSPIRE) – Generic strategies for buildings in Switzerland – Swiss contribution to ERA-NET «ERACOBUILD». TEP Energy and Econcept on behalf of Swiss Federal Office of Energy (SFOE), Bern, March.

Jakob M., Jochem E., Christen K. (2002). Grenzkosten bei forcierten Energieeffizienzmass-nahmen bei Wohngebäuden, CEPE und HBT, ETH Zürich, Studie im Auftrag des Forschungsprogramms EWG des Bundesamts für Energie (BFE).

Jakob M., Jochem E., Honegger A., Baumgartner A., Menti U., Plüss I. (2006). Grenzkosten bei forcierten Energie-Effizienz-Massnahmen und optimierter Gebäudetechnik bei Wirt-schaftsbauten. Bundesamt für Energie (Hrsg.). Bern.

Jakob M., Grodofzig B., Gross N (2010). Energetische Gebäudeerneuerungen – Wirtschaft-lichkeit und CO_2-Vermeidungskosten. Auswertung des Gebäudeprogramms der Stiftung Klimarappen. TEP Energy, Meier+Steinauer, Hochschule Luzern i.A. Stiftung Klimarappen, Zürich.

Janson, U. (2010). Passive houses in Sweden - From design to evaluation of four demonstration projects. Lund University, Faculty of Engineering LTH, Report EBD-T--10/12. Online available: http://www.ebd.lth.se/fileadmin/energi_byggnadsdesign/images/Publikationer/Doc_avhandling_UJ_Bok_webb.pdf

Jensen, L. (2012). Kommunal facilitering af privat energirenovering. Online available: http://rudar.ruc.dk/bitstream/1800/8572/1/Specialerapport%20-%20Liselotte%20Jensen.pdf

Kessler et al (2005). Kosten und Nutzen von Solarenergie in energieeffizienten Bauten, Studie im Auftrag des Bundesamts für Energie, Forschungsprogramm Energiewirtschaftliche Grundlagen.

Khan, J. (2006). Evaluation of the Energy Audit Programme in Finland. Online available: http://www.aid-ee.org/

Københavns Kommune (2012). Inspiratlonskatalog: om lavenergibyggeri i nye byudviklingsområder, 15.11.2012.

Kragh J., Wittchen K. (2010). Danske bygningers energibehov i 2050, Statens Byggeforskninginstitut, Aalborg Universitet.

Kiss B. and Neij L. (2011). The importance of learning when supporting emergent technologies for energy efficiency — A case study on policy intervention for learning for the development of energy efficient windows in Sweden. *Energy Policy*, 39, 6514–6524.

Kiss, B. (2013). Building Energy Efficiency - Policy, learning and technology change. Doctoral Dissertation. IIIEE at Lund University. Online available: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=3738662&fileOId=3738663

Larsson, B., Elmroth, A. & Sandstedt, E. (2003). Västra Hamnen – Bo01 Framtidstaden. En utvärdering [Western Harbour – Bo01 The city of the Future. Evaluation]. Online available: http://www.malmo.se,(30 October 2012)

Lenzlinger et al. (2012). 2000-Watt-Gesellschaft – Bilanzierungskonzept (in German). Editors: EnergieSchweiz für Gemeinden, Stadt Zürich, Schweizerischer Ingenieur- und Architektenverein (SIA), Ettenhausen, March. Online available: http://www.2000watt.ch/data/downloads/Bilanzierungskonzept_2kW_Experten2012_neu.pdf

Mahapatra, K., Gustavsson L., Mid Sweden University; Haavik, Trond Aabrekk, Synnøve Segel AS; Vanhoutteghem, Lies, Svendsen, Svend DTU; Paiho, Satu Ala-Juusela, Mia VTT Technical Research Centre of Finland (2012). One-stop-shop service for sustainable renovation of single-family house, Nordic Innovation Publication 2012:21.

