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Energy efficient Renovation Strategies

Estonia and European Sustainability Project

Metropolia University of Applied Sciences

Bachelor of Engineering

Sustainable Building Engineering

Bachelor's Thesis

10 November 2020

Author Title Number of Pages Date	Dmitri Matskevits Energy efficient Renovation Strategies Estonia and European Sustainability Project 31 pages 10 November 2020
Degree	Bachelor of Engineering
Degree Programme	Sustainable Building Engineering
Instructor	Sergio Rossi, Senior Lecturer

The final year project aimed at reviewing and analysing current energy efficient renovation strategies for Soviet era residential buildings, using Estonia as an example. A local renovation support scheme called *KredEx* and EU´s SmartEnCity project, both of which aim at reducing energy consumption in residential buildings and communities.

A renovation project engineer was interviewed to get technical details of the solutions applied for 17 multi-story residential buildings renovated under the SmartEnCity project in Tartu, Estonia. Literary sources were studied in order to establish if the local renovation grant scheme is successful in achieving its goals, such as getting apartment owners involved into renovation and making the buildings significantly less energy demanding

It was established that a combination of state support and rising of community awareness about the benefits of energy saving play a significant role in increasing the apartment owners' willingness to renovate. Furthermore, it was established that the EU aims at creating pan European sustainability regulations and practices, which may lead the European community towards a cleaner future with significantly reduced CO^2 emissions.

The study showed that combination of energy efficiency regulations, technical supervision and state funding can lead to significant energy savings by retrofitted buildings while maintaining the monthly apartment costs almost on the same level as before the renovation. This thesis might help to take a closer look on outcomes of renovation stimulating programs and their cost effectiveness as well as to compare different community sustainability solutions.

Keywords	retrofitting, KredEx, SmartEnCity, sustainable community

Contents

1 Introduction

In Estonia about 24 300 multi-storey residential buildings were built between 1960-1990 to fulfil the demand of the growing city population due to urbanization processes. These buildings make up about 90% of the total existing residential buildings. All of them were built using Soviet-era architectural solutions and strategies, which served to fulfil the fast-growing demand for apartment buildings. In order to fulfil the needs the buildings were designed in such way that only economically efficient constructional solutions were applied, without any architectural delights. Fast and cheap replicability was the priority. [1;2.] Nowadays the buildings are still in a good shape in terms of load bearing properties, but they are well beyond today's energy efficiency requirements for buildings. In addition, their load bearing outside walls are aging with excessive speed because they are open to atmosphere impacts. There are also indoor environment issues in non-renovated buildings due to their passive ventilation and large temperature fluctuations. [3.]

There were different solutions implemented starting from the 2000s in order to solve mainly the mould, heating comfort and air quality issues. Considering the features of the apartment building market in Estonia before 2010, the solutions bought and implemented were usually random, mostly the cheapest due to the post-Soviet era economic crisis. Their solutions were usually not based on any serious technical research due to the absence of local energy efficiency requirements for buildings until 2010s. [3;4.]

Estonian residential buildings are among the most energy demanding in Europe. The average energy consumption of a building in Estonia in 2010 was 300 kWh/m^2 per annum while the EU average was 160 kWh/m^2 [5]. According to the local studies made in 2014 in Estonia, the annual energy savings potential for thermal energy in residential buildings was approximately 80%, which could possibly save around 9.3 TW/ h of energy yearly. On the other hand, significant pure electricity savings are not reachable due to the growing number of ventilation systems installed in residential buildings, both renovated and new. It means that if for example during a renovation, the lighting in a house is replaced with a smart LED system and a ventilation system is installed at the same time, the energy consumption of the ventilation system will consume the energy saved by LEDs. [1.]

After the year 2010, the first minimum energy efficiency requirement regulations were introduced by the Ministry of Economic Affairs of Estonia, taking the EU building energy performance regulations as a template [6]. After the energy efficiency regulations were implemented, it became possible to get national funding for a renovation level which is based on energy efficiency achievements. The share of the funding might be up to 40% depending on energy efficiency level achieved [1]. Later, in 2014 in order to study more cost effective renovation possibilities, the Smartovka project was launched in Tartu, Estonia. It is the first project which has implemented the same renovation solutions on not just one but 17 buildings. The Smartovka project is funded by both the local KredEx fund and EU's SmartEnCity project whose aim is to explore long term, sustainable renovation practices for the renovation of old buildings in different parts of Europe, as well as to explore sustainable solutions on different levels of urban planning. The solutions range from energy efficient district cooling systems to implementing community engagement practices. [7.] Local project in Estonia is called Tartu Lighthouse project which includes a Hrustsevka's renovation solution and urban planning solutions [4]. In this thesis, a closer look is taken on the KredEx grant system and SmartEnCity project in order to evaluate how they affect the renovation of panel buildings and urban planning strategies in Estonia.

Multiple projects have been chosen for this thesis because both KredEx (Estonia) and SmartEnCity (European Union) have a similar aim: to implement cost effective renovation practices which could lead to significant energy demand reductions which, in turn, lead to lesser CO_2 emissions. The main difference between the two projects is that the SmartEnCity goes beyond just renovation. It also studies the cost effectiveness and CO_2 pollution reduction effects of different sustainable solutions for the whole community while KredEx is an effective local tool for energy efficient renovation. Thus, the SmartEnCity project has a significantly larger scale than the local KredEx funding scheme. [7.]

2 Soviet-era Residential Buildings in Estonia

There are about 24 300 apartment buildings built before 1990 were built quickly for the same reason as in many other cities of Europe in the post war period: in order to fulfil the needs of the growing populations of cities [8]. The first types of the panel buildings were developed in the 1950s when Nikita Hrustsev was the leader of the Soviet government. In the 1950s, Nikita Hrustsev announced an architectural strategy reform main aim of which was to build cheap functional apartment buildings instead of expensive neo-classicist style buildings (figure 1). Last ones are rich with architectural solutions, have original look but are considerably more expensive to construct. That is why the typical panel buildings are called *Hrustsevkas*. [1; 2.]

