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Tero Ahonen, Mika Luoranen, Jero Ahola,
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APPLYING NORDIC ENERGY EFFICIENCY AND RENEWABLE ENERGY SOLUTIONS IN KALININGRAD OBLAST, RUSSIA

RENSOL

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Abstract

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RENSOL (Regional Energy Solutions) project deals with the use of Nordic energy efficiency and renewable energy solutions in Kaliningrad Oblast to tackle the climate change. Overall objective of the RENSOL work package 1 is to build awareness and knowledge on solutions for energy efficient buildings and street lighting applications. This project report describes available solutions to improve housing energy efficiency.

Firstly report discusses about barriers and possible solutions related to the housing energy efficiency improvements. Nordic solutions to improve energy efficiency in buildings are then introduced. Energy efficiency in street lighting applications is also studied. Two example cases in Kaliningrad Oblast are finally studied with a modelling tool, and their energy efficiency improvement potentials are determined. Based on the obtained results, suggestions for improvement actions are given. Finally, generalised conclusions are formed according to the obtained results.

Contents

Executive summary

Here, main findings of the conducted study are listed:

- There is need both for political and financial instruments supporting energy efficiency actions, and practical guidance for conducting successful energy efficiency improvements. Especially motivation or even regulation towards energy renovations and having sustainable financing methods for them are seen important factors.
- Technically there are proved solutions available that can be used for improvements: in practice, it is important to have a clear plan on renovations that will be done, so correct technical solutions can be selected for the building. Also the forthcoming changes (e.g. improved district heat availability) should be asked from the municipality, as they affect feasibility of different technical solutions.
- Simulation tool can be used to have indicative results for the building energy efficiency, and the effect of different actions can be tested with it. However, the simulation tool cannot consider leaking pipes, opened windows, non-operating heaters etc. that have a notable effect on the building energy consumption. Therefore, site inspections and interviews are as important to determine the present condition of the building and possibilities for technical improvements: for instance, ineffective use of electrical appliances and waste of heat can be detected by site inspections.
- In the studied cases, improvement of heating system operation (both space and water heating), ventilation and insulation were seen important factors to improve both housing energy efficiency and quality of living. However especially insulation-related improvements tend to be costly and laborious, which is why they may not be the most realistic alternative for older buildings. In such cases, improvements in heating system operation should also look through if some parts of the building are unnecessarily warm, and there is no possibility to control the room temperature energy efficiently.
- Besides heat, energy savings can also be obtained with the more efficient usage of

electricity (LED lighting, energy efficient appliances, etc.).

- Of the studied renewable energy solutions, air heat pumps, sun collectors and PV solar panel systems are seen as a feasible topic for future study. As an example, separate electric water boilers could be replaced with a centralized solution where a sun collector or a heat pump is used to heat water instead of direct electric heating. Related to this, also other sources of waste heat (exhaust air, waste water) can be used as a heat source for domestic water heating where applicable. However, the practical use of these solutions can be limited by the building structure and available area for the devices. Therefore, the feasibility of having new devices in the building needs to be studied case by case.

Chapter 1

1 Introduction to RENSOL project

RENSOL (Regional Energy Solutions) project deals with the use of energy efficiency and renewable energy solutions in Kaliningrad Oblast to tackle climate change. The project is divided into five work packages with the following main targets:

- WP 1 builds knowledge on possible solutions through identification of the latest energy efficient and renewable energy solutions in Finland, Sweden and Denmark, and adapting them to the Kaliningrad context. Besides this project report, a study trip to Nordic countries has been organized in spring 2012 as a part of this work package to realize new partnerships and co-operation. Work in the WP 1 has especially produced partnership between Lappeenranta University of Technology (LUT), Immanuel Kant Baltic Federal University (IKBFU) and Environmental Center "ECAT-Kaliningrad", which is closely used in the Green Light project for having video conference between Finnish and Russian students [Norden, 2013]. Also the production of common research papers both in English and in Russian by LUT and IKBFU is under consideration.
- WP 2 deploys the obtained knowledge of WP 1 by producing an analysis of existing energy saving street lightning (LED) projects in municipalities of Kaliningrad Oblast and presenting an analysis of best available technologies (BAT) on energy efficient housing and accommodating financial mechanism to stimulate deployment of energy efficient technologies in buildings.
- WP 3 promotes the use of energy management standards via onsite training of Russian representatives by European energy experts and by organizing a seminar focusing on theories and standards for energy management according to the international energy management standard, ISO 50001.
- WP 4 studies feasible Financing Models required for up-scaling and realizing the proposed energy efficiency improvement actions. Proven Nordic financing models and their applicability to the Kaliningrad oblast will be analyzed and these results are documented as a project publication.
- In WP 5, the obtained results are multiplied to other regions of Northwest

Russia. Clear feasible plans for the project results multiplication are produced in this work package.

Overall objective of the RENSOL work package 1 is to build awareness and knowledge on solutions for energy efficient buildings and street lighting applications. The research for RENSOL WP 1 has been done by literature reviews containing both scientific and marketing publications; by interviews with experts in Finland and in Russia; and by site inspections, simulation studies and renovation cost analyses for two example cases in Kaliningrad Oblast. The studied cases comprise a soviet-era kindergarten and residential building, which were selected as examples of typical public and private buildings in Kaliningrad Oblast.

In WP 1, co-operation has been done between Lappeenranta University of Technology, Environmental Center "ECAT-Kaliningrad" and Immanuel Kant Baltic Federal University for producing feasible renovation proposals for the example cases in Kaliningrad Oblast. ECAT-Kaliningrad and IKBFU have communicated with involved municipality personnel from Svetlyj and Gurievsk, who have given permission to make practical installations and also provided realistic feedback concerning the practicality of given renovation proposals.

Besides project-related discussions, a possibility for writing research papers in co-operation with IKBFU has arisen during the project for having further academic collaboration between LUT and IKBFU. In addition, LUT, ECAT-Kaliningrad and IKBFU are also organizing video conferences between Finnish and Russian students about energy and energy saving for the Green Light project during autumn 2013.

The research findings and proposals of RENSOL WP 1 are further used in the work package 2 by ECAT-Kaliningrad for deploying practical knowledge in small scale pilots. This work package has especially involved communication with local municipal organizations and their personnel, as for instance kindergarten buildings and street lighting systems are under the responsibility of municipalities. In practice, good communication is essential here to ensure that the municipality is actively participating to the project and the proposed efficiency improving solutions are understood and accepted by the municipality personnel.

In addition, the research findings related to the possible financing models and practical barriers can be utilised as background information in work packages 4 and 5.

This report is the documentation of research findings and proposals in RENSOL WP 1, introducing Nordic solutions to improve energy efficiency in buildings. Based on available knowledge, basic framework for realizing a successful energy efficiency improvement project is first explained. Two example cases in Kaliningrad Oblast are then studied with a modelling tool, and their energy efficiency improvement potentials are determined. Based on these results, suggestions for actions are given.

This report is divided to nine main chapters with the following contents after this introduction chapter:

Chapter 2 provides a basic introduction to barriers and issues that prevent energy efficiency improvements in buildings. It also shows generic action recommendations and reviews Nordic solutions allowing improvements in building energy efficiency. Especially political and financial possibilities are studied in the chapter. Chapter also introduces main points of a successful energy renovation project that aims to the improvement of building energy efficiency.

Chapter 3 presents Nordic products and solutions allowing improvements in building energy efficiency. Especially technical possibilities are studied in the chapter including also the energy efficiency of electrical appliances.

Chapter 4 discusses on the energy efficient street lighting. It provides main guidelines for having lighting renovation project and presents some pilot cases, where lighting energy efficiency has been improved with the use of LED lighting technology.

Chapter 5 describes main parts of the energy renovation projects that aim to improvement of building energy efficiency. Finnish energy renovation examples with their documented effects are also presented in the chapter.

Chapter 6 introduces methodology and tools that were used to evaluate two pilot buildings studied in this project. Also reasons for selecting the example cases are highlighted in the chapter.

Chapter 7 introduces the kindergarten building, evaluation results for its insulation-related energy efficiency and suggestions for further actions with rough cost approximations.

Chapter 8 studies a five floor residential building with the corresponding evaluation for its insulation-related energy efficiency. Suggestions for further actions are again given with rough cost approximations.

Chapter 9 provides the summary of this study and obtained results.

Chapter 2

2 Factors affecting energy efficiency in buildings

Energy consumption in building is affected by its technical characteristics and appliances, condition, location and surrounding climate, and by the people living in the building. Therefore effective improvement of building energy efficiency requires not only technical improvements, but also behavioural changes.

Realization of improvements can be helped through regulations or by motivating building owners with education and economic benefits such as incentives. The topic has been thoroughly studied in the Energy Efficiency in Buildings (EEB) project organized by World Business Council for Sustainable Development [WBCSD, 2009], where the following three levers were given for improving energy efficiency in buildings:

1) The right financial mechanisms and relationships to make energy more valued by those involved in the development, operation and use of buildings, and to stimulate investment in energy efficiency.
2) A holistic design approach, from city level to individual buildings, to encourage interdependence and shared responsibility among the many players in the building value chain. This relates to integrated design, incentives that stimulate whole building action rather than encouraging changes only to individual elements and using advanced technology as part of an integrated solution to energy reduction.
3) Behavioural changes to achieve action on energy efficiency by building professionals and building users. A variety of approaches are needed to motivate people, including mobilization campaigns, clear incentives, training and education.

This chapter points out practical barriers that should overcome in order to improve housing energy efficiency. Chapter also introduces practical actions that need to be done to realize energy efficient buildings.

2.1 Practical barriers

EEB project has identified several barriers for improving energy efficiency in public and multi-family residential buildings, which describe well the situation also in Russia:

- Split incentives – meaning that the benefit of energy savings does not go to the person making the investment. This is especially true in buildings, where heating costs are not paid by the building owner, or the user and owner are financially two different instances.
- Tenants have no incentive or motivation to save energy, for instance heating costs may be fixed, or there is no possibility to control heating system operation. In Russia, possibility to save heating energy is often limited, as buildings are directly connected to the district heating network (no room-independent possibility to control temperature) and the energy price does not motivate to improvement actions.
- Financial constraints – multi-family housing residents often have low incomes. Although they stand to save the highest percentage of income, they are likely to have the greatest difficulty paying for efficiency improvements.
- Misperceptions – energy efficient, multi-family housing is still perceived in the marketplace to be much more expensive to build than standard construction. This should be remembered when new buildings are designed. In the case of older buildings, costs of the insulation-related energy renovation may become substantial, meaning that the energy renovation may be as costly as constructing a new building.
- Building market sector in general is diverse and complex: as a typical building project has several participants with different roles. Therefore efficiency improving actions should be supported in all levels.

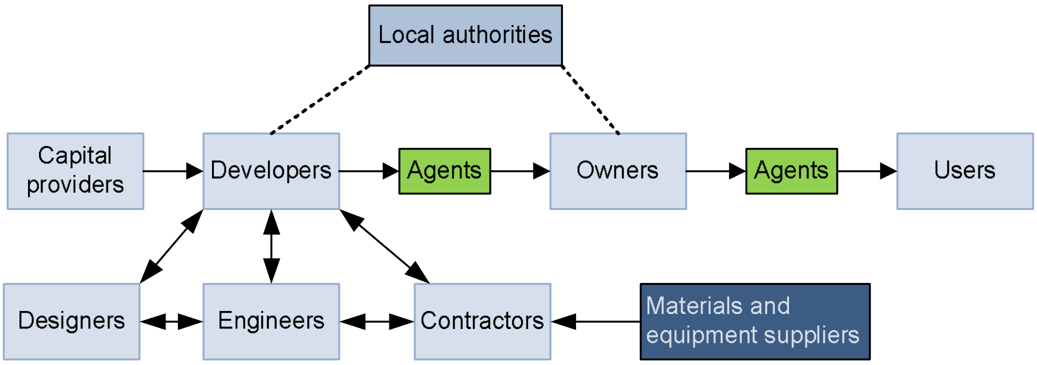


Fig. 2.1: Commercial relationships in the building supply chain. Complexity of interactions among these participants is one of the barriers to energy efficient buildings. [WBCSD, 2009].

Besides the generic levers, The EEB project has resulted six recommendations to generally overcome the noticed barriers for improving building energy efficiency:

1) Strengthen building codes and labelling for increased transparency.
2) Incentivize energy-efficiency investments.
3) Encourage integrated design approaches and innovations.
4) Develop and use advanced technology to enable energy-saving behaviours.
5) Develop workforce capacity (expertise) for energy saving.
6) Mobilize for an energy-aware culture.

Of these actions, improvement of possibilities to have incentives for energy-efficiency investments and feasible energy-saving technologies are studied further in this project report.