Malmö City. (2009). Environmental Programme for the city of Malmö 2009-2020. Malmö stad: Environmental Department

Malmö City (2010). Ansökan till Delegationen för hållbara städer: Hållbar Stadsutveckling Malmö – från Öst till Väst [Application for the Delegation of Sustainable Cities: Sustainable Urban Development Malmö – from East to West]. Malmö stad

Malmö City (2012). Rosengård i förvandling [Rosengård changes]. Broschure. Online available: http://www.malmo.se/hallbararosengard (October 2012)

Maneschi, D. (2012). Emerging actors in sustainable renovations of single family houses, In Proceedings of the 15th European Roundtable on Sustainable Production and Consumption, Bregenz, Austria

Maneschi, D., Strandgaard, C.K., Sperling, K. (2013). Local action policies to increase energy efficiency: the changing role of municipalities, Paper presented at World Sustainable Energy Days 2013, Wels, Austria.

McCormick, K. & Neij, L. (2009). Experience of Policy Instruments for Energy Efficiency in Buildings in the Nordic Countries. Lund October 2009. Online available: http://www.lowcarbonoptions.net/Downloads/files/Norway_EE_policyIns.pdf

McCormick K., Neij L. (2009). Experience of Policy Instruments for Energy Efficiency in Buildings in the Nordic Countries. International Institute for Industrial Environmental Economics at Lund University. Online available: http://www.cerbof.se/documents/Projekt/Rapporter/Slutrapport_CERBOF_projekt_65.pdf [2012-12-12]

Menti U.P., Gadola R., Plüss I., Klauz S., Ménard M. (2010). Gesamtenergieeffizienz von Bürobauten mit tiefem U-Wert - Optimierung der Gebäudehülle vs. Optimierung der Gesamtenergieeffizienz. Hochschule Luzern – Technik & Architektur und Lemon Consult i.A. Bundesamt für Energie (BFE), Stadt Zürich, Amt für Hochbauten, Amt für Umwelt und Energie BS, Bern.

Möller, B. (2010) Analyser af varmebehovets geografi, varmebesparelser og udvidelser af fjernvarmedækningen In: Poul Alberg Østergaard (ed.) (2010) Baggrundsrapport for Energivision for Aalborg Kommune 2050, available at http://www.turas-cities.org/uploads/biblio/document/file/66/AalborgKommune-Baggrundsrapport3103.pdf, accessed on December 23, 2014

Mundaca L., Neij, L. (2009). An implementation guide for the use and development of the EEB_Sweden Model v1.0; IIIEE report, Lund University.

Müller M., S. Ulli-Beer (2012). “How can the diffusion of energy-efficient renovations be accelerated? Policy implications from a system dynamics modelling study for Switzerland.” Proceedings of the 30th International System Dynamics Conference, July 22 - 26, 2012, St. Gallen, Switzerland.

Middelfart Municipality (2009). Middelfart kommune, Online available: http://www.goenergi.dk/publikationer/baggrundsnotater/esco-i-middelfart-kommune, November 2012.

Middelfart Municipality (2011). Pressemeddelelse, Middelfart Kommune vinder ’European Energy Service Award 2010’ 26th September 2011.

Ministry of Environment (2012). The National Building Code of Finland. Annex to the explanatory memorandum for the Ministry of Environment Decree on improving the energy performance of buildings undergoing renovation or alteration : Calculation. (Unoffical translation) Online available: http://www.ym.fi/download/noname/%7B4AAFEDEB-B199-4D23-BB5A-48084328513D%7D/57172

Ministry of Social Affairs and Integration (2011). Vejledning om totaløkonomiske merinvesteringer i nye lavenergiboliger i alment byggeri m.v. Ministry of Social Affairs and Integration.