Figure 1. Neo- classicist residential building in Tallinn. Beautiful but expensive

In such a big housing shortage due to a rapid urbanization process, individual projects were less cost-effective comparing to a design that could be used throughout the country with prefabricated concrete panel walls and floors, or, rarely, brick walls (figure 2). Prototypes of such buildings had been tested in Moscow in 1958 and were pronounced as successful solution. Hrustevkas, as well as the next generations of soviet-era panel buildings, were intensively built until the end of the Soviet Union. Despite of many shortcomings, such as relatively small space (figure 2) of apartments and poor sound insulation, people were more than happy to move from barracks and communal apartments to a private apartment. [8;9;10.]

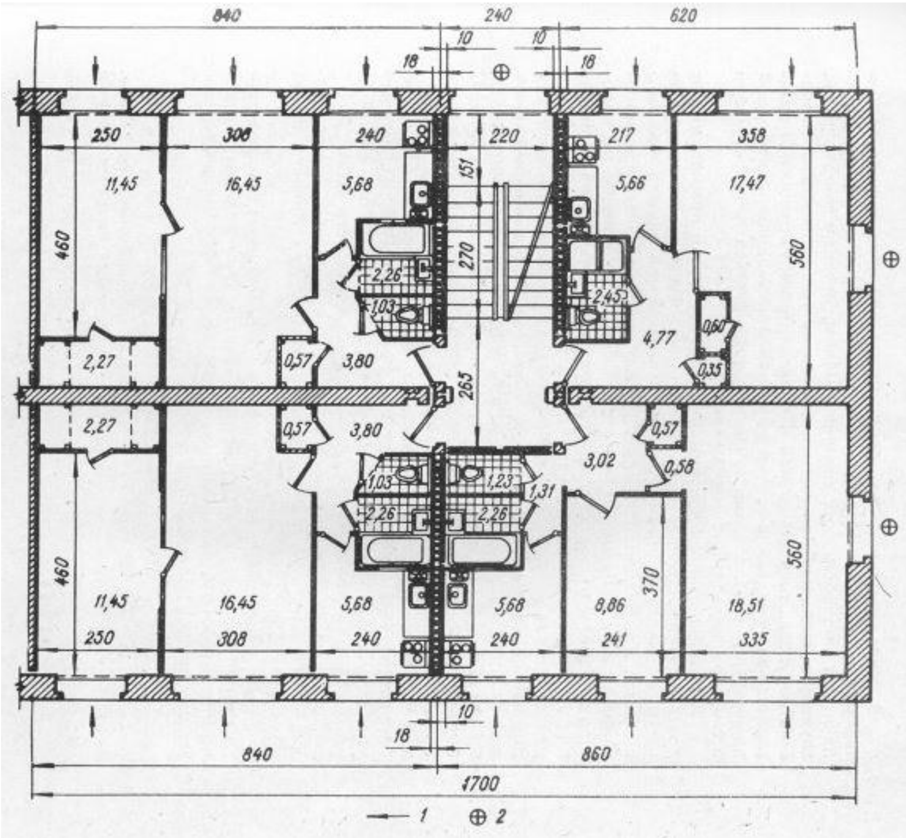

Figure 2. Typical floor plan of Hrustsevka [2.]

Families could now hide from the eyes of neighbours, organize private meetings in their apartments and call friends to visit for different celebrations. However, this property was still owned by the authorities. [9;10.]

Figure 3. Typical Hrustsevka somewhere in USSR [2.]

After 1968, a new type of panel buildings was introduced in the USSR, called the series 111-109. It utilized the same strategy as the Hrustsevkas and was built with the same materials. The main difference to typical Hrustsevkas was that the new series was designed to have also a 9-storey option in addition to a 5-storey one, of which the 9-storey option has an elevator. The apartments in the 111-109 series were also about 10% bigger. In addition, the room height was raised from 2.5 m to 2.8 m. [2;10.] From the constructional point of view, the buildings were the same unified panel buildings with the same building envelope and passive ventilation, which also means that they have the same problems with energy efficiency and indoor environment as the Hrustsevkas. The reason for not making any major constructional changes was, on one hand, that it was cheap to build the same building and, on the other, that energy was still cheap. In addition, excessive CO_2 emissions were still considered a minor threat for the environment. [9.]

Another difference between the 111-109 series and Hrustsevkas was that the Hrustsevkas were planned to serve for 50 years but the new type panel buildings were planned to serve up to 100 years [2]. However, periodical building surveys and service such as periodical change of seams between the outside panels or insulation of those panels can significantly prolong the service life of the Soviet-era panel buildings according to various studies made by both Russian and Estonian building surveyors [2;10]. One of the reasons for such a relatively long service life is that the designed structural load-bearing capacity of the Soviet-era panel or brick buildings has more safety reserve than modern buildings. In other words, to be in a safe side, designers in the 1960’s used more load-bearing material than actually necessary to prevent the building from collapsing. [10;11.]

Thus, the main problem that the panel buildings from the Soviet-era cause for the environment was the fact that the country at that time relied on cheap energy. In addition, there was lack of awareness of the disadvantages of excessive CO_2 emissions at the time of their construction.

2.1 Design and Renovation Need

Hrustsevkas and other Soviet-era panel building projects were designed to be fast, easy and cheap to build, but without any compromise to safety and load-bearing properties. If properly maintained, they are still considered safe to live in although non-energy efficient. [12.] The core of the Hrustsevka and 111-109 projects are the reinforced concrete panels or bricks, manufactured in innumerable concrete and brick factories built in order to fulfil the needs all around the Soviet Union. The building envelope of the panel buildings consisted of the panels or bricks. The average construction time for a 5-storey Hrustsevka was 15 days, sometimes even only one week. [9.]