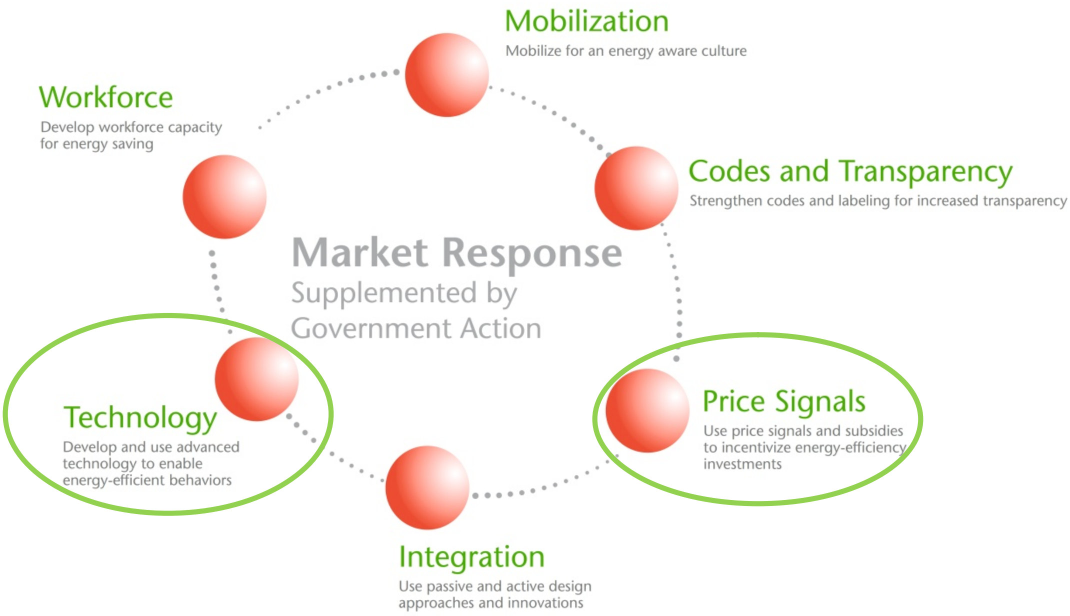


Fig. 2.2: Recommendations of EEB project. This project report focuses on the feasible energy-saving technologies and financial instruments supporting energy efficiency improvements in housing. [WBCSD, 2009].

2.2 Political measures in Nordic countries

The Nordic countries have often been seen as "fore-runners" of energy efficiency in buildings – in both the implementation of policy instruments and the evaluation of effects. Since the 1970s, the Nordic countries have introduced a range of policy instruments for energy conservation in buildings. The choice of instruments and experiences however differs between countries. This chapter represents main findings originally given in [Kiss, 2010].

Over several decades the Nordic countries have introduced a number of policy instruments for a more efficient use of energy in buildings, e.g. building codes, subsides, labels and declarations, information campaigns and energy taxes. However, the choice of instruments and the experiences differs between the countries: we can talk about a Swedish way with the use of extensive subsidies, a Finnish way with focus on voluntary measures, a Danish way by actively implementing different types of policy instruments including their evaluations, and a Norwegian way with the focus on training and education. Examples of policy actions in Nordic countries are shown in Table 2.1 and in Fig. 2.3.

Table 2.1: Some of policy measures for improved efficiency in households in Nordic countries [Nordic Council of Ministers, 2007].

Country	Measure
Finland	Energy conservation program for municipalities and non-profit housing properties (2002)
	Energy conservation program in oil-heated buildings (2002)
Denmark	Energy saving activities by electricity, natural gas and DH companies (2001)
	Energy labeling of larger buildings (1997)
	Energy labeling of smaller buildings (1987)
	Energy labeling of electrical appliances (1993)
Norway	Grants to electricity savings in households (2003)
	Labeling and energy efficiency requirements on appliances (1996)
Sweden	Grant to convert from electric heating or fossil fuels to DH or heat pumps (2006)
	Information campaign (2006)
	Energy declarations (2006)

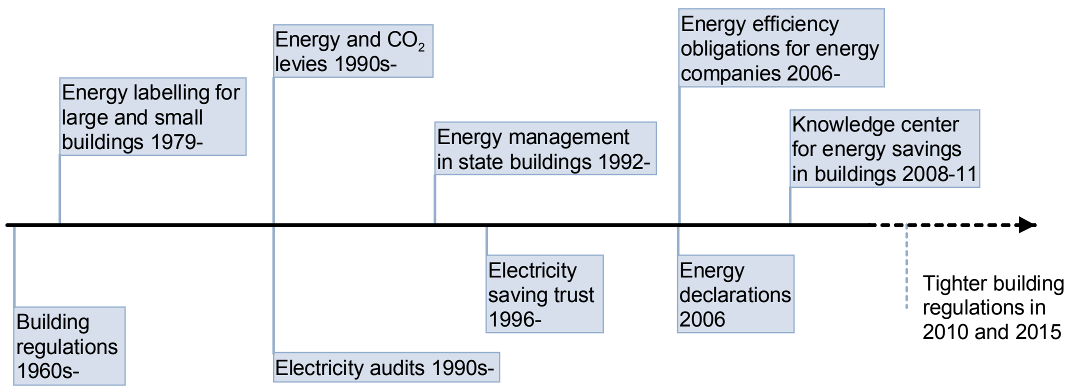


Fig. 2.3: Timeline of key policy instruments implemented in Denmark [Kiss, 2010].

Basically the instruments can be classified as:

- Traditional policy instruments, including building codes, regulations, subsides and taxes, supported by information campaigns and education.
- Innovative policy instruments, such as initiatives for networking between diverse actors in the building sector, high performance building codes as a voluntary option, technology procurement, labels, declarations, and

professional trainings on energy efficiency.

- Policy evaluations.
- Organizational matters.

Typical examples of policy instruments are the energy and carbon taxation, different measures (campaigns, networking, building codes) towards energy efficiency and fiscal support for increased use of renewable energy sources and energy efficient devices [Nordic Council of Ministers, 2007].

2.2.1 Traditional policy instruments

Regulatory instruments such as building codes and regulations are generally viewed as one of the most effective ways to improve housing energy efficiency – if their enforcement can be ensured. In Denmark, the evaluation conducted by Energy Analysis, Niras, RUC and 4-Fact states that building codes have been important in reducing energy consumption in new buildings. There are high expectations for the long-term and strategic tightening of building codes in 2010 and 2015 in Denmark. Finland has also taken stricter building codes in use in 2012.

In general, economic instruments show diverging results. They can lead to high savings, and can also be helpful to kick-start a market, but they can also be less effective. With taxes, we can internalize negative externalities, increasing energy prices.

For instance, taxes can be used to regulate energy consumption via higher costs. However, there are limits on how much taxes can be raised and the impact of higher prices, especially in the longer term. Taxes should be combined with strong advocacy efforts that convey a general knowledge of energy efficiency and provide specific guidance on how energy efficiency can be realised. Taxes and awareness should then also be combined with instruments that support the introduction of new technologies, such as research and development, technology procurement, public procurement, and strategic investment. Energy taxes together with support for the use of energy efficient solutions have shown to be effective to support energy efficiency in the Nordic countries.

About information activities, it is often very difficult to evaluate their impact and actual effect. However, this should not undermine the importance of information activities in supporting other policy instruments and raising the profile of energy efficiency in general.

2.2.2 Innovative policy instruments

Within the Nordic countries a number of innovative policy instruments have been developed over time. Such instruments include initiatives for networking. Cooperation with diverse actors in the building sector is required for increased energy efficiency, particularly for promoting and implementing very low energy buildings.

To further promote enhanced energy efficiency in buildings, high performance building codes as a voluntary option is suggested in several countries. This can be a guideline for those that want to go beyond the average standards and create foundations for greater innovation. In addition, Nordic countries are developing additional voluntary standards for passive and low energy houses.

Greater and targeted support for professional training or education on energy efficiency for architects, engineers, designers and professionals in the building industry appears also to be a necessary foundation for a market for energy efficiency.

2.2.3 Organizational matters

Organizational structures related to energy efficiency are often dispersed in the Nordic countries. One exception may be the Danish Electricity Saving Trust. One way to better coordinate information operations and activities on energy efficiency may be to invest in such an energy trust, as the Electricity Saving Trust in Denmark. This trust would be able to coordinate and strategically work with energy efficiency in general and specifically work with campaigns, subsidies, and provide qualified advice and training for households and enterprises. Furthermore, it could work on coordination between the players on the market. Funding could be through government and private funds or through a fee that is channelled through energy bills.

Dedicated research centres on buildings and energy efficiency, such as the Research Centre on Zero-Emission Buildings established in Norway, appear to be important to create a critical mass of expertise that can carry out regular, in-depth and scientific research and evaluations. This centre is an exciting development for research on zero-emission buildings in Norway, but also for the Nordic countries. The ambitious vision of the centre is to eliminate the GHG emissions caused by buildings.

2.2.4 Policy evaluations

Improvement of energy efficiency over the long term will require different types of policy instruments at different stages. As stated in [Kiss, 2010], except for the case of Denmark, where an overall policy assessment had been carried out, there is no strategic evaluation approach with a focus on how to improve learning. In Finland, both ex-ante and ex-post evaluations are conducted, mainly concerning the possible energy savings and GHG emission reductions as well as the impact of EU Directives the evaluations are undertaken in a rather sporadic manner. It is also seen that the vast majority of policy evaluations focus on cost effectiveness and economic efficiency with less emphasis on innovation effects. Furthermore, across the Nordic countries, existing policy instruments in the whole have had very moderate effects on innovation, typically resulting in incremental changes in existing building practices and diffusion of existing technology. Market transformation, improved networking between diverse actors, and new technologies and systems are vital to realising more significant energy savings in buildings.

2.3 Suggested mechanisms for financing capital repairs and energy efficiency improvements in multi-family apartment buildings

Possibilities and practical barriers for energy efficiency improvements in Russian residential buildings have been extensively studied within the "Program on improving urban housing efficiency in the Russian Federation" [EBRD, 2012a]. Especially the report on key measures for capital repairs of residential buildings lists different applicable renovations that can be carried out for residential buildings [EBRD, 2012b]. The report proposes three different renovation packages that can be carried out for the building. Of the proposed packages, the energy efficient option contains following actions:

1. Measures designed to improve heat retention properties (heat insulation) of

enclosing structures of buildings, such as roof and walls.

2. Measures aimed at a complete reconstruction (replacement) of in-building utility services, such as heating system and water pipes.
3. Measures to improve heating and hot water supply systems in buildings allowing controlling the firing rate for heating and hot water supply. In this case, heat loss due to imbalance of supply and demand (in a building) is reduced.
4. Measures designed to install single-building utility meters (heat energy meters, electricity meters, cold and hot water meters and natural gas meters).
5. An energy-saving measure consisting of installation of occupancy sensors in public spaces. This measure allows to automatically control light intensity in public spaces.

The project has also provided proposals to have sustainable financing solutions to realize these renovations. According to project summary for policymakers, sustainable financing requires

1. Regular contributions (on a compulsory basis, by all apartment owners) into a dedicated fund for maintenance and repair (the "collective building repair fund") – an essential prerequisite in every multi-family apartment building.
2. Credit facilities extended by commercial banks to Homeowners' Associations, Housing Cooperatives, or Housing Management Companies, facilitated through residents' regular payment of contributions for the repair and maintenance of their building, held in a dedicated account or collective building repair fund for that purpose.
3. Financial support from government in the co-financing of capital repair projects and the provision of state guarantees to banks through dedicated state financial development institutions (guarantee agencies, specialized state banks, investment funds, and so on).

The project report also lists practical issues that need to be considered, such as current legislation in Russia that does not oblige building residents to be members of the Homeowners' association or other form of collective residents' association for the building [EBRD, 2012c]. In addition, project summary introduces a financing model that could be taken into use to improve possibilities for having energy renovations (see Fig. 2.4).

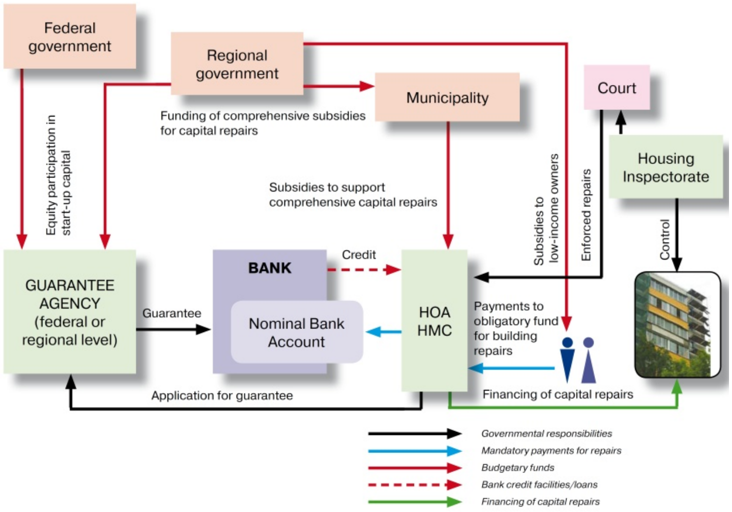


Fig. 2.4: Main actors and their functions in the proposed financing model for building renovations (capital repairs) [EBRD, 2012c].