Nagy-György T., Fülöp L., Demeter I., Panelépületek felújítása – Miért? Miként? (Rehabilitation of Panel Buildings – Why? How?), Conference on Civil Engineering and Architecture – EPKO, June 2012 (in Hungarian)

Nagy Z., Fülöp L., Talja A. (2012). Are we too capitalists for a comfortable life? business models for future and existing flat building administration, Quality - Access to Success, Volume 13, Issue SUPPL.5, 2012, Pages 205-210.

NEEAP (2007). Finland's National Energy Efficiency Action Plan (NEEAP 2008-2010). Ministry of Trade and Industry, Ministry of Transport and Communications, Ministry of Agriculture and Forestry, Ministry of Finance, Ministry of the Environment. June. Online available: http://ec.europa.eu/energy/demand/legislation/doc/neeap/finland_en.pdf

NEEAP (2011). Sweden's Second National Energy Efficiency Action Plan. Adopted at the Cabinet meeting of 30 June 2011. Online available: http://www.buildup.eu/publications/20833 [2012-12-12]

NEEAP (2011). Finland's Second National Energy Efficiency Action Plan (NEEAP-2). Report for the European Commission under Article 14 of the Energy Services Directive (32/2006/EC). June. Online available: http://www.buildup.eu/sites/default/files/content/FI%20-%20Energy%20Efficiency%20Action%20Plan%20EN.pdf

Neij L. (2004) Metoder för utvärdering av klimatpolitiska styrmedel. [Methods for the evaluation of climate policy instruments]. Report for the Swedish Environmental Protection Agency.

Neij L., Kiss B., Jakob M. (2012). Heat Pumps – Innovation and Diffusion Policies in Sweden and Switzerland. Global Energy Assessment – Toward a Sustainable Future. Cambridge University Press, Cambridge UK and New York, NY USA and the International Institute for Applied System Analysis, Laxenburg, Austria.

Official Journal of the European Union: European Commission, Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012, supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings, 2012/C 115/01; Official Journal of the European Union, C 115/1 - C 115/28, 19.4. 2012

Ott W., Jakob M., Baur M., Kaufmann Y., Ott A., (2005). Mobilisierung der energetischen Erneuerungspotenziale im Wohnbaubestand. Econcept und CEPE, ETH Zürich im Auftrag des Programms "Energiewirtschaftliche Grundlagen (EWG)" des Bundesamtes für Energie. Zürich, Bern.

Ott W., Klingler G (2007). Einsatz von Sonnenkollektoren auf dem Gebiet der Stadt Zürich - Markthemmnisse und Massnahmen zu ihrer Überwindung, econcept, ewz, Zürich 2007.

Ott. W., Klingler G., Rom N. (2011). Die Zukunft leitungsgebundener Versorgungssysteme, econcept i.A. von BFE/EWG, AWEL Kt. ZH, VSG, Fernwärme Zürich, Erdgas Zürich, Industrielle Werke Basel.

Ott W., Philippen D., Umbricht A. (2009). Energieeffiziente Baustandards für Neubauten: Energie- und Treibhausgaseinsparungen und Mehrkosten bis 2030, econcept i.A. von Alpiq, Zürich, Dezember.

Ott W., Philippen D., Umbricht A., Baumgartner A., Vogel U., Jakob M, Gross N. (2011). CO2-Vermeidungskosten bei der Erneuerung von Wohnbauten (CO2-Abatement Costs of Energy Related Renovation Measures of Residential Buildings). i. A. Bundesamt für Energie (BFE). Bern, Juni.

Palm, J. (2004). Makten över energin—policyprocesser i två kommuner 1977–2001 [Power over energy – policyprocesses in two municipalities 1977-2001]. Linköping Studies in Arts and Science No. 289, Linköpings Universitet.