The main design shortcomings of the panel or brick buildings include poor thermal and sound insulation properties, no elevator in buildings up to five storeys high, ineffective passive ventilation and poor architectural appearance. Such shortcomings lead to excessive energy consumption due to heating demand, poor air quality, major temperature fluctuations due to the need of opening a window to allow the air to change, condensation on cold outside walls, and mould growth. [10;11.]

As the Soviet-era buildings are more than 30 years old and, at the time of their construction, extensive energy consumption was not taken into consideration, the question of renovation or demolition is becoming ever more important. In some cities, like Tartu and Tallinn, the demand for the apartments is stable, so renovation is considered as the number one option in big cities for at least another 10 years. That is why banks are also granting funding for such renovations-they are confident that money will return. [1;4.]

On the other hand, there are cities in which renovation is not economically feasible as their population gets significantly lower from year to year, and the typical occupants of the panel buildings are retired people who cannot afford paying for a renovation even if the state partly funds the renovation. Sometimes whole buildings are abandoned in such cities, even if the building were in a relatively good shape (figure 4).

Figure 4. Abandoned Hrustseva in Kohtla- Järve

Nevertheless, there is still a great number of the buildings occupied in Tallinn (figure 5) and Tartu, and the real estate market forecasts show that this demand will be stable. None of the buildings have been demolished so far in Tallinn or Tartu. The apartments in the panel buildings are relatively affordable as a three-room apartment in a Soviet-era building in Tallinn costs €70 000 in average, while in new buildings the prices start at €90 000 [12]. Because various studies made by the city authorities show that the buildings can last at least 50 years more, the apartments are popular, even if they have not undergone any major renovation. However, it is widely accepted that not all of the buildings will be renovated. A considerable amount of them will be demolished, mostly because there are simply too many of them and the speed of renovation is relatively slow. [1; 13.]

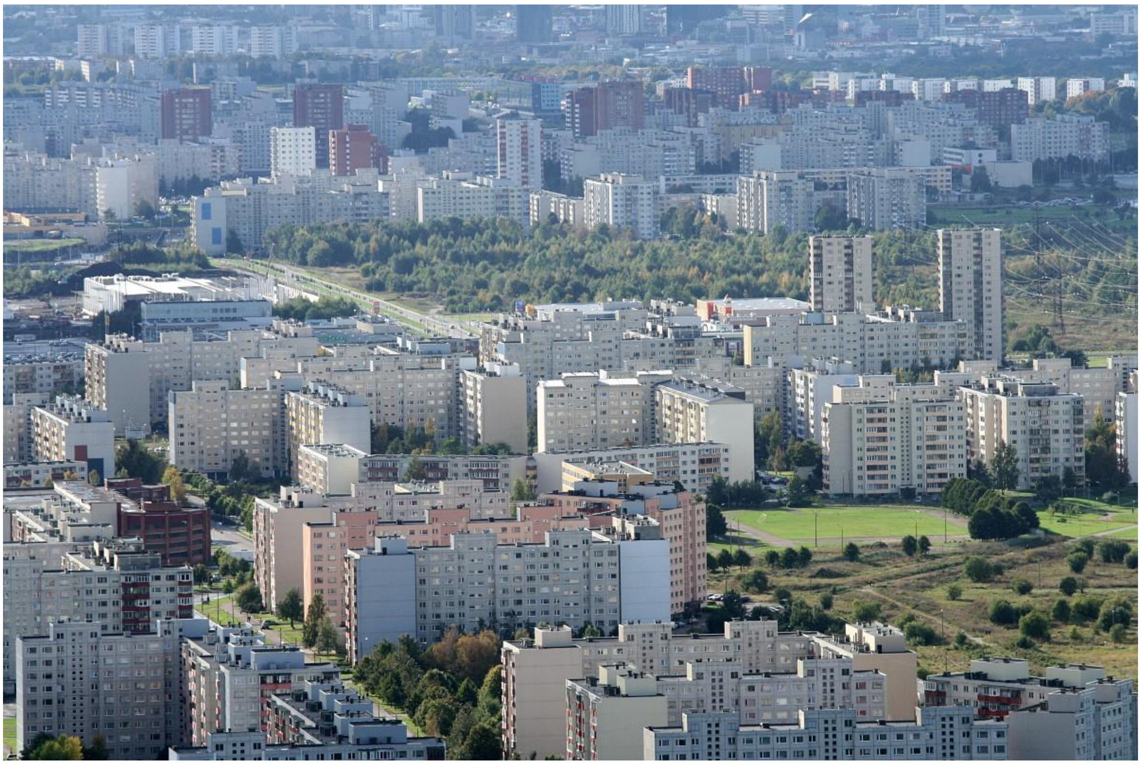

Figure 5. Part of Lasnamäe district of Tallinn

The energy efficiency of the building envelope is defined by its U-value, or thermal transmittance coefficient. It helps to explain and calculate heat losses due to different properties of building envelope parts. Thickness and material define the U-value of the building envelope part. For energy calculations, the U-values of walls, roof, floor slab, windows and doors located in external building envelope are considered. The smaller the U-value the better is the energy performance, if the envelope has no significant air leakages or thermal bridges. Apartment buildings constructed between 1960 and 1990 have concrete panels as their external wall material with the U-value $U_{wall} \approx 0.8\text{-}1.1\ W/(m^2 \cdot K)$, roofs and ceilings with the U-value $U_{roof} \approx 0.9\text{-}1.1\ W/(m^2 \cdot K)$; windows with the U-value $U_{window} \approx 2.9\ W/(m^2 \cdot K)$ and windows after minor renovation with the U-value $U_{window} \approx 1.6\ W/(m^2 \cdot K)$. Ventilation is passive. Without major renovation, the average primary energy usage in the buildings is 200-270 kWh/ m^2a. The windows and panels were specially installed in such way that major air leakages are allowed into the apartments to make the passive ventilation work. The ventilation uses the chimney effect. [1.]