2.4 Realization of a successful energy renovation project

Main steps of an energy renovation project according to [RIL 249-2009] are shown in Fig. 2.5. It is generally recommended that the building owner should have a **long-term renovation plan** ("building strategy") with certain objective state for the building technical condition, which works as the basis for renovations.

When the renovation project is decided to be started, the current condition of the building needs firstly to be determined. **Condition inspection** should give information on the technical condition and repair need of the building. Depending on the renovation need, the inspection can have separate, detailed studies on the building condition (e.g. material study of concrete walls) or it can be just a generic, visual study of the building condition. In practice, the visual study can also consider the present use and condition of the building, resulting in a list for improvements and renovation needs in the building. In any case, the condition inspection should provide **a report on the building condition and a long-term plan or suggestions for the renovation**. If possible, condition inspection should be performed by an independent professional, as an erroneous inspection report may lead to unneeded or inefficient repairs.

In practice, these suggestions need to consider the previously mentioned objectives of the renovation: if the objective is to have a low-energy building, then required actions may be more costly than in the case of building with B or C energy class. However, these can be compensated over time by lower energy consumption resulting in lower life-cycle costs. Therefore general objectives of the renovation need to be defined for instance according to their economic and technical effects. Improvement of building energy efficiency to a certain level (for instance from E to B level) or optimization of building life-cycle costs are the typical objectives for the renovation project.

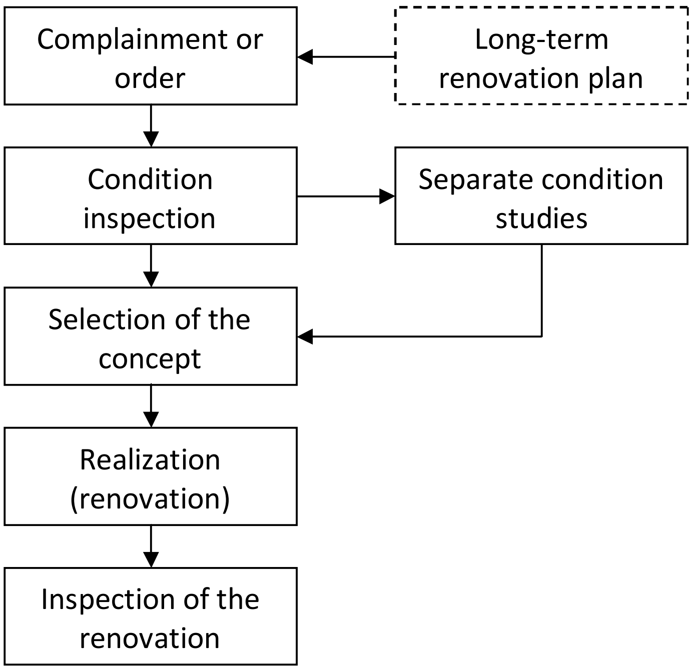


Fig. 2.5: Main flowchart of a renovation project [RIL 249-2009].

When the building owner or consultant has knowledge on the general renovation objectives and current technical condition of the building, he can choose different concepts to reach this objective state: an energy renovation can contain improvement of building insulation (walls, floor, roof), replacement of windows, improvement of ventilation system with heat recovery, decrease of water and electricity consumption etc. with different product alternatives and different levels of costs. Often this project phase is recommended to be carried out by an experienced consulting company, which can suggest and compare different possible concepts and provide basic design documents for the renovation (needed for renovation inquiries), although indicative calculations can be done with existing calculation spread sheets. It is also very important that the consulting company has understanding on the local technology: for instance insulation improvements may not decrease building heat consumption at all, if the district heating system and related water radiators do not have thermostats. Correspondingly a ventilation system with heat recovery is useless if the air leakage in the building is too significant. Selection of the concept may require detailed analysis on the effects of different improvements on the building energy efficiency: for instance selection of renovation actions for walls and ventilation system are done in this phase. Main reasons (both economic and technical) for the selected concept and renovation actions should however be understandable by the building owner.

When the concept has been selected and renovation actions have been decided, basic design documents can be used as a template for final design documents and also as a basis for bidding competition on the actual renovation. Often it is most beneficial that the same consulting company takes care of the final design documents, and selection of the construction company, if they have knowledge on the local companies. If several companies are participating to the renovation, the consulting company should be able to coordinate the actual renovation.

When the energy renovation has been carried out according to local regulations, it should be verified afterwards. This means both technical inspection of the renovation and also determination if the energy renovation has been successfully improved energy efficiency of the building.

Chapter 3

3 Review of Nordic Best Technologies for Energy Efficiency Improvements

This chapter presents Nordic practices and different technical solutions that can allow improvement of energy efficiency in housing. Introduced products are seen applicable for energy renovation projects. Renewable energy sources are also presented in this chapter, main focus being in the solar energy systems that can be installed and used separately for each building.

3.1 Technologies allowing improvements in building energy efficiency

Known and proved solutions to improve building energy efficiency are retrofitting the building insulation, replacing the old heating systems, use of heat recovery systems in ventilation, and also improvement of electrical appliances such as lighting systems. There are several Nordic manufacturers providing products to realize these savings. Therefore, this chapter introduces some products (and manufacturers), which could be used in the improvement of building energy efficiency. Contents of the chapter are partially based on Norden report "Nordic Energy – clean, clever and competitive" [Norden, 2008].

In the EU, 40% of energy is consumed in buildings, more than either in transport (32%) or industry (28%). Partly because of its large share of total consumption, the largest cost-effective savings potential lies in the household (27%) and commercial buildings sector (30%):

- In households, retrofitted wall and roof insulation offer the greatest opportunities to save energy, while improved energy management systems are important for commercial buildings.
- 2/3 of energy used in European buildings is accounted for by households; their consumption is growing every year as rising living standards are reflected in greater use of air conditioning and heating systems. Half of the projected increase in energy need for air conditioning – expected to double by 2020 – could be saved through higher standards for equipment, particularly for electrically driven cooling units. In addition, minimizing energy use inside

buildings (lightning, kitchen machines etc.) or using non-electricity-based cooling methods could essentially reduce the demand for electricity.

- 10 million boilers in European homes are more than 20 years old; their replacement would save 5% of energy used for heating. Significantly more could be saved by switching to renewable sources of energy.
- 30-50% of lighting energy could be saved in offices, commercial buildings and leisure facilities by using the most efficient systems and technologies, such as Light Emitting Diodes (LED).

Nordic companies offer intelligent, efficient and integrated solutions for reducing the energy consumption inside buildings, for HVAC, building automation, lighting, domestic hot water and waste management. Many of these companies offer complete tailor-made solutions specified to customer needs that are often designed to be used in combination with renewable sources of energy, especially geothermal, such as ground heat pumps, or solar-based systems.

3.2 Insulation products, windows and doors for buildings

As regulations concerning building energy consumption have tightened over the years, it has also increased requirements for the insulation of the building, which is normally the main component affecting the building heating energy consumption. There are several product manufacturers, such as Paroc and Isover, who provide **insulation products** for buildings. These products can be used during façade and roof renovations to improve building energy efficiency.

As an example, Paroc is participating to Innova project, where prefabricated façade elements with substantial insulation are used to renovate a 1970s Finnish apartment building into a passive building (see Fig. 3.1). This approach provides several benefits including lower costs, faster renovation process and no need construction scaffolds or overall covering of the building. Paroc is also providing products and concepts for new passive houses, marketed under the name “Energywise house” [Paroc, 2012a].

Fig. 3.1: Paroc's passive house concept is based on prefabricated facade elements with substantial insulation and energy efficient windows [Paroc, 2012b].

Windows and doors are typical sources for air and heat leakages, which is why their correct selection and installation is important to ensure pleasant and energy efficient living atmosphere, when a façade or window renovation is carried out. Nowadays window manufacturers (e.g. Tiivi Oy) have products even with A+ energy classification, meaning a 3+2 layered window with the *U* value of 0.67 W/m^{2}K. As a comparison, the present *U* value requirement for windows and doors in Finland is 1.0 [RakMK C3, 2010]. Correspondingly also doors are available with *U* value below this limit.

U value and energy class: 0.87 A 1.1 B 0.78 A 0.85 A 0.67 A+

Fig. 3.2: Examples of Tiivi window models and their U values [Tiivi, 2012].

3.3 Heating, ventilation and air conditioning systems

Typical buildings' heating systems in the Nordic countries are electric heating, district heating, oil heating, heat pumps and wood heating. There are some others heating types also, but those are not very common. [Statistics Finland, 2012] Electric heating can be divided into storage, partial storage and direct heating systems. In turn, air-air heat pump, air-water heat pump, exhaust air heat pump, ground source heat pumps are the most common heat pump systems.

The need for heating capacity is based on the demand for space heating and warm water heating. Demand of needed heat and warm water capacity is dependent of building type and size. All available heating system alternatives cannot work for the both systems or as a main heating system [Motiva, 2012]. For instance, air-air heat pump cannot heat the warm water or it cannot be a main heating system. On the other hand, it should be noted that requirements for the heating system between new and existing buildings may be different. In practice, it might be difficult and economically unprofitable to change heating system e.g. from direct electric heating system to district heating system, if the building structure does not allow easy installation of water radiators. Correspondingly, the existing district heat system may not allow installation of air-water heat pump

In existing **district heat systems**, update of the system components and addition of controllability are key possibilities to reduce heat energy consumption in buildings, if this is allowed by the building insulation. Practically, district heat systems should be two-circuit systems, meaning that the building heating system is separated from the municipal district heating network. This provides several advantages that are more discussed in detail in [Eliseev, 2011].

Gebwell's G-Power unit is an example of device used in Finnish kindergarten and apartment buildings to separate municipal network and building's own heating system. This unit contains circulation pumps, valves and control system allowing basic control of the heat distribution.

Fig. 3.3: Gebwell G-Power district heat unit that can be used to separate municipal and building heat network from each other, allowing controllability of the distributed heat. [Gebwell, 2012].

Besides having controllability with two-circuit systems, living quality in buildings with district heat can be improved with the **renovation of water radiators**. If the radiators are installed with **thermostats**, significant energy savings can be obtained as heat water consumption can be limited according to the desired room temperature.

Enervent Oy Ab produces **domestic and commercial ventilation applications**. The company uses also heat pump technology combined with heat recovery. Heat pumps that represent green technology allow differences in temperatures to be used to provide energy efficient domestic and industrial heating and cooling. Heat recovery is a way of ensuring that heat is recovered from exhaust air and returned for use inside building rather than being lost to the outside air. This means better efficiency and lower heating bills.

Enervent has introduced the Greenair HP to meet growing market requirements for effective air handling systems. The system is suitable for new construction or renovation projects, particularly for buildings where external units are restricted by planning regulations as some models have no outside units; everything is installed inside the building. “Once in operation, the Greenair HP offers long term energy savings and up to 40% reduced energy bills. Hence, payback times can be as short as only two to three years compared to cooling and heating combined with traditional ventilation with no energy recovery,” points out Mr Timo Luukkainen, Managing Director at Enervent.

The Greenair HP combines heat pump technology with rotating heat exchangers. A heat exchanger works by capturing and storing heat from the warm exhaust air and then transferring this energy to the fresh air before it is blown into the rooms. The rotating or regenerative heat exchanger used by Enervent has a yearly efficiency that can be up to 85%. Competing technologies by comparison can in sub-zero temperatures often achieve between 30 and 40% efficiency.

Regenerative heat exchangers can save energy also in cooling by reversing their action. Heat exchange technology can also be combined with heat pumps, or any other source of heating for smaller or larger installations. The company offers a versatile control system that works automatically to provide precise ventilation control according to user requirements. Ventilation can be regulated by carbon dioxide and humidity levels. The control system automatically regulates heating and cooling also taking into account seasonal differences.

Fig. 3.4: Enervent’s Greenair HP unit is a combination of ventilation system with heat recovery and of a heat pump [Enervent, 2012].

In the case of **buildings with a natural ventilation system**, renovation and installation costs can notably affect the feasibility of having mechanical ventilation system: if the natural ventilation system is working correctly (e.g. there is no visible moisture in windows) and if the installation of ventilation ducts is not easily possible, then the installation of mechanical ventilation system with required ducts may not be economically justifiable [jENERGIA, 2011]. If there are problems with the natural ventilation operation, at least the air inflow to the building can be easily improved with **air supply valves**. If possible, these valves should be separate parts that are installed through the wall or window [Terveysilma, 2013]. A less efficient, but easier to install option is to have new windows with integrated air supply valves or to install valves onto the windows [Dry-Air, 2013].

If natural ventilation operation cannot be improved enough in an existing building and it is replaced with a mechanical ventilation system, it should have high heat recovery efficiency: besides the needed ductwork for the ventilation system, the efficiency of the heat recovery system is major factor affecting the payback time of the renovation [jENERGIA, 2011]. In buildings having already ducts for the exhaust air (typical in Finnish residential buildings), installation of new ventilation system with heat recovery is often a justified action, if additional ducts can be installed to the apartments.