Palm, J. (2006). Development of sustainable energy systems in Swedish municipalities: A matter of path dependency and power relations, Local Environment: The International Journal of Justice and Sustainability, 11:4, 445-457

Roshardt, S. (2007). Evaluation of the Bonus for a Free Consultation for Energy Savings in the Building «Erfolgskontrolle Energieberatungsgutschein», Sibylle Roshardt for the : Department for Construction, Traffic and Environment, Canton of Aargau, Switzerland, July 2007

Salminen, J. (2009). Municipal energy conservation agreements in Finland. Online available: http://www.energychange.info/

SCB/STEM (2006). Energy statistics for one- and two-dwelling buildings in 2005. Statistics Sweden and Swedish Energy Agency. Report # EN 16 SM 0601. Available at http://www.scb.se/statistik/EN/EN0102/2005A01/EN0102_2005A01_SM_EN16SM0601.pdf

SCB (2007). Bostads- och byggnadsstatistisk årsbok 2007. Statistics Sweden. Available at http://www.scb.se/statistik/_publikationer/BO0801_2007A01_BR_BO01SA0701.pdf

SCB (2010). National accounts. Statistics Sweden. Available at http://www.scb.se/Pages/ProductTables____11052.aspx

SIA (2009). Thermische Energie im Hochbau, Schweizerischer Ingenieur- und Architektenverein, SIA 380/1:2009, Schweizer Norm SN 520 380/1.

SKAT (2012). Håndværkerfradrag (servicefradrag), Online available: https://www.skat.dk/SKAT.aspx?oId=1947018, (24 October, 2012)

Skanska (2012). The official Skanska project homepage. About Brogården Project. Online available: http://www.skanska.se/sv/Projekt/Projekt/?pid=7318 [2012-12-12]

SMHI: Swedish Meterological and Hydrological Institute, http://www.smhi.se/en

Smedby, N. & Neij, L. (2012). Experiences in urban governance for sustainability. Unpublished manuscript.

SP (2010). SQUARE - Ett system för kvalitetssäkring vid renovering av befintliga byggnader till energieffektiva byggnader. Slutrapport från det svenska pilotprojektet Brogården. [SQUARE – A quality assurance system for energy efficient building renovations. Final report of the Swedish pilot project Borgården]. Online available: http://www.iee-square.eu/InformationPublications/Reports/SQUARE_Pilot_project_Sweden_SE.pdf

SP (2009). SPCR 114 - Certifieringsregler för P-märkning avseende Innemiljö. [Certification rules on the P label with regards to indoors environment.] Online available: http://www.sp.se/sv/units/certification/product/Documents/SPCR/SPCR114.pdf

SR 1907-1/97 (1997). Heating plants; Design heating requirements computation for buildings; Computation specifications (in Romanian).

Strandgaard C. K. (2012). Energirenovering i håndværkernetværk, Aalborg, 2012.

Summerton J. (1992). District heating comes to town: the social shaping of an energy system. Linköping Studies in Arts and Science No. 80, Linköpings Universitet.

Swedish Ministry of Sustainable Development (2006). National programme for energy efficiency and energy-smart construction: Fact sheet.

Swiss Federal Office of Energy (2011). Determinants of the implementation of energy policy measures by the cantons «Determinanten des Vollzugs energiepolitischer Massnahmen auf kantonaler Ebene»: Thomas Widmer, Felix Strebel, Institute for political Science, University of Zurich; for the Swiss Federal Office of Energy, July 2011: «Steuerliche Anreize für energetische Sanierungen von Gebäuden»: Dr. Martin Baur (Swiss Federal Tax Administration, Lead), Dr. Lukas Schneider (Swiss Federal Tax Administration), Margit Himmel (Federal Finance Administration), Dr. Lukas Gutzwiller (SFOE), Stefan Wiederkehr (SFOE), Felix König (Federal Housing Office), Joint working group of the Swiss Federal Tax Administration, Swiss Federal Office of Energy, Swiss Federal Housing Office and the Swiss Federal Finance Administration. Swiss Federal Office of Energy, July 2011.