Before a radiator system renovation, which done in almost every building, the heat output of district heating radiators is not always enough in such apartments during the cold winters to reach a comfortable indoor temperature. In such cases, additional electrical heater might be used by the occupants to compliment the district heating. Due to the absence of any kind of insulation, there is a problem of condensation on the walls during the cold periods of the year, which in some apartments causes mould to grow (figure 6).

Figure 6. Mold problems in Hrustsevka

Especially apartments situated on the top of the buildings are sensible for this kind of a problem due to the top ceiling panel being open to the atmosphere. The problem was partly solved by building a well-insulated roof or by fully insulating the building envelope. However, those small renovations did not significantly affect the heating demand. [1;11.]

2.2 Housing Stock Features in Estonia and Kredex Renovation Grants

In Estonia, around 95% of living area is privately owned. About 75% of the population is living in apartment buildings. Of those buildings, 90% or about 24 300 were built before 1990. Before 1960's some amount of wooden apartment buildings was built but from year to year those often get abandoned and demolished so most of those buildings are made of block and brick (figure 7). [1;3.]

The KredEx renovation grant scheme was developed in order to support the renovation of aging Soviet-era buildings and other similar projects. The scheme was introduced in 2010 and its main aim was to attract demand on the renovation of old buildings. [1.]

Figure 7. Typical Soviet-era buildings in Estonia. From left to right: wooden, large block, brick, large panel

The grant is given for construction works on the basis of the achieved energy performance of the building. The grant can fund 15 %, 25 % or 40 % of renovation expenses. It is funded by the European Regional Development Fund as direct funding and the Council of Europe Development Bank. The assistance of the European Development Bank allows local banks to grant more flexible loans with lower interest rates and longer repayment periods than those of average loans. The aim of the fund is to engage (figure 8) people to renovate old buildings. [1.]

Figure 8. KredEx advertisement on typical panel building saying ”Renovation is cheaper than heating the outside air”

Energy performance is defined by primary energy consumption per m^2 of floor area per annum. Energy consumption is evaluated after renovation. Energy consumption calculation considers the energy demand for space heating, ventilation, domestic hot water and all electricity loads and considers weighting factors provided by the Estonian Ministry of Economic Affairs. By calculating the Primary Energy (PE) consumption, energy performance certificate (EPC) can be obtained which will state that building has achieved one of 8 available energy efficiency levels (figure 9). [1.]

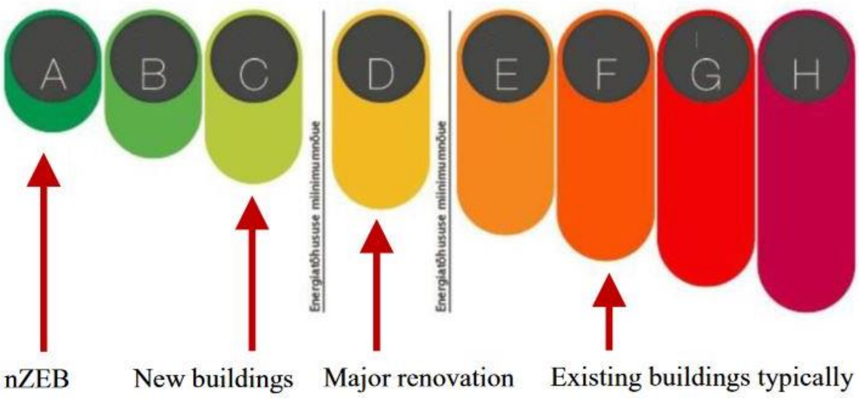

Figure 9. Official levels of energy efficiency for the buildings in Estonia

A 40% grant can be applied for when a renovation of a building results in at least a class C performance, which is also the requirement for new buildings. According to latest regulations, the PE demand of new buildings should be less than 125 kWh/ m²a. 25% grant can be applied when achieving class "D" performance, or when PE demand is less than 180 kWh/ m²a. Finally, 15% can be granted when achieving class E performance, or when PE demand is less than 220 kWh/ m²a. Economic Affairs of Estonia takes care of energy performance regulations for the buildings since 2010. Regulations are being periodically revised after revised European energy efficiency regulations coming into force. [1; 6.]

In addition, in order to get the KredEx grant of 25% or 40% building envelope should have efficient pre- calculated thermal transmittance properties (table 1).

Table 1. Requirements for U values of building envelope

Renovation grant share levels	15%	25%	40%
Thermal transmittance of external walls, $W/(m^2K)$	-	0.25	0.22
Thermal transmittance of the roof, $W/(m^2K)$	-	0.15	0.11
Thermal transmittance of windows, $W/(m^2K)$	-	1.1	1.1
Linear thermal bridge in connection of window and external wall, W/(mK)	-	-	0.05

Other requirements for KredEx funding include the installation of a heating system with thermostats, which could allow room-based temperature adjustments. [1.]

During early 2010's it was found that after many renovations for which grant was spent there were problems with ventilation properties, usually lack of air flow rate. Thus, latest KredEx grant rules require the ventilation system to have the properties defined in Estonian Building Code. System design is assessed by independent specialist before any works or purchases are made. This is the basic requirement for all 3 grant schemes. In addition, for 40% grant scheme heat exchanger is needed to be present in ventilation unit.