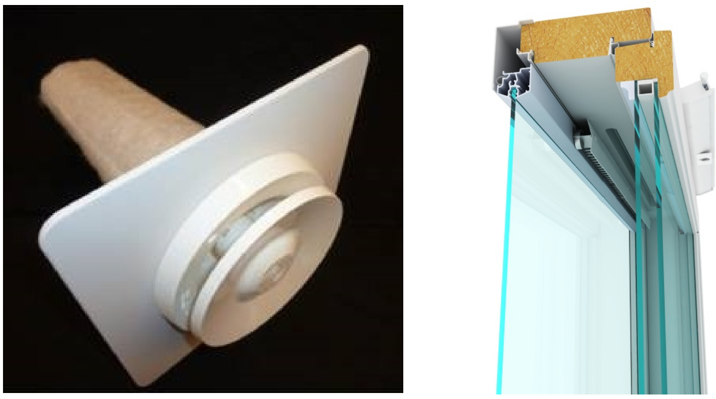


Fig. 3.5: Air supply valves provided by VELCO and Dry-Air Oy in Finland. [Terveysilma, 2013], [Dry-Air, 2013].

Air heat pumps produced for instance by IVT Nordic are an applicable alternative to improve heating energy efficiency, if the original heaters are used with electricity and ease of installation is important. As air heat pumps can be installed onto the wall, they are good alternative for additional electric heaters, if both heating and cooling are needed in the building. Air heat pumps are also feasible choice for domestic water heating that is often realized with electric boilers in Russia. Following technical details describe some benefits of air heat pumps [IVT Nordic, 2012a]:

- Heating power 0.9-6.5 kW with 0.16-1.7 kW electricity consumption (flow rate within 5.7-11.2 m^3/min)
- Cooling power 0.9-4.0 kW with 0.2-1.25 kW electricity consumption (flow rate within 5.2-9.3 m^3/min).

More costly, but also more efficient heat pump solutions use **geothermal energy**. As these solutions require more space for their installation (see Fig. 3.6 as an example), their applicability with existing buildings or in the case of single building is seen limited in the city area. Practical questions are that is there applicable space for heat pipes and are there limiting regulations affecting the installation.

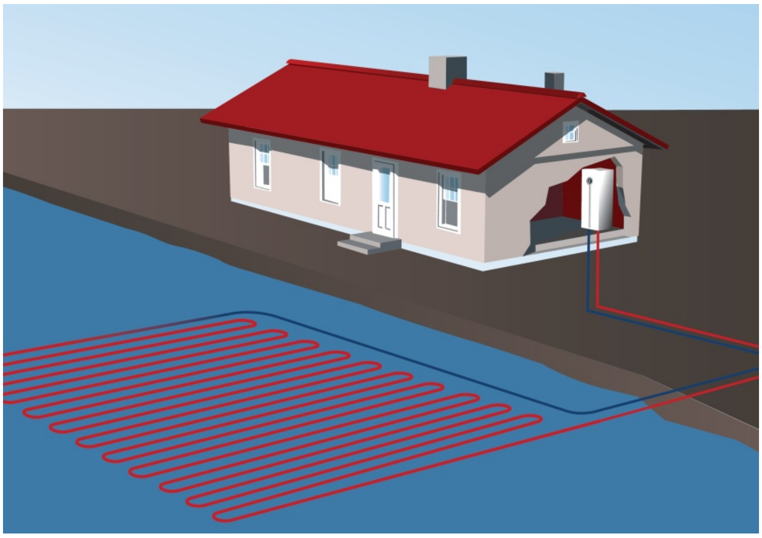


Fig. 3.6: Geothermal heat pump system requires installation of piping to the ground or for instance to the sea [IVT Nordic, 2012b].

However, if buildings are located near seawater or lake, and if the geothermal heat pump system can be connected to a municipal (district) heating network providing heat to several buildings, then the geothermal heating system can be considered as a potential source of clean heating energy for larger number of buildings. As an example, Suvilahti residential area in Vaasa, Finland is using geothermal energy from the seawater as a source for heating and cooling of 42 buildings [Mateve, 2008]. Practically the residential area has a separate low-energy network, from which each building is taking the needed heating/cooling with a heat pump [Motiva, 2010]. Informed results from the project are promising, indicating a good example of area-wide energy efficiency improvement project.

3.4 Energy efficiency in electrical appliances

Electricity consumption has increased during the last decades and it has been predicted that consumption will also increase in the future. Electricity consumption varies a lot in different buildings and between different appliances. In [Adato, 2006], residential electricity consumption has been forecasted in future with the methods of business as usual (BAU) and best available technique (BAT). The results are presented in table 3.1.

Table 3.1. Residential electricity consumption in 2006, 2015 and 2020 in Finland. Technical saving potential in 2015 and 2020 [Adato, 2006].

		BAU	BAT	BAU	BAT	Saving potential	
	2006	2015	2015	2020	2020	2015	2020
	GWh	GWh	GWh	GWh	GWh	GWh	GWh
Refregerating appliances	1 627	1 405	1 028	1 227	767	377	459
Cooking	653	683	618	693	577	65	116
Dishwasher	261	288	266	290	268	22	22
Washing	392	412	357	423	347	56	77
Entertainment electronics	834	1 177	888	1 076	860	289	215
Computer appliances	408	323	121	240	87	202	153
Sauna heater	852	930	930	971	971	0	0
HPAS-appliances	669	741	545	809	566	196	243
Under floor heating	206	221	221	227	227	0	0
Car heating	218	221	221	225	225	0	0
Indoor lighting	2 427	2 233	843	2 002	845	1 389	1 157
Outdoor lighting	89	95	21	99	22	75	77
Others	2 572	2 600	2 600	2 650	2 650	0	0
Total	**11 207**	**11 336**	**8 657**	**10 931**	**8 412**	**2 669**	**2 519**

Despite that results of the table are made for Finland, it can be seen that indoor lighting has the greatest saving potential in energy efficiency of electrical appliances. The next greatest saving potential can be achieved from the refrigerating appliances and HPAS-appliances.

Indoor lighting can be executed in the many ways. EU energy efficiency directive prohibited using of incandescent lamps. Some typical lighting trends have been listed in [Adato, 2006], which are:

- the amount of lamps in households is increasing;
- improvement in the quality of lighting;
- the amount of fluorescent lamps is increasing.

Approximately, more than a tenth of all electricity consumption is consumed in lighting in Finland. For instance, lighting at school might consume a fifth and hospital a third of the all electricity usage in that kind of buildings. Recently has been a lot of talk of removing of light bulbs from the markets. Many other changes in lighting sector in Europe will also appear in the future. For example in Finland, the biggest parts of the street lighting have been lighted with mercury lamps, which will get off the markets in the next years. [Motiva, 2009]

The Energy Service Directive obliges to Finland to use electricity more efficiently. The Directive emphasizes the role of public sector to achieve the targets. EU's EcoDesign Directive orders about lighting: [Motiva, 2009]

- Import of mercury lamps in the markets will be forbidden in the beginning of 2015.
- New fluorescent lighting systems have to include electronic ballasts from 2017.
- Light bulbs will be removed from the markets in stages by 2012.

Energy saving potential in lighting can be 30-70 % depending on the building by the latest technology, modern lighting control system and refinement of the saving targets. Energy consumption in lighting is depending on many things: lamps, lighting, the position of lighting, electronic ballasts and control system. The using light only when it is needed, is one of the most important things. It is good to understand that decreasing of electricity consumption does not necessary decreasing of quality and the amount of light. The new technology can improve the quantity and quality of lighting and still save in operational costs. [Motiva, 2009]

If the traditional T8 2x36W fluorescent lamps, including the electronic ballast and lighter, are replaced by the modern T5 1x35W fluorescent lamps, decreases the overall costs by 30%. This calculation includes investment, energy costs, service and maintenance. [Motiva, 2009]

3.5 Renewable energy sources

Renewable energy sources such as photovoltaic solar panels, solar energy collectors and wind turbines offer possibilities to improve housing energy efficiency. Especially solar panels and collectors can be used to replace electrical water heaters during summertime. In a sun collector system, solar thermal radiation is absorbed by the collector panel typically mounted on the house roof. From there heat is carried by the heat transfer fluid and passed to the hot water tank through the exchange coil [Rica, 2012]. For instance, Rica, ROTO and Savo-Solar provide sun collector systems both in Finland and Russia.

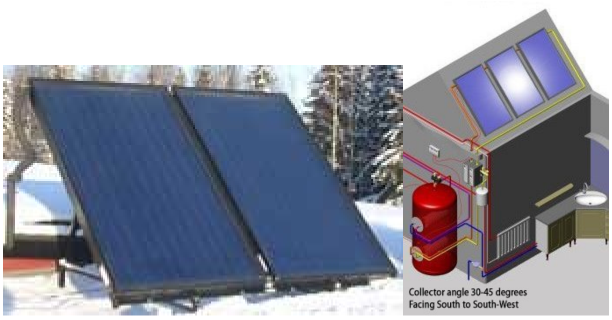


Fig. 3.7: Sun collector system provided by Rica can be used for water heating [Rica, 2012].

Another option is to use photovoltaic (PV) solar panels to produce electricity into the building or to the electricity network. In such case, there can be PV solar panels on the building roof, and an inverter that converts the produced electricity onto the alternating current. An example of such installation is located for instance in Lappeenranta, Finland, and the 2.95 kW plant has been able to produce 1780 kWh of electricity during five months.

Fig. 3.8: PV solar plant on the roof of residential building in Lappeenranta, Finland.

Germany is currently a world-leading country considering the solar energy products and use of solar energy, as individuals have a possibility to connect PV solar systems into the network and have a feed-in tariff (remboursement) on the produced electricity. The same approach is currently proposed to be taken in use in Finland and in other Nordic countries. Some examples of known solar system manufacturers are SMA Solar Technology AG and SunPower Corporation.

Besides PV solar panels, wind turbines are an option to generate electricity locally. However, there are several reasons why solar panels are more feasible solution for renewable energy:

- Panels have no moving parts requiring maintenance
- Easier installation, no need for separate construction permits
- Wind turbines are more prone to mechanical failures (high winds, lightning).

Third alternative option to generate electricity could be the use (or atleasting updaring) of micro-sized CHPs (combined heat and power) plants for buildings, and natural gas as the energy source. Fig 3.9 presents an example of possible benefits in using a CHP system instead of separate generation of heat and electricity.

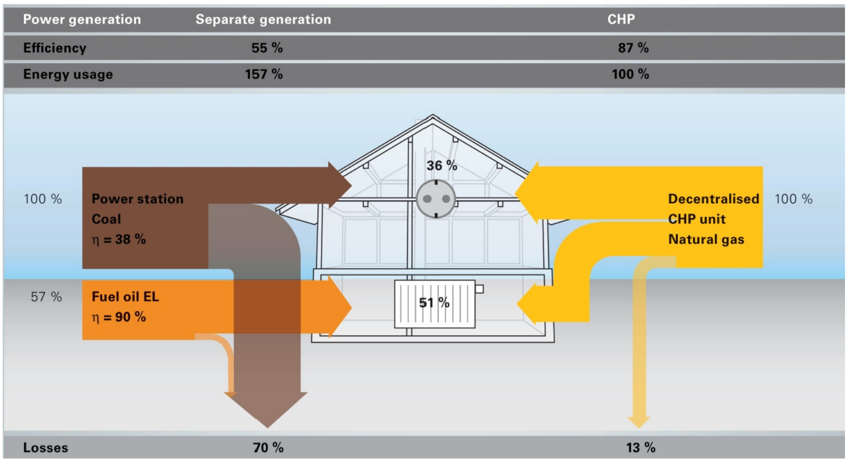


Fig. 3.9: Efficiency comparison of natural-gas-based CHP and separate generation of heat and electricity [Viessman, 2012].

3.6 Summary

There are several technical solutions allowing improvements in the housing energy efficiency. Of the introduced solutions, improved insulation, control of the heating, and sufficient ventilation with heat recovery are seen as effective methods to improve both housing energy efficiency and quality of living. Renewable energy sources are available in different scales, and for instance micro CHPs can provide additional option for using natural gas. For this project, tests with air heat pumps, solar PV panels or sun collectors are seen technically possible because of their easier installation and lower costs compared to the CHP units and wind turbines.

Chapter 4

4 Energy efficient street lighting

Street lighting is one of the most visible and expensive responsibilities of a city or community: inefficient lighting wastes significant financial resources each year, and poor lighting creates also unsafe conditions. It is shown that energy efficient technologies and design can cut street lighting costs dramatically, often by 25-60%. In Europe, annual savings 38 TWh of electricity could be reached by use of intelligent streetlights (adaptive lighting).

This chapter introduces solutions for energy efficient street lighting and also goes through the generic steps to increase energy efficiency in the street lighting. Contents of the chapter are based on references [E-Street, 2007] and [USAID, 2010].