TABULA (2012). Byggnadstypologier Sverige [Building typologies for Sweden]. Mälardalen University in the frame of the Tabula Project. Online available: http://episcope.eu/fileadmin/tabula/public/docs/brochure/SE_TABULA_TypologyBrochure_Mdh.pdfTogeby M., (2012). Evaluering af energiselskabernes energispareaktiviteter, Ea Energianalyse, NIRAS, Viegand og Maagøe, 18.05.2012.

Togeby M., (2012). Evaluering af energiselskabernes energispareaktiviteter, Ea Energianalyse, NIRAS, Viegand og Maagøe, 18.05.2012.

Togeby, M., Dyhr-Mikkelsen, K., Larsen, A., Hansen, M.J. & Bach, P. (2009). Danish energy efficiency policy: revisited and future improvements. Online available: http://www.eceee.org/summer_study/

Tommerup, H. & Svendsen, S. (2006). "Energy savings in Danish residential building stock", Energy and Buildings, vol. 38, no. 6, pp. 618-626.

Tommerup, H., Rose, J. & Svendsen, S. (2007). "Energy-efficient houses built according to the energy performance requirements introduced in Denmark in 2006", Energy and Buildings, vol. 39, no. 10, pp. 1123-1130.

I. Tuca, D. Dubina, Sustainable Retrofitting of Precast Concrete Residential Buildings, Seventh International PhD & DLA Symposium, 24-25 Oct. 2011, Pecs, Hungary

Ungureanu V., Fülöp L., (editors) (2013). Opportunities in sustainably retrofitting of large panel reinforced concrete building stock, Editura Orizonturi Universitare, Timişoara, Romania, 2013.

UNFCCC (United Nations Framework Convention on Climate Change) (2007). Report of the centralised in-depth review of the fourth national communication of Denmark. Online available: http://unfccc.int/

UNFCCC (United Nations Framework Convention on Climate Change) (2006a). Report of the centralised in-depth review of the fourth national communication of Finland. Online available: http://unfccc.int/ (2012-12-12)

UNFCCC (United Nations Framework Convention on Climate Change) (2006b). Report of the centralised in-depth review of the fourth national communication of Sweden. Online available: http://unfccc.int/ [2012-12-12]

Ürge-Vorsatz, D., Eyre, N., Graham, P., Harvey, D., Hertwich, E., Jiang, Y., Novikova, A. (2012). Chapter 10 - Energy End-Use: Building. In Global Energy Assessment - Toward a Sustainable Future (pp. 649–760). Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria: Cambridge University Press.

V&S PrisData (2012). http://www.byggecentrum.dk/data-og-software/vs-prisdata/

Vækstfonden(2012), Ansvarlige lån, http://www.vf.dk/saadan-goer-vi/ansvarligt-laan.aspx, accessed December 23, 2014.

Volland B, Gessler R., Püntener T. (2011). On the way to the 2000-watt society Zurich's path to sustainable energy use. Publisher City of Zurich, Office for Environmental and Health Protection Zurich (UGZ), Zurich, April. http://www.stadt zuerich.ch/content/dam/stzh/gud/Deutsch/Ueber%20das%20Departement/2000-Watt/Publikationen_und_Broschueren/OnTheWayToThe2000WattSociety.pdf

Wade, J., Guertler, P., Croft, D. & Sunderland, L. (2011). National energy efficiency and energy saving targets – further detail on Member States. 24 May 2011. Online available: www.eceee.org [12 May 2012]

Wallbaum H., Jakob M., Heeren N., Toloumis Ch. (2010). 7-Meilenschritte - Wirkungsanalyse anhand des Gebäudeparkmodells Stadt Zürich. ETH Zürich und TEP Energy i.A. Stadt Zürich, Amt für Hochbauten, Fachstelle nachhaltiges Bauen, Zürich, Mai.

Wallbaum H., Jakob M., Heeren N. (2012). Towards a 2000 Watt society – assessing building-specific saving potentials of the Swiss residential building stock. International Journal of Sustainable Building Technology and Urban Development, DOI: 10.1080/2093761X.2012.673917, May 2012: pp. 43-49. http://www.ibi.ethz.ch/nb/publications/papers/2011_SB11_Heeren_et_al._published.pdf.