The loans and grants should be applied for by the apartment association chairman as the representative of apartment occupants. . For the project to be approved by the occupants, the apartment association chairman is to organize meetings to introduce the plans and financial models. At least 51% of building occupants are required to approve of the renovation and loan in order to initiate a loan application and the beginning of renovation. [1.] Perhaps, this process takes time due to specific features of local communities. There might be that old people sometimes do not understand the solutions or lack the will to believe in them. On the other hand, a family's income may also affect the attitude towards new expenses. Not everyone sees practical benefits with a 20-year payback period for the investment.

KredEx funding continuously develops its approaches towards engaging the communities to renovate their non-energy efficient buildings. For example, nowadays there is always a qualified technical consultant involved in the pre- evaluation of the solutions the apartment association wants to use. This could possibly steer the decision-making in apartment associations. The consultant can also simplify a rather complex renovation process that involves many parties such as the bank, representative of building association, contractor, energy auditor and designer. Another innovation is the evaluation process of developed design solutions by third party experts in order to ensure that the solutions will meet energy efficiency aims and requirements. The latest innovation is the commissioning of ventilation functionality, as previously there were issues with achieving the designed airflow rates. Once the ventilation system is operational, a measuring protocol is made which should state that the ventilation rates are achieved in order to get KredEx funding for ventilation. [1.]

Steps needed for grant preparation and application are listed below in brief:

- Energy audit and an EPC for the building
- Renovation work approval by apartment association
- A qualified technical consultant for making the process smoother and faster
- Designer for the develop
- Building permit
- Estimation of renovation costs
- Preliminary credit decision from the bank

Grant application steps include:

- The grant application
- A review of designed developed
- If required, an improved revision of design document
- If all requirements are met- a funding decision
- Tender for contractor company
- Final credit decision from the bank

The new requirements, such as ventilation rate assessment and energy requirements came into force after 2014, which is a big step towards independent and correct energy efficient building renovation and construction. Before 2010, it was easier for construction companies to mislead the apartment associations due to the absence of energy efficiency and ventilation requirements and a lack of independent experts involved in evaluation. [1.]

A typical building applying for renovation has a net floor area of 2000 m^2 and has about 30 apartments. Average cost of 40% renovation is € 500 000, of which building associtation, or occupants, need to pay € 300 000. It is essential to ensure that the renovation cost does not raise during the project so people would be afraid to renovate due to possible extra costs. [1.]

A renovation cost analysis for such a funding scheme has shown that the biggest possible grant of 40% and a major renovation are the most favourable options in terms of energy and money savings. The monthly apartment cost per m^2 rises by about 10% in both the 40% and the 25% option, but after a major renovation, the monthly energy savings are also higher. [1.]

KredEx funding has examined the renovation projects of the panel-type buildings in Mustamäe, Tallinn, that have used either the 25% or the 40% grant options (table 2). The main differences in the renovations are that the 40% grant projects have installed a ventilation system with heat recovery and moved the existing windows into the insulation layer to compliment new windows. [1.]

Table 2. Renovation project for 25% grant (on the left) and for 40% grant (on the right) [1.]

Renovation grant share levels	25%	40%
Building details (sample photos are taken after the completion of renovation work)		
Average net area, m²	1,669	1,253
Average heated area, m²	1,271	995
Average apartment area, m²	1,154	899
Renovation work	Insulating building envelope, swapping out old wooden windows, installing a new heating system and a new mechanical ventilation system without heat recovery	Insulating building envelope, installing new windows and moving existing windows into the insulation layer, installing a new heating system and a new mechanical ventilation system with heat recovery
Average renovation cost, €/net m²		
Total cost	192	265
Grant	50	107
Apartment association investment	143	158

Both the 25% and 40% grant projects resulted in significant energy savings (table 10). The results have been calculated taking into consideration real energy consumption. [1.]

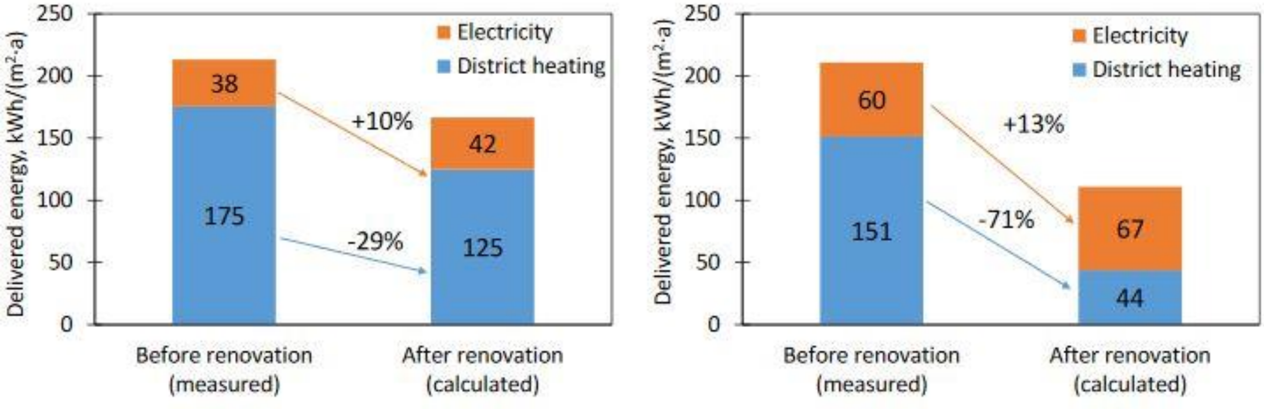

Figure 10. Delivered energy savings for 25% project (on the left) and 40% project (on the right) [1.]

The monthly cost for an apartment of a 25 % renovation scheme rose from 1.74 €/ m² to 2.16 €/m² or plus 25%, for a 40% renovation the cost rose from 1.83 to 2.02 or plus 10%

(figure 11). [1.] However, due to the difference in the occupants' income, the extra 16 euros per month might be too much, especially if a house is mostly occupied by retired people who, in many cases, live alone, maybe with the Estonian minimum pension of 221.63 €. [14.]