Generally the most common reasons for inefficient street lighting systems in municipalities are:

- Selection of inefficient luminaries
- Poor design and installation
- Poor power quality
- Poor operation and maintenance practices

It is shown in E-Street project that as much as 50-70 % of the original energy consumption can be saved by reinvesting in new technologies where old inefficient luminaries have been replaced, lighting arrangements have been changed and stepless dimming in relation to adaptive lighting has been introduced. By replacing the luminaries only, between 40-50 % energy reductions is achieved.

Fig. 4.1 introduces generic steps for project to increase energy efficiency in street lighting. As a basis, requirements and needs set for the lighting should be known to determine the best available technology and design to meet the lighting requirement. Existing lamp technologies are listed in Table 4.1 and further information on their characteristics can be found from [USAID, 2010].

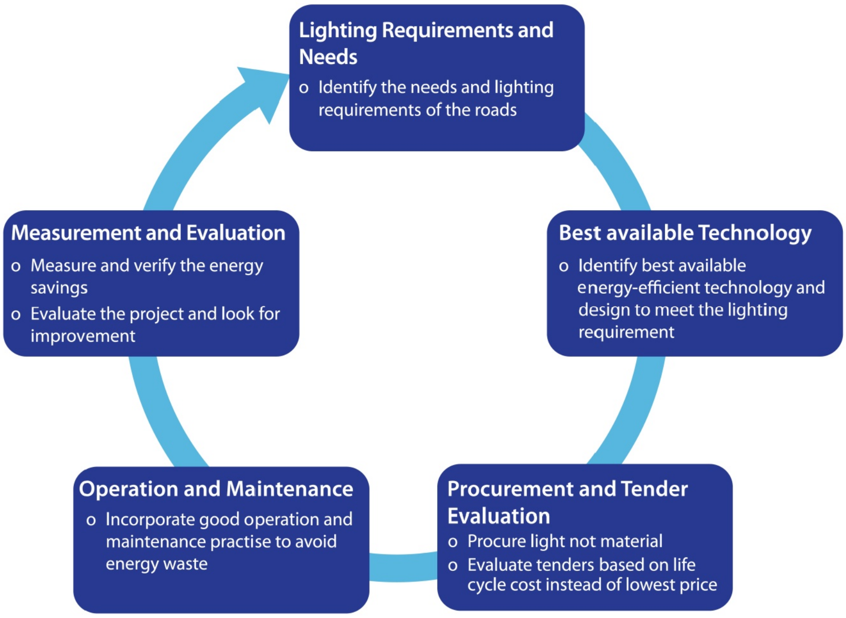


Fig. 4.1: Generic steps to increase energy efficiency in street lighting [USAID, 2010].

Table 4.1: Comparison of existing lamp technologies [USAID, 2010].

Lamp type	Luminous Efficacy (lm/W)	Colour Rendering Properties	Lamp life in hours	Remarks
High Pressure Mercury Vapour (MV)	35-65 lm/W	Fair	10 000-15 000	High energy use, poor lamp life
Metal Halide (MH)	70-130 lm/W	Excellent	8 000-12 000	High luminous efficacy, poor lamp life
High-Pressure Sodium Vapour (HPSV)	50-150 lm/W	Fair	15 000-24 000	Energy-efficient, poor colour rendering
Low-Pressure Sodium Vapour	100-190 lm/W	Very Poor	18 000-24 000	Energy-efficient, very poor colour rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 &T8)	30-90 lm/W	Good	5 000-10 000	Poor lamp life, medium energy use, only available in low wattages
Energy-efficient Fluorescent Tubular Lamp	100-120 lm/W	Very Good	15 000-20 000	Energy-efficient, long lamp life, only available in

(T5)				low wattages
Light emitting diode (LED), (Golden DRAGON with Oval lens, 100 pcs., during operation at 350mA)	55 lm/W	Fair	10 000-50 000 (50% light decrease)	Most energy-efficient technology, long lamp life, only available in low wattages (several pieces needed for a single lamp)

Intelligent Road and Street lighting in Europe (E-Street) project has produced an extensive research report considering improvements in street lighting systems [E-Street, 2008]. According to the report, approximately one third of the European roads and motorways are lit using energy inefficient 1960’s technology with mercury vapour lamps. These lamps consume a relatively large amount of electricity during their lifetime with limited efficiency. In addition they contain mercury and are therefore environmentally unfriendly. By shifting to high-pressure sodium lamps (HPS) or metal halide (MH) lamps efficiency improvement in the lamp itself can go as high as 40%. This could reduce total energy consumption for street lighting for Europe with approx. 15% taking into account 1/3 of the installed base is really old. A normal replacement would be from 250W to 150W means 40% reduction per Shifting all lamps (also the newer types) to most efficient lamps could reduce energy consumption another 5-10%. The total energy saving potential in lamps used is therefore approx. 20%.

The report discusses also about LED lamps, but it does not list efficiency improvement figures for the LED technology. According to the manufacturer information and more recent research reports, LED technology can provide further energy savings of 40 % compared with the previously mentioned high-pressure sodium lamps and metal halide lamps: as an example a 105 W LED light can be used instead of previously mentioned 150W HPS or MH lamp. As a practical example, Gurievsk town located in Kaliningrad region, Russia is replacing the existing obsolete street lamps with low-energy LED lights, which is expected to reduce electricity consumption by 270,000 kWh per year. In economic terms, this means an annual saving of 1,267,000 roubles.

In conclusion it is possible to reduce the amount of energy used significantly going from an old to an entirely new situation. Replacing the lamp, luminaries and ballast will account for about 37% reduction in energy consumption.

Besides the change of the actual lamp, intelligent control of the lamps is shown to produce further cost savings. E-street project has verified that the intelligent road light control can result in further cost savings as it allows stepless dimming of individual lamps according to the changing weather conditions. An example of successful installation can be found from Oslo, as described in [CUD, 2008].

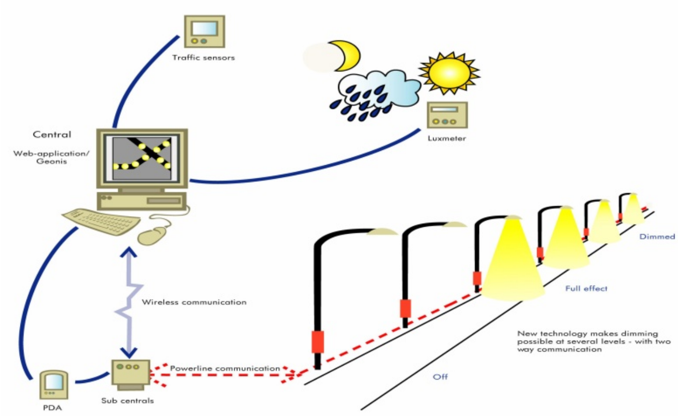


Fig. 4.2: Example on the intelligent road light control [CUD, 2008].

For the control, it is also good to observe the lighting times in street lighting. Finnish agency for energy efficiency Motiva has published a guideline book with the following information concerning the lighting time: good twilight setting to shutdown or start the lamps seems to be 20 luxes for light level. Already 20 minutes unnecessary lighting per day makes two hours in a week, which means about 50 € extra cost per year per street kilometer. [Motiva, 2009]

Chapter 5

5 Improvement potential in the building energy efficiency

Energy efficiency of an existing building can be often improved with an energy renovation project. Objective of an energy renovation should be the improvement of building energy consumption to a certain level (e.g. defined by regulations) or optimization of building life-cycle costs and related emissions. The second objective practically means selection of renovation actions that result in the lowest life-cycle costs for the building and also an improvement in the building energy efficiency meaning less energy consumption. Energy renovations should be further seen as part of improvements that a building needs during its lifecycle.

5.1 Requirements of an energy efficient building

Building is a sum of several factors and smaller technical parts. Therefore an energy efficient building practically requires that its structures and technical solutions (heating, ventilation, electrical appliances) are sufficient, but also that the building is well built, maintained and correctly used. In the Finnish building professional's publication concerning low-energy houses [RIL 249-2009], the main factors providing an energy efficient building are listed as shown in Fig. 5.1. Of these, following actions for an energy efficient building are especially important:

- A good quality design and implementation process with efficient quality control. For instance the correct selection and installation of building materials are primary requirements for an efficient building.
- Well working technical systems and solutions, such as use of heat recovery in ventilation systems and the use of electricity and water saving equipment.

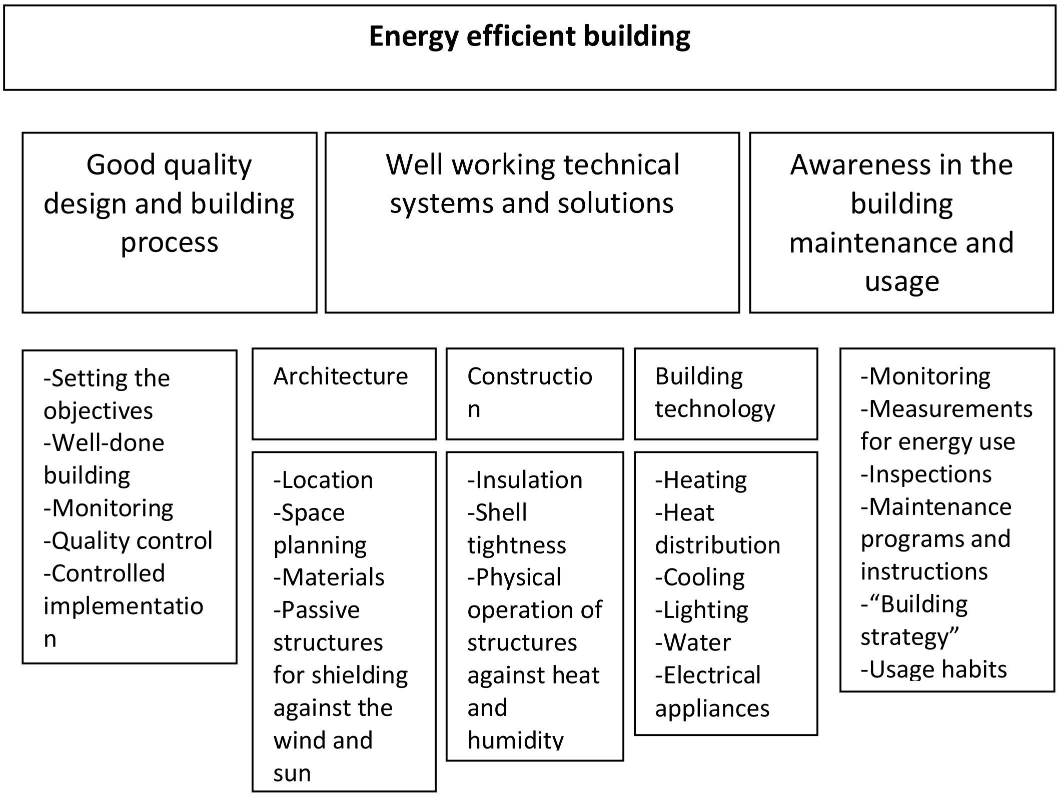


Fig. 5.1: Main factors in the realization of an energy efficient building.

5.2 Typical energy consumption in buildings in Finland

Energy consumption can be mainly divided in three parts: space heating, warm water heating and electricity usage. Typically, up to half of residential customers' energy is consumed in heating. Water heating consumes a fifth of total energy amount and electricity appliances consume the last third. [Motiva, 2012] On average, one residence in block of flats have 1,63 people in Finland and average electricity consumption can be seen in Table 5.1 [Adato, 2006].

Table 5.1. Electricity consumption in residential block of flats in Finland. [Adato, 2006]

Building type	Year	Number	On average consumption per residence [kWh]	The whole consumption [GWh]
Block of flats	1993	890 116	1 950	1 736
Block of flats	2006	1 065 423	2 109	2 247
Change		20 %	8%	29%

It can be noticed that electricity consumption in individual residence has been increased during 1993-2006. In the block of flats the portions of electricity consumption are the highest in refrigeration devices, lighting and entertainment devices. Altogether those appliances consume almost 2/3 of all electricity consumption in block of flats.

Table 5.2: Consumption of electricity appliances in residential block of flats in Finland. [Adato, 2006]

Device	GWh	Portion [%]
Refrigeration device	490	22%
Indoor lighting	469	21%
Entertainment devices	283	13%
Cooking	245	11%
Computers	168	7%
Washing	110	5%
Electric sauna heater	91	4%
Under floor heating	83	4%
Dishwasher	54	2%
HVAC devices	52	2%
Other devices	202	9%
Total	**2247**	

From the table 5.2 can be seen that electricity consumption varies a lot. The biggest part of electricity is consumed in refrigeration devices in residential block of flats.

5.3 Pilot studies in Finland

5.3.1 VTT's pilot research in 2008

Energy renovations and their effects in Finland have been thoroughly studied by Aalto University and VTT. The following analysis is originally presented in [Holopainen, 2008] and [Norden, 2008].