Wegner J, Stokar M, Hoffmann C, Winsauer G, Binz A, Bürgi P (2010). Untersuchung von Mehrkosten von Minergie-P – Bauten.

Wittchen K. B., Kraggh J. (2012). Danish building typologies - Participation in the TABULA project, Danish Building Research Institute, Aalborg University.

Whyte, J., Sexton, M. (2011). Motivations for innovation in the built environment: new directions for research. Building Research and Information, 39 (5). pp. 473-482. ISSN 1466-4321 doi: 10.1080/09613218.2011.592268

Zeyer Ch. (2008). Die Wirkungen von MuKEn, Minergie und Minergie-P – Kombinierte Energie- und Kostensimulation zur Untersuchung der Auswirkungen des Bauherrenentscheides für einen Standard bezüglich Kosten. E Plus U i.A. Bundesamt für Energie (BFE), Bern.

A-2 Interviews

The following Table presents interviews as data sources for Chapter 3 and Chapter 4. For the Danish and the Swedish cases, more detailed interviews were carried out with experts and practitioners in the field; for the cases in Finland, Romania and Switzerland, project partners were interviewed.

Name of interviewee	Organization (affiliation)	Date of interview
Denmark		
Søren Grøn	Sanden Bjerggaard (manager)	29 March 2011*
Jan Gjøl	Sparekassen Vesthimmerland, Brovst (manager)	30 March 2011
Jan Skov	Sparekassen Vesthimmerland, Vrå (manager)	30 March 2011
Ulrik Kristensen	Kai Rasmussen (owner, electrician)	30 March 2011
Poul Hansen	Verner Ranum (employee)	29 March 2011
Finn Pretzmann	Energy Consultant (self-employed)	29 March 2011
Sweden		
Trevor Graham	Malmö City (director)	13 May 2011
Lena Eriksson	Malmö City (manager)	22 June 2011*
Roland Zinkernagel	Malmö City (manager)	15 April 2011
Åse Danneman	MKB Housing Company (manger)	15 June 2011*
Ulla Janson	MKB Housing Company (manager)	26 June 2012
Kristina Mjörnell	SP (consultant)	18 June 2012
Kjell Hult	Alingsås Municipality (director)	21 May 2012
Ing-Marie Odengren	Alingsåshem Housing Company (director)	23 May 2012*
Ulf Alexandersson	Alingsåshem Housing Company (manager)	6 July 2012*
Martin Jorlöv	Skanska AB (manager)	22 May 2012*
Hans Eek	Passivhuscentrum (director, architect)	20 June 2012
Helena Westholm	EFEM (architect)	11 May 2012
Kerstin Nilsson	Architect	20 June 2012
Anders Bernestal	Andersson & Hultmark Consutling (energy designer)	3 July 2012
Arnoud Vink	WSP (consultant)	2 July 2012
Carina Corriere	Hyresgästföreningen (project coordinator)	22 May 2012
Finland		
Asko Talja	VTT (manager)	25-29 September 2012
Sirje Vares	VTT (researcher)	20 September 2012
Ludovic Fülöp	VTT (manager)	25-29 September 2012
Pertti Koivisto	City of Tampere (Property management manager)	15 August 2012
Romania		
Viorel Ungureanu	"Politehnica" University of Timisoara (researcher)	25-29 September 2012
Alexandru Botici	"Politehnica" University of Timisoara (researcher)	25-29 September 2012
Ludovic Fülöp	VTT (manager)	25-29 September 2012
Switzerland		
Martin Jakob	TEP Energy (director, research engineer)	25-29 September 2012
Walter Ott	Econcept (director, research engineer)	25-29 September 2012
Roman Bolliger	Econcept (manager, researcher)	25-29 September 2012

** More than one interview was carried out, the date of the first interview is indicated in the table.*