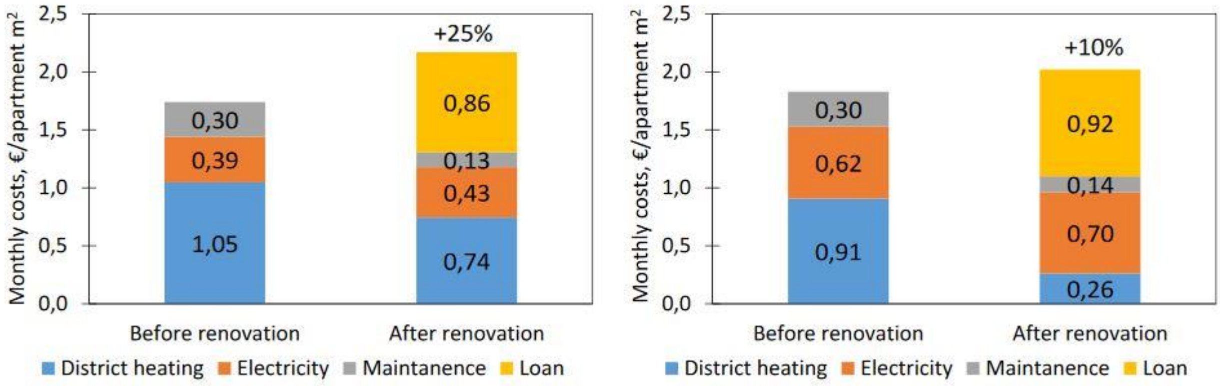

Figure 11. Cost of monthly fee for 25% project (on the left) and 40% project (on the right) [1.].

Result demonstrates why the 40% grant projects are more popular than the 25% ones. In a 20-year period, the 40% renovation project is more profitable for the owners than the 25% one. But sometimes the apartment owners are not interested in what is going to be profitable in such a long run. Those who made this research concluded that the Estonian renovation grant scheme is a useful tool for renovation promotion. According to the study, the owners are willing to invest in renovation and it is beneficial to raise the awareness among residents about the different solutions and outcomes in order to encourage them to renovate. [1.]

3 SmartEnCity Project

The SmartEnCity project looks at a community as a whole, and its strategy is to create smart zero- carbon cities with a systematic approach, make cities sustainable and improve the quality of life in communities, create new jobs and offer equal growth opportunities. The main aim of the project is to develop replicable strategies which can be implemented throughout Europe in order to reduce energy demand and maximize the renewable energy supply. The methods to achieve this include building retrofitting, sustainable mobility development, integration of infrastructures, intelligent use of ICT technologies, and engaging local communities. Three cities have been chosen to become so called Lighthouse cities, that is cities which can demonstrate their achievements to other cities. The Lighthouse cities are Vitoria Gasteiz in Spain, Tartu in Estonia and Sondenborg in Denmark. They will receive European Union funding of 28M EU and the process is planned to be replicated in two “follower” cities, Asenovgrad in Bulgaria and Lecce in Italy. [7.]

One of the key aspects of the SmartEnCity is the improvement of the energy efficiency of existing buildings because the buildings in the EU consume 30-40% of the total energy produced in the EU, which means that buildings have a great potential for CO_2 emission reduction. [7.]

The SmartEnCity expectations are that 2 500 dwellings with the total usable floor area of 165 000 m^2 will be retrofitted, which will lead to energy savings of 30 000 000 kWh per year and reduce the CO_2 production by 19 000 tonnes per year. Besides retrofitting, an increased use of renewable energy sources for heating is implemented, along with smart lighting solutions and innovative concepts for sustainable mobility such as electric vehicles, car and bicycle sharing, and biogas-fuelled buses. [7.]

3.1 Evaluation of Building Energy Efficiency Standards by SmartEnCity

In the project, SmartEnCity looks for the most suitable standards and sustainability evaluation tools which could guide the cities on implementing the citizens engagement, energy supply and use, mobility, information and communication technologies, BIM management and building retrofitting. The guideline is called “SmartEnCity Urban Regeneration Strategy”. [15.]

The main objective of the SmartEnCity Urban Regeneration Strategy project is the development and reinforcement of a unified systematic urban regeneration model towards Zero Carbon City and Smart strategies. Strategy is based on citizen and stakeholder’s involvement as well as optimal technology and modern sustainable solution selection. [15.]

According to the SmartEnCity project the aims can be achieved by reducing energy demand through the renovation of existing buildings, by making sustainable and clean transport systems, by applying smart ICT solutions and by getting all stakeholders involved through awareness raising. A second important mean of achieving the goal is renewable energy use maximization through the utilization of locally accessible sources. [15.]

SmartEnCity also looks into financial aspects and people engagement questions, thus, into integration of all the components into urban intervention regeneration and, as a result, into Integrated Urban Plan. [15.]

The SmartEnCity project has reviewed various energy performance evaluation tools both in the scale of community planning and in residential buildings. SmartEnCity concludes that a combination of Building Research Establishment Environmental Assessment Method (BREAAM) and the Passive House Certificate for retrofits (EnerPHit) standards can help to make a template for future EU- wide standard for retrofitting. The conclusion is based on the fact that there are many examples of certified buildings available around the world and those tools complement one another. [15.]

The main principles of BREAAM are the promotion of sustainable refurbishments, recognition of existing building limitations and sustainable community planning. The Passivehaus certification criteria, on other hand, are aimed at improving the energy efficiency. In order to fulfil the Nearly Zero Energy building requirements, the heating and cooling demand should be no more than 15 $kWh/(m^2a)$ for new buildings and 25 $kWh/(m^2a)$ for retrofitted buildings. The total primary energy usage should not exceed 120 $kWh/(m^2a)$. In addition, a building should not leak more than 0.6 times of building volume per hour. SmartEnCity sees those standards as potential baselines for future EU retrofitting standard [15.]