Energy renovations, such as supplementary insulation and heat recovery from outlet air, can be performed to reduce the buildings energy use and CO_2 emissions. VTT's Energy renovation technologies-project studied the profitability of energy renovation measures for buildings. Different energy renovation technologies for structural improvements (retrofit insulation, air tightening), heat supply systems, ventilation systems, lighting, electrical appliances, solar shading and cooling, were evaluated. The effects of different energy renovation measures to reduce heating or cooling energy need were simulated. In every case, the measures were done in certain order so the insulation is improved to allow ventilation heat recovery work efficiently.

The calculations were made for two single-family houses and for three apartment houses. The energy consumptions of the example buildings were simulated before and after the renovation.

The heating systems of the two studied single-family houses were direct electrical heating and water central heating with an oil-fired boiler. Common energy renovation technologies for the houses were retrofit insulation to fulfil the present heat insulation regulations, air tightening, and changing the mechanical exhaust ventilation system to a mechanical supply and exhaust ventilation system with heat recovery. The effect of an outdoor air heat pump, a ground heat pump and solar heating system were evaluated, too. The combined renovation steps reduced the annual electricity consumption of the electrically heated house by 67%. The annual heating energy consumption of the oil-heated house was reduced by 65% (Fig. 5.2). Each of the studied renovation procedures have their own costs and payback times, which are shown in Table 5.4. It should be noted that the payback time of an air heat pump was 2.5 years in the case of electrically heated house.

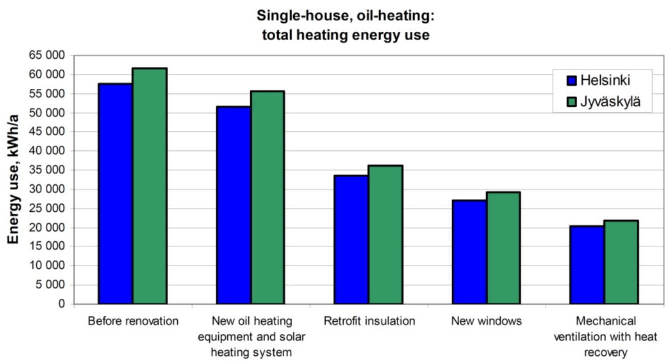


Fig. 5.2: The effect of different energy renovations on the total heating energy use of an oil-heated house in two Finnish towns; Helsinki in Southern Finland and Jyväskylä in Central Finland [Holopainen, 2008].

Table 5.4: Payback times for separate energy renovations procedures in an oil-heated house [Holopainen, 2008].

	Total investment cost €	Annual net saving in Helsinki, €	Payback time in Helsinki, a
New oil-heating system	8585	346	17.5
Retrofit insulation	17800	1155	12.1
New windows	11200	416	18.6
Mechanical ventilation with heat recovery	3500	429	7.1

Three studied apartment houses were built in years 1950, 1960 and 1970. The houses are heated by district heating and the original annual specific heat consumptions are 255 kWh/m^2 (1950), 213 kWh/m^2 (1960) and 188 kWh/m^2 (1970). The apartment houses were renovated with exterior retrofit insulation and new surface structure for the outside walls. The windows, balcony doors and front doors were renewed. The district heating centre and the heat supply system were modernized. Mechanical supply and exhaust ventilation systems with heat recovery (annual efficiency 30 %) were installed in all apartments. After the renovation the specific heat consumption was between 82-138 kWh/m^2. The specific heat consumption was thus reduced between 46-56 %.

With the energy prices in 2008, the pay-back times of the inspected energy renovations were generally over ten years. An exception to this is the improvement of heating system operation that is shown to shorter payback times, such as three years [Lindstedt, 2010]. Generally energy renovation actions can be cost-effectively carried out in connection with another renovation procedures (i.e. building façade renovation, renovation of the ventilation system), decreasing also their payback times. Renewable energy sources should be utilized, when possible. Air heat pumps were seen as an exemplary device to improve energy efficiency cost-effectively instead of electrical heating.

5.3.2 VTT's and UEF's pilot researches

VTT and University of Eastern Finland has had two pilot studies, which have researched how heat pumps effect on energy consumption. These researches have been done in Kuopio and Suonenjoki.

In Kuopio pilot case, where were metered different kind of values and information during 7 years. In the pilot had previously direct electric heating, which total electricity consumption had been 45 000 – 49 000 kWh in a year. Direct electric heating system was changed into a ground source heat pump system (GSHP), which has 1000 m of pipes in the depth of 3 meters under water, Lake Kallavesi. The model of heat pump is IVT Greenline E15 (15 kW). Heat pump installation year was chosen the reference level and after that weather conditions have been almost the same as during direct electricity heating. [VTTb, 2012]

After the ground source heat pump installation, GSHP has been the main heating system. GSHP has heated the house and warmed water. The total electricity consumption has been only 16 500 – 18 000 kWh in a year. At the best time, coefficient of performance (COP) has been almost 4. During the worst years COP has been 2.5. Energy saving windows and additional insulations has decreased about 9 % energy consumption during the similar cold seasons. [VTTb, 2012]

In Suonenjoki, a detached house with area of 150m2 was a pilot case. Previously direct electric heating have been as a heating system. Total electricity consumption was about 36 000 kWh in a year during electric heating system. [VTTb, 2012]

Into the pilot building was decided to install GSHP system. The pipe length was 450 m and it was put in 1,25m depth underground. Heat pump was IVT Premiumline X11 (11kW), which has an inverter technology. Total electricity consumption decreased from 36 000 kWh to 13 500 kWh with the heat pump. In the best case COP has been 2.67. During the -20 degrees, underground pipes transits 0–0.5 degree fluid to heat pump, whereas pipes in the lake can transits 2.5 – 3 degrees temperature to heat pump. In this case, the worse

COP has been a consequence from the way to collect the heat into the pipes. [VTTb, 2012]

Chapter 6

6 Methodology and tools used to study pilot cases

Example cases were selected so that they would represent a typical soviet-era public building and also majority of buildings in Kaliningrad oblast: based on this, a Kindergarten in Svetlyj was proposed as the first pilot case to be studied in this project. Another case was selected to be a typical residential building in Kaliningrad city area.

Pilot cases were studied by site inspections and with a Finnish Excel energy efficiency classification tool for buildings. This tool allows analysis of the building heating energy demand according to given technical values and comparison of different improvement on the building heat energy consumption. It is originally designed for Finnish climate, which is why it has been modified to consider the warmer climate in Kaliningrad Oblast in the calculations.

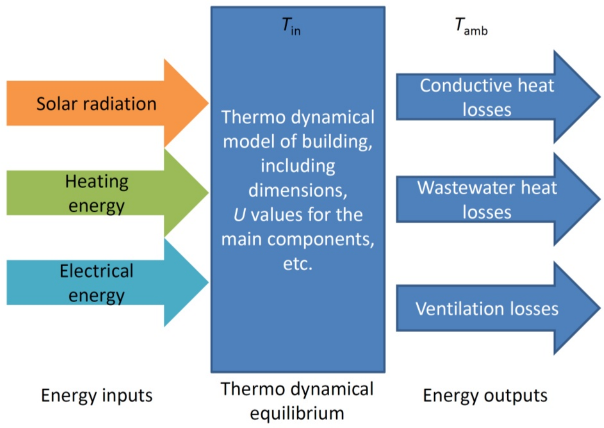
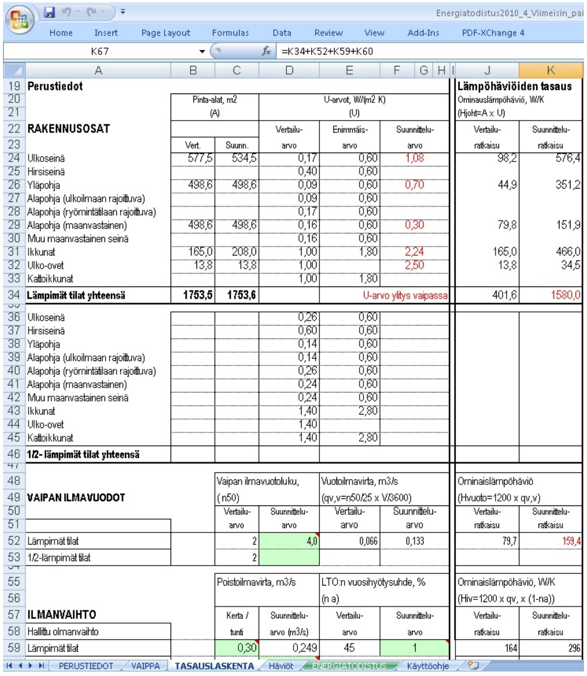


Fig. 6.1: Operational principle of the energy efficiency classification tool. It calculates the annual building heat energy consumption based on the given technical details of the building.

Calculation tool comprises sheets for general building details (dimensions, areas of heated space) and technical details of different building parts (*U* values and thicknesses of wall materials etc.). As shown in Fig. 6.2, this information is used to calculate specific heat loss *H* in each part of the building, which sum up the total annual heat energy need based on the inside-outside temperature difference.



	A	B	C	D	E	F	J	K
19	**Perustiedot**						**Lämpöhäviöiden tasaus**	
20		Pinta-alat, m2		U-arvot, W/(m2 K)			Ominaislämpöhäviö, W/K	
21		(A)		(U)			(Hjoht=A x U)	
22	**RAKENNUSOSAT**			Vertailu-	Enimmäis-	Suunnittelu-	Vertailu-	Suunnittelu-
23		Vert.	Suunn.	arvo	arvo	arvo	ratkaisu	ratkaisu
24	Ulkoseinä	577,5	534,5	0,17	0,60	1,08	98,2	576,4
25	Hirsiseinä			0,40	0,60			
26	Yläpohja	498,6	498,6	0,09	0,60	0,70	44,9	351,2
27	Alapohja (ulkoilmaan rajoittuva)			0,09	0,60			
28	Alapohja (ryömintätilaan rajoittuva)			0,17	0,60			
29	Alapohja (maanvastainen)	498,6	498,6	0,16	0,60	0,30	79,8	151,9
30	Muu maanvastainen seinä			0,16	0,60			
31	Ikkunat	165,0	208,0	1,00	1,80	2,24	165,0	466,0
32	Ulko-ovet	13,8	13,8	1,00		2,50	13,8	34,5
33	Kattoikkunat			1,00	1,80			
34	**Lämpimät tilat yhteensä**	**1753,5**	**1753,6**		U-arvo ylitys vaipassa		401,6	1580,0
36	Ulkoseinä			0,26	0,60			
37	Hirsiseinä			0,60	0,60			
38	Yläpohja			0,14	0,60			
39	Alapohja (ulkoilmaan rajoittuva)			0,14	0,60			
40	Alapohja (ryömintätilaan rajoittuva)			0,26	0,60			
41	Alapohja (maanvastainen)			0,24	0,60			
42	Muu maanvastainen seinä			0,24	0,60			
43	Ikkunat			1,40	2,80			
44	Ulko-ovet			1,40				
45	Kattoikkunat			1,40	2,80			
46	**1/2- lämpimät tilat yhteensä**							
48			Vaipan ilmavuotoluku,		Vuotoilmavirta, m3/s		Ominaislämpöhäviö	
49	**VAIPAN ILMAVUODOT**		(n50)		(qv,v=n50/25 x V/3600)		(Hvuoto=1200 x qv,v)	
50			Vertailu-	Suunnittelu-	Vertailu-	Suunnittelu-	Vertailu-	Suunnittelu-
51			arvo	arvo	arvo	arvo	ratkaisu	ratkaisu
52	Lämpimät tilat		2	4,0	0,066	0,133	79,7	159,4
53	1/2-lämpimät tilat		2					
55			Poistoilmavirta, m3/s		LTO:n vuosihyötysuhde, %		Ominaislämpöhäviö, W/K	
56					(n a)		(Hiv=1200 x qv, x (1-na))	
57	**ILMANVAIHTO**		Kerta /	Suunnittelu-	Vertailu-	Suunnittelu-	Vertailu-	Suunnittelu-
58	Hallittu olmanvaihto		tunti	arvo (m3/s)	arvo	arvo	ratkaisu	ratkaisu
59	Lämpimät tilat		0,30	0,249	45	1	164	296

Fig. 6.2: A screenshot on the calculation tool. Technical details of building parts are used to calculate the total specific heat loss of the building that is the base for calculating annual heat energy consumption.

This information is further used to determine ET number and class for the building according to its annual energy consumption per gross heated area (kWh/m^2): Finnish building regulations define seven energy efficiency classes ranging from A to G with ET number limits for each class.

Kindergarten	Residential building
0–140	0–100
141–180	101–120
181–230	121–140
231–300	141–180
301–390	181–230
391–500	231–280
501–	281–

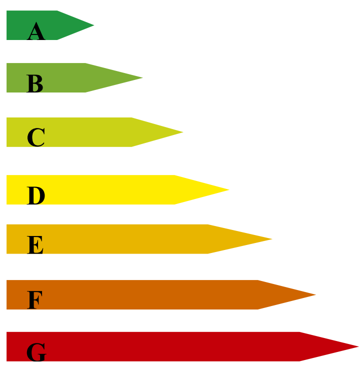


Fig. 6.3: Seven energy efficiency classes defined in Finnish building regulations with ET number that is the annual energy consumption of the building per its gross heated area (kWh/m^2) [RIL249-2009].

Since the studies are basically simulations with the available technical values, results can have errors, requiring further and local evaluation of the building condition and characteristics before starting actual renovation (see Chapter 5 on energy renovation projects). Therefore, the simulation results have been informed to ECAT-Kaliningrad and Immanuel Kant Baltic Federal University, where Mr. Sergey Molchanov has done corresponding calculations with similar results and conclusions during autumn 2012, when also the results were studied during the project meeting.

As the site inspections were conducted to have a general idea on the building condition and its renovation needs, some of the structural issues in the building may have been undetected. Some practical examples are locally missing insulation from the wall or holes on window frame edges, which require thermal imaging or inspection of each window for their detection. The same inaccuracy also applies to the costs of proposed actions, which are rough estimates, because they are based on general cost knowledge given in Finnish building cost database [Haahtela, 2012], by our Russian partners and by the product manufacturers.

Besides heat consumption and buildings characteristics, consumption of water and electricity were studied for the first pilot case by comparing them to a Finnish and a Swedish kindergarten. This part of the study is documented in detail in two Master theses done by Alexander Solomennikov and Mayya Tambovskaya [Solomennikov, 2012], [Tambovskaya, 2012].

One should also note that the calculation tool cannot detect unoperating heaters or consider the effect of uncontrollable heating system on the building energy consumption. Often the improved operation and controllability of the heating system can improve the living quality and decrease the heat energy consumption at the same time [Eliseev, 2011]. Correspondingly, calculation tool cannot tell about locally missing insulation or pipe leaks in the heat system. Therefore, results of site inspections and interviews with local experts have been taken into account when proposing technical improvements to the example cases.

Chapter 7

7 Energy efficiency analysis of Svetlyj kindergarten

Kindergarten 'Firefly' located in Svetlyj, Kaliningrad Oblast was chosen to the project to represent a Soviet-era public building, as other kindergartens are also built according to the same model. This kindergarten was built in 1963, and currently provides day care for 125 children. Building has two floors and its total area is 996 m^2. The Firefly kindergarten total electrical energy consumption was 46 377 kWh and electricity costs 5 433 € in a year, heat consumption was 227 599 kWh and heat costs 12 397 € in a year. Two site inspections by LUT researchers were carried out in Svetlyj to determine the building condition and its renovation needs. Both visual inspection and interviews with kindergarten and municipality personnel were conducted during both visits.

Fig. 7.1: Outside view of the 'Firefly' kindergarten located in Svetlyj, Kaliningrad Oblast.

Main building materials are lime sand bricks on the outside, concrete and wooden floors with plastic matt or other resilient surface for public spaces, flat roof, mainly original double-layered windows with wooden edges and 14 new plastic/metallic edged windows. There is no separate insulation material on the walls nor on the roof.

Building is connected to the district heating system that is mainly in its original condition. Heaters (basically water radiators) have no thermostats or valves, as they are a direct part of the district heating network. For this reason, distribution of heat is unbalanced in the building, and windows need to be kept open in some rooms, while some other rooms were notably cooler: electrical heaters are used there when needed. Fig. 7.2 shows an example of radiator covered with plywood, so children wouldn't accidentally touch it.

Ventilation in the building is based on natural ventilation, only the renovated kitchen has a ventilation system. Usage of heat and water are both metered.

Fig. 7.2: Example of water radiators in the kindergarten.

Since district heating system is used only for a part of the year, separate electric boilers are used in the kitchen and four other rooms to heat water during summer time. In practice, these boilers could be well replaced with a more energy efficient solution.

Fig. 7.3: One of the electric boilers used to heat domestic water.

Another noted thing in the site inspection was the laundry room of kindergarten, which did not have proper appliances (meaning a heated drying room or energy efficient tumble dryer) for drying up the laundry effectively, as the room did not have separate ventilation or heating devices for clothes.

A building model was constructed with the obtained data from Svetlyj and from ECAT-Kaliningrad. Table 7.1 represents the initial data and assumptions for building *U* values. Based on these values, the energy efficiency classification of the building was noted to be poor, meaning annual energy consumption of 940 kWh/m^2 and class G in the Finnish energy efficiency scale.

Table 7.1: Initial data and assumptions for building *U* values in Svetlyj kindergarten.

Heat loss	Description	Area [m^2]	*U* value [W/m^2 K]	Nominal heat loss [W/K]
Exterior walls	Lime sand bricks	651	1.41	917
Roof		636	1.04	662
Base floor	Concrete slab	566	0.22	127
Doors	Fireproof doors	14	2.79	39
Windows	Double-glazed with wooden frames	210	2.27	477
Building structures, total				2222
Air leaks	Leaking through building elements			160
Ventilation	Manual			296
Total				2678

Basically this building has several parts to be renovated ranging from the roof to the heating system. As this building has small children as its “customers”, the quality of indoor climate should be considered as the first priority for renovations, and energy efficiency of the building as the second priority. Therefore, it is recommended that the energy renovation project should start from the upgrade of building heating and ventilation systems to ensure that the balanced temperature and proper air exchange are available. It has been shown that these actions may decrease building energy consumption, although more electricity may be consumed by renewed devices.

The effect of improved ventilation on the building energy efficiency was further studied with the classification tool. If the air exchange rate is increased from assumed 0.3 1/h (30% of ventilated space volume per hour) to recommended 0.5 1/h, and there is possibility to have heat recovery with 70 % efficiency, then the ventilation heat loss can decrease from 296 to 289 W/K and annual energy consumption can remain nearly the same, being 942 kWh/m^2.

7.1 Estimated effect of different actions on the building energy efficiency class

When the heating and ventilation of the building are working correctly, energy efficiency could be improved especially by retrofitting the building insulation and by changing windows. Different possible renovations were studied according to their effect on the building heat loss and energy efficiency. Material thicknesses were selected so that renovations fulfil the Finnish regulation RakMK C3 (2010) for *U* values [RakMK C3, 2010].

Table 7.2: *U* value requirements for new building parts in Finland.

Building part	Finnish regulation RakMK C3 (2010)
Exterior wall	0.17
Base floor	0.09–0.17
Roof	0.09
Window	1.0
Solid window	1.0
Entrance door	1.0

Table 7.3 summarizes different insulation-related renovation possibilities and their effects on the building heat energy consumption. In terms of costs, a feasible renovation alternative is the improvement of windows, if the original ones are in the need of change. Larger improvements can be achieved by facade renovation with retrofitted insulation. This option requires that the operation and possible renovation need of heating and ventilation systems are considered at the same time. Otherwise, improved insulation may lead to unbalanced indoor climate conditions.

Table 7.3: Calculated effect of different energy renovations on the building energy efficiency.

Action	**New *U* value [W/m² K]**	**New comp. nominal heat loss [W/K]**	**New ET number&class based on the change in heat loss Δ*H***
Replacement of old windows with Tiivi 2+2 windows (*U*=0.85) [1]	Avg. 0.95 (old 2.27)	200 (old 477) -10.3%(1)	845 (G)
Insulation of roof with 500 mm of Paroc eXtra mineral wool sheets (λ_D=0.036) [2]	0.07 (old 1.04)	45 (old 662) -23%	725 (G)
Insulation of two end-walls with 300 mm of PAROC COS 10 mineral wool sheets (λ_D=0.035) [3]	0.11 for end walls, otherwise 1.41	786 (old 917) -4.9%	896 (G)
Insulation of all walls with 300 mm of PAROC COS 10 mineral wool sheets (λ_D=0.035) [4]	0.11 (old 1.41)	72 (old 917) -31.6%	645 (G)
Replacement of old windows and insulation of walls and ([1]+[4], details above)	Given above	Given above -54.6%	428 (F)
Insulation of walls and roof + replacement of old windows ([1]+[2]+[4)]	Given above	Given above -64.9%	330 (F)

(1) Relative change in the building total heat loss.

Cost estimates have formulated for these actions based on available Russian data, and these are summarized in Table 7.4. It should be noted that these estimates cannot consider all the possibly occurring design and installation costs due to the renovation.

Table 7.4: Estimated renovation costs for the proposed actions. Total cost figures contain 10% to the design and project costs.

Action	**Material costs [thousands of roubles]**	**Labour costs [thousands of roubles]**	**Total costs [thousands of roubles]**
Replacement of old windows with new ones (39 pieces)	560	256	900 (25 750 €)
Insulation of roof with mineral wool sheets	972	350	1344 (38 400 €)
Insulation of two end-walls with mineral wool sheets	159	1500-2000 (indicative estimate)	1825-2375 (52 150-67 900 €)
Insulation of all walls with mineral wool sheets	689	3000-4500 (indicative estimate)	4025-5675 (115 000-162 150 €)

According to the simulations, building heat losses can be almost halved to F class with insulated walls and roof. Walls have the individually largest energy savings potential. Full realization of this potential requires facade renovation with substantial costs (over 50 000 €) exceeding the project budget, or at least the further study of wall characteristics to see if only certain parts of the building walls need to be insulated. Correspondingly, also the floor insulation could be improved, but practically this can be too costly option, since the floor base plate is against the ground.

7.2 Suggested actions and their cost estimates

Based on the simulation studies, visual inspection of the kindergarten and also the available project budget, installation of **1) centralized domestic water heating system utilizing primarily sun collectors or air heat pumps** was first proposed during fall 2012 for kindergarten to be realized in this project. It would have allowed the replacement of separate electric boilers with more energy efficient and centralized solution for providing hot water and also heat water to the building around the year In terms of this project, this solution would have also been financially possible to be realized in the kindergarten. Fig. 7.4 presents an exemplary schematic of solar heating system by Savo-Solar that is meant for heating both the domestic hot water and also for the building heating when the district heat is not available.

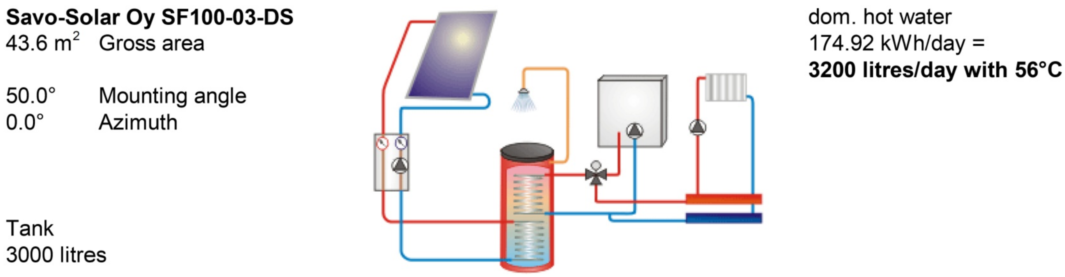


Fig. 7.4: Exemplary solar heating system proposal to the kindergarten.

According to comparison calculations for a sun collector (investment about 12 700 €) and an air to water heat pump (investment about 11 350 €), the heat pump with payback period of 14 years would have been economically possible alternative for building heating.

In practice, this proposal was prevented by the lack of suitable electrical supply and available space in kindergarten, and also by the forthcoming improvement to district heat availability throughout the year as commented by the Svetlyj municipality personnel.

Based on this information and comments given by the municipality personnel, **2) condition inspection and repair of the heating system** is proposed as the second improving action to the kindergarten. As the heating pipes are original, this would require replacement of piping system and possibly the heat exchanger between the district heat network and the kindergarten, which is located in another building. When the total costs for the heating system renovation including all the pipes are approximated by using 50-100 €/m^2 estimate for the renovation, the resulting costs may go over 50 000 €. During this project, more detailed design documents could be defined for improving the heating system.

As a smaller and more practical improvement, water radiators (or at least a part of them) could be either installed with three-way valves and bypass lines for hot water or totally replaced with newer ones that would be equipped with control valves or thermostats. Object of this action is to balance room temperatures if allowed by the district heating system and allow decrease of heat energy consumption in the building when its insulation will be improved: it has been shown that the controllability of room temperature can allow 15 percent heat energy consumption decrease. As a conclusion, a practical solution could be the **3) replacement of existing radiators with Purmo low-energy radiators and installation of Danfoss thermostats** or manual valves into them. For a single room, the estimated devices costs of three Purmo heaters with Danfoss thermostats are about 800 € (28 000 roubles). With the installation and possible piping works the costs can be two to three times the material costs. The resulting device costs for seven rooms would then be around 11 000-22 000 € plus the other possibly occurring device and installation costs.

In some rooms, where both cooling and heating are, but the radiators cannot be renewed or a central heating system cannot be installed due to too high installation costs, an applicable solution would be to use air heat pump if allowed by the electrical supply: although this may not be the most energy efficient solution, the heat pump could provide both heating and ventilation to the room. Price of a single heat pump is around 1300 €, and its benefits would be practically improved ventilation and more balanced room temperature. For seven Panasonic air heat pumps to be used in the second floor of kindergarten especially during summertime, the informed investment cost would be around 7600 € and the installation costs around 4200 €.