If compared to KredEx, SmartEnCity considers not only the energy performance of the buildings but also many other community parameters which can help to save the energy by other means. SmartEnCity, for example, considers people's behaviour, movement and means of transport community is using [15.]

3.2 Tartu Lighthouse Project - Facts about Tartu

One of the cities involved in the pilot SmertEnCity project is Tartu, Estonia. The project is called *Tartu lighthouse project*, it started in 2014 and is still ongoing. [15.]

Tartu is the second largest city of Estonia with a population of about 100 000 and a total area of 38.86 km². It is known as the intellectual capital of Estonia for its university which was opened in 1632. During the Soviet years, it was a relatively closed city because of a strategic airbase located in it. After WW2 and before 1990 more residential and public buildings were built in Tartu than for the previous 200 years together. Between 1970 and 1980 about 25 000 m² of new living space was constructed and around 70% of Tartu residents moved into these apartments between those years. The urbanization process was influenced by soviet city planning strategies as towns and urbanization played significant role in the economic development of Soviet Union. Tartu was divided on neighbourhoods, industrial areas and outskirts like many other soviet cities. [16.]

After gaining independency, the Estonian building stock was privatized and building occupants became the owners of the apartments they were residing in. In Soviet Union there was no need to pay for municipal services, but after 1990 it was now occupant's responsibility to think about building repairs and raised energy prices. Along with gained freedom, this led to disadvantages, such as rapidly increasing communal costs, and generated new types of problems like energy poverty and homelessness for those who were the most vulnerable or simply unable to survive in the new era of market economy. [17.]

After Estonia gained its independence, it was in the hands of the building residents to make decisions on building renovations. Due to the absence of energy efficiency regulations developers in 1990's were mostly building cheat housing with poor energy efficiency properties. Any strict regulations were considered by the business like vestiges of Soviet-era and were not popular among politics. As a result, apartment buildings constructed before 2010 have poor energy performance. On the other hand, those buildings share 8% of the apartment building market. [11.] National energy efficiency regulations were established in 2010's and took EU regulations as a template, with those regulations era of energy efficient building begun.

only 38 buildings were renovated under Kredex funding between 2010 and 2014 in Tartu, which is 4% of all existing apartment buildings in Tartu. [4.]

3.3 Tartu Lighthouse Project - from Hrustsevka to Smarovka

Smartovka is a part of SmartEnCity project whose main idea is to turn soviet era *hrustsovkas* in Tartu (figure 12) into *smartovkas* (figure 13), high quality housing environments. The Main aims are to inspire community residents to act friendly to the environment and change their attitude towards consumption behaviour as well as to reduce the energy use of the buildings. Smartovka retrofitting package includes 17 Hrustsevkas with a total floor area of 32 071 m^2 in Tartu city centre which underwent a retrofitting. As a result, the PE consumption is expected to fall from 270 kWh/m^2y to 90 kWh/m^2y. [4.] The retrofitting solutions include:

- outer walls insulation
- windows and outer doors replacement
- roof reconstruction
- low- temperature cooling system to complement the district heating system
- -photovoltaic panels installation
- -central heating system reconstruction
- -installation of ventilation system with heat exchanger
- facade art solutions
- ICT solutions

Figure 12. Hrustsevka before renovation [4.]

3.4.1 Tartu lighthouse project- Retrofitting package

The aim of the Tartu retrofitting package is to reduce the primary energy consumption of the retrofitted buildings from 270 kWh/m²y to 90 kWh/m²y, an aim pre–set by the SmartEnCity project. [4.]

The result was calculated with the help of the energy demand calculation method approved by the Estonian Ministry of Economic Affairs and Communications in 2014. Like any other building energy demand calculation tool, it includes various factors such as internal heat gains due to hot water usage, air leakages, lighting gains and thermal transmittance coefficients of building envelopes. [4.]

The calculations forecast that electricity consumption will be in the level 46,9 kWh/ (m² a) and district heating demand will be 42,8 kWh/(m²a), local energy weighting factors included. Previous average energy consumption of Hrustsevka was 210 kWh /m²a for heating demand and 57 kWh /m²y for electricity. Significant difference in electricity consumption is caused by PV panel implementation and ventilation unit consumption [4.]

According to the latest revision of the Estonian building energy efficiency act, the energy demand of multi-storey residential buildings should be 125 kWh/(m²·a) for new buildings, 150 kWh/(m²·a) for renovated buildings and 105 kWh/(m²·a) if building wants to be officially recognized as “Nearly- zero energy building”. [4.]

The Planned demand for the energy consumption of the Tartu project fits into the “Nearly-zero energy buildings” definition of Estonian regulations. That is a good result considering that this is a renovation project which means that the project is restricted in terms of design and space utilization as the building already exists. [1; 4.]

Figure 13. Hrustsevka after renovation in Tartu. [4.]

3.4.2 Retrofitting solutions in Smartovka project

To reach the building energy efficiency aims set for the Tartu retrofitting project, several solutions in retrofitting package were used. Most importantly, the building envelope was significantly improved compared to the non- renovated conditions (table 3). [4.]

Table 3. U- values for building envelope

	g	U_i,
	-	W/(m^2·K)
Outside wall		0,149
Plinth wall		0,212
Roof		0,076
Floor		0,35
Doors		1,40
Windows	0,63	0,90

In addition, a completely new ventilation system with the heat exchange rate of 85% and CO2 detector for automatic adjustments was installed in the apartments. The Ventilation has no cooling option available. According to a project engineer, it was the most challenging task as the buildings simply did not have a special space designed for air ducts. [4.]