Electricity consumption of the building can be decreased with the **4) replacement of light bulbs with LED lights** and with the **replacement of broken and inefficient electrical appliances with energy efficient ones** having at least class A energy efficiency rating. These are the easiest actions to realize, and they should effectively reduce electricity consumption. For fluorescent lights having T7 classification, they could be replaced with new T5 classified lights. This kind of improvement could also be done for the laundry as the purchase of energy efficient laundry drying equipment.

The repair of heating system should be followed **5) by replacement of old windows and additional insulation of roof**, if allowed by the budget. As already shown in Table 7.4, the floor improvement can have notable renovation costs (around 40 000 €), but it also has doubled effect on the heat energy losses compared with the replacement of windows. Other more costly operations are retrofitting insulation to the walls and floor, but at least a **condition inspection** and further analysis by an experienced building/consulting company is recommended to determine the actual condition **of the walls and floor**. The **condition inspection** is also recommended **for roof and ventilation system** before their change to newer components.

Water consumption can be affected in the building firstly by ensuring the instant supply of warm water and for instance by **installing mixing and water saving water taps**, total costs of installing 18 taps would be around 1000 €, which could be carried out during the renovation of heating system.

Smaller improvements, such as individual door replacements can also be carried out, if they have locally effect on the building temperature and ventilation. This considers also the use of windows and electrical appliances, which should be closed when they are not needed. Practically this needs motivation and for instance small signs to remember these things in everyday life.

Summary of estimated costs for these actions can be given to these actions based on approximate renovation prices per m^2 in Finnish apartment buildings [Haahtela, 2012], [VTT, 2012] and separately informed prices in Russia. Generally the total renovation costs for insulation-related improvements are easily several ten thousand euros, although a single improving device or component may cost for instance 1300 € (typical price for an air heat pump in Finland). Therefore the most influential renovation actions must often be excluded because of their too high costs compared with the condition and remaining lifetime of the building.

Table 7.5: Cost approximations for suggested renovations based on typical renovation prices per m^2 in Finland [VTT, 2012] and informed prices in Russia. Total cost figures contain 10% to the design and project costs.

Action	**Unit price (e.g. €/m^2)**	**Total sum**
Changes in water heating from electric heating to AWHP	8 300 €	11 350 €
Changes in water heating from electric heating to solar collectors	8 700 €	12 700 €
Changes of incandescent light bulbs to LEDs (111 pieces)	10-30 € per unit	1110-3330 €
Replacement of radiators	800 € per room having three radiators	11000-22000 € for seven rooms including the installation costs
Substitution of windows (39 pieces)		25 750 €
Renovation of rooftop		38 400 €
Heating system replacement containing all the pipes	50-100 €/m^2	55 000-110 000 €
New energy efficient, centralized ventilation system	100-150 €/m^2	100 000-150 000 €
Improving of outer wall insulation: Substitution of the old outer wall structure with a modern structure	150–250	115 000-162 150 €

More detailed cost estimates require practically consultation of a local building or design company (see Chapter 2), as condition inspections, designing, used materials and project leading costs may notably vary from between different projects.

7.3 Summary

In this building and with available funds, the most feasible improvements are related to its heat and electricity consumption: both the heating energy and electricity consumption can be easily improved with modern technology. As an example, Panasonic or IVT air-to-water heat pumps were first recommended to be used for domestic hot water heating during summer season instead of electrical boilers. In addition, lamps and electrical appliances can be easily replaced with energy efficient ones, when they are broken.

Discussions with kindergarten personnel and ECAT-Kaliningrad brought front the need for improvements in the laundry of kindergarten. This was also noted during site inspections, as laundry was dried in the laundry room having no energy efficient equipment. If improvements are done to the laundry, installation of energy efficient laundry drying equipment for instance from Talpet is recommended.

Since insulation-related façade renovations tend to be very costly (e.g. over 50 000 €), their reasonability for over 50 year old buildings should be carefully studied: if the expected remaining lifetime of the building is shorter than the payback time of the renovation, renovation cannot be seen reasonable. This is especially true for soviet-era buildings having significant need for energy renovations.

Besides improved insulation, heat energy consumption of the building can be affected by renovating the radiators with new ones having also thermostats (such as Purmo heaters with Danfoss thermostats). If allowed by local norms and characteristics of the substation, the present district heating substation could be replaced with a Gebwell heat exchanger unit. When the heating system has controllability, the improvements in insulation (windows, floor) will also decrease more effectively the heat energy consumption

Chapter 8

8 Energy efficiency analysis of ul. Artilleriyskaya residential building

Another pilot case was selected to represent majority of residential buildings in Kaliningrad city area. As the selection was done during summer 2012, site inspection was done by ECAT-Kaliningrad. Therefore, this building is primarily studied by available design information and site inspection information provided by ECAT-Kaliningrad.

This pilot case is a five floor residential building located in ul. Artilleriyskaya. It was built in 1983, and the total floor area of the building is 2107 m^2. The building has a natural (gravity-based) ventilation system, and there are no central control or thermostats in the heating system. Air exchange rate of 0.38 1/h has been informed for the building.

Fig. 8.1: Outside view of the residential building located in ul. Artilleriyskaya, Kaliningrad.

Deterioration and technical details of the building were informed by building administration and ECAT-Kaliningrad. General level of the building deterioration was approximated to be 40 % with the following details:

- Window unit – 80%
- System of the central heating – 60%
- System of cold water supply – 60%

- System of electrical equipment – 40%

Also technical details of the building were informed (see Table 8.1). These values were firstly compared with both Finnish and Russian limit values, as shown in Table 8.2, to see which building parts have the largest energy savings potential.

Table 8.1: Informed technical details of the residential building.

Type of exterior constructions	Resistance to heat transfer (standardized by Building norms and rules 23-02-2003, tabl. 4, m2*˚C/Wt	Square, m2	Heat losses, Wt/˚C
Walls	0.30 / 2.68	916.40	3054.67
Heat-insulated walls	1.20 / 2.68	325.10	270.92
Roofing	0.96 / 4.02	562.4	585.83
Ceiling panels over underground floor	0.64 / 1.45	562.4	878.75
Windows	0.35 / 0.42	439.8	1256.57
Enter doors	0.76 / 0.67	20.2	26.58
Total			6073.32

Table 8.2: Comparison of given technical data with Finnish and Russian limit values.

Building part	Informed *U* value [W/m^2 K]	Assumed *U* value of Svetlyj kindergarten [W/m^2 K]	*U* value in Finnish RakMK C3 (2010) [W/m^2 K]	*U* value in Russian building norms and rules (23-02-2003) [W/m^2 K]
Wall	3.33	1.08	0.17	0.37
Heat-insulated wall	0.83	1.08	0.17	0.37
Ceiling panels over the floor	1.56	0.30	0.09–0.17	0.69
Roof	1.04	0.70	0.09	0.25
Windows	2.86	2.50	1.00	2.38
Enter doors	1.32	2.50	1.00	1.50

8.1 Estimated effect of different actions on the building energy efficiency class

It was noted that the major part of the walls are uninsulated, causing over half of the building heat losses. As also the deterioration level of windows is significant, the effect of window replacement and insulation improvement on the building heat losses was tested with the classification tool. According to the simulations, heat losses could be decreased up to 40 % with proper insulation of walls. Another tested options were the replacement of windows and retrofitting the roof with insulation.

Table 8.3: Calculated effect of different energy renovations on the building energy efficiency.

Action	New *U* value [W/m^2 K]	Is *U* value below Finnish regulation RakMK C3 (2010)?	New comp. nominal heat loss [W/K]
Replacement of old windows with Tiivi 2+2 windows (*U*=0.85)	0.85 (old 2.85)	Yes (ref: 1.0)	374 (old 1257) -12.3%[(1)]
Insulation of roof with 500 mm of Paroc eXtra mineral wool sheets (λ_D=0.036)	0.07 (old 1.04)	Yes (ref: 0.09)	39 (old 586) -7.6%
Insulation of walls with 300 mm of PAROC COS 10 mineral wool sheets (λ_D=0.035)	0.11 (old 3.33)	Yes (ref: 0.17)	105 (old 3055) -41.0%

[(1)] Relative change in the building total heat loss.

8.2 Suggested actions and their cost estimates

According to the given data and analyses, insulation of the building is not sufficient, leading to a poor energy efficiency class. Especially non-insulated walls are causing heat losses, having thus the largest energy saving potential. Other critical points are the lack of proper ventilation (ventilation rate of 0.38 per hour is clearly below required 0.84) and lack of heating system controllability. As the windows are in any in the need of change, the following actions are proposed for this building:

1) Check of the heating system operation, installation of heat exchangers and control apparatus (such as thermostats) to allow control of the heating system operation. Possibly installation of heat pumps to some apartments.
2) Improvement of building windows and insulation.

3) Check of the housing ventilation operation and possibly improvement of it with new air supply valves or with new windows having integrated air supply valves. Estimation of renovation costs, if mechanical ventilation system is desired to the building.

Again approximate costs have been calculated for these renovations, and they are shown in Table 8.4. Also in this case the total cost approximations are notably larger than the prices of individual components (single air supply valve unit ~100 €, a heat pump ~1 300 €; large central ventilation unit with heat pump technology ~10 000 €).

Table 8.4: Cost approximations for suggested renovations in the residential building [VTT, 2012].

Action	Euros/m^2	Total sum
Renovation of rooftop	50–100	20 000-40 000 €
Installation of air supply valves to the building walls		20 000
New energy efficient, apartment-based ventilation system with duct work	50–100	100 000-200 000 €
Substitution of windows and outer doors		50 000-100 000 €
Improving of outer wall insulation: Substitution of the old outer wall stucture with a modern structure	150–250	300 000-500 000 €

In the available information, there was no mention about the domestic hot water heating. It can be possible also here to use an air heat pump for water heating purposes or some other alternative, if improvements to domestic hot water availability are desired. Correspondingly, the benefits of insulation-related renovations should be studied based on their payback time to see their reasonability. In any case, the improvements in heat energy consumption can be started by checking (and balancing) the current heat system operation and installing thermostats onto the radiators.

Chapter 9

9 Conclusions

This report has introduced methods and policies to improve housing energy efficiency in Russia. Shown results are based on available scientific and marketing publications, interviews, and on simulation studies for two example cases in Kaliningrad Oblast.

According to the gathered information, there is need both for political and financial instruments supporting energy efficiency actions, and practical guidance for conducting successful energy efficiency improvements. Especially motivation or regulation towards reduced wasting of energy, energy renovations and having sustainable financing methods for them are seen important factors. Technically there are proved solutions available that can be used for improvements. In any case, it is important to have a comprehensive renovation plan (including timetable for each planned renovation stage), so the most feasible technical solutions can be selected for the building. Also the forthcoming changes (e.g. improved district heat availability) should be asked from the municipality, as they affect feasibility of different technical solutions.

When forming a renovation plan, site inspections and interviews with building owners and users are important to determine the present condition of the building and possibilities for technical improvements: for instance, wasting of heat can be detected by site inspections and further affected with improved heating system. In addition, site inspections can consider the present use of the building and electrical appliances in it, so inefficient or even unsafe use of devices could be avoided in the future.

In the studied cases, improvement of heating system operation, ventilation and insulation were seen important factors to improve both housing energy efficiency and quality of living. Although the results of this report are case-specific, improvements of previously mentioned components are also general key factors to improved buildings if they can be realized. It should be noted that every renovated building has to be considered as a separate case when renovation plans and decisions are made.

As a realistic example, the insulation-related renovations tend to be costly (even over 50 000 €), which is why their reasonability for over 50 year old buildings should be carefully studied by experienced consultant (for instance Engineering Office Granlund). A good way to see the reasonability of renovation is to compare its payback time to the expected remaining lifetime of the building. A good example of feasible renovation is the replacement of windows with energy efficient ones, which can decrease the building heat energy need by 10%.

Even without improvements to the building insulation, a previously proven solution is to improve heating system controllability, if this is allowed by the local district heat system. This was noted in the case of kindergarten, where forthcoming improvements in the district heat availability make also the renovation of heat exchanger and water radiators reasonable. In practice, the possibility and benefits of improving heating system operation are case-specific as they are affected by existing pipelines, their condition, available budget etc. In addition, the improvements in heating system operation should also be in line with improvements to the building insulation to have best energy savings potential.

As a simple and efficient improvement with small payback time, electricity consumption can be easily reduced with the improvement of applied lighting technology and replacement of old electrical appliances with more energy efficient ones. Renewable energy sources also provide a possibility for energy efficiency improvements. Of the studied solutions, air heat pumps were seen as a feasible topic for further study for heating if their use is technically possible and direct electric heating (such as separate electric water boilers) could be replaced with them.

As a summary, this report provides a list of proposals that could be considered to improve energy efficiency and living quality in buildings. Although the results of pilot cases are case-specific, they give indication on typical heat energy savings potential of energy renovations.

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