The Windows that were installed in the Smartovkas are not typical for Estonian renovation projects, windows have triple glazing and a relatively low U value of 0.9 W/m² K. In addition, all the main doors were changed to more energy efficient ones. The anticipated result of the renovation is that the energy demand of the retrofitted buildings will drop from 270 kWh/ m²a to 90 kWh/m²a which is 65% less than the original value, a significant reduction. [4.]

The replicability of the Smartovka project is achievable as the means used to achieve the aimed energy performance are common: improving the envelope, and installing ventilation and PV panels. However, the price of the renovation might be a problem. Smartovka project is important not only for Estonia but also for other countries like the Czech Republic, where 3.5 million people live in same type of apartments, as well as for Hungary, where 1.7 million of people live in the same type of apartments, and Latvia and Lithuania, where plenty of those buildings were constructed. [2; 16]

3.4 Tartu lighthouse project- other sustainable city solutions

Other solutions implemented citywide in Tartu were a district heating system that uses residual heat, reuse of batteries from electric cars, public bike sharing system, gas buses in the whole city and smart street light controllers. [16.]

The district cooling system uses residual heat (figure 14) to transfer the heat from heated backflow water of the cooling system to domestic hot water. The system uses PV panels to partly cover the energy that is needed to run the system. At the moment, project is implemented only for supermarket building. In order to implement this solution for the residential building district expensive cooling piping works are needed which requires €6.4 million for connection of pilot buildings. According to the Tartu Lighthouse project papers there are some financial problems to be solved before major pipe routing works will start. [16.]

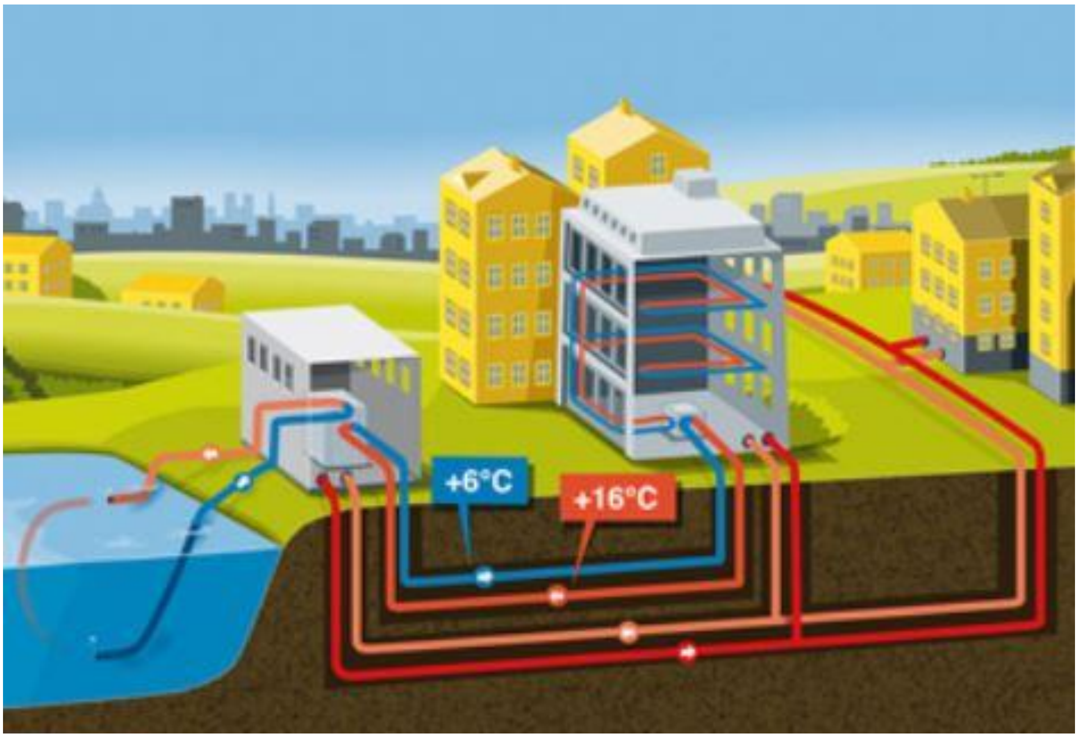

Figure 14. Cooling system with residual heat recovery

Tartu also implemented old electrocar battery reuse solution. Those batteries are serving as power banks to store energy gained by PV panels. Stored energy is used to power up the electro taxies. Tartu has a privately owned fleet of around 40 electric taxis and when efficiency of battery of the electric taxi drops to 70-80% of their original efficiency, battery is dismantled and used as power bank. For taxi recharge station project, 300 m² of PV panels were installed in order to be able to recharge 30 electric vehicles every day. [16.]

Some 5 years ago Public bike sharing system (figure 15) could surprise city occupants, nowadays it is an ordinary solution for relatively populated cities. In Tartu, the system launched in 2019 consists of 750 bikes and 69 bike share points. There are 510 electric bikes in addition to 240 regular ones. A bike can be rented by using a valid Tartu bus ticket or with a separate bike share membership, which can be added to credit card. [16.]

Figure 15. Public bike sharing park in Tartu

Tartu has also purchased 64 new gas busses from Scania which cost 20-25% more that diesel busses but for which the fuel expenses are 42% less than the costs of diesel busses. There is a potential shortcoming in the gas busses-they need warm-up procedure in order to start up the engine when the temperature outdoors is below -10 degrees Celsius. [16.]

In addition, streetlights with smart controllers were implemented and completed in Tartu in 2017 (figure 16). The system includes 322 LED luminaries with a wireless connection to the controller. The Sensors of the controller can define when the weather is wet, dry, or snowy and separate vehicles from people. They need 80% less energy than normal lights and save 70% in maintenance costs through the longer luminary lifetime. [16.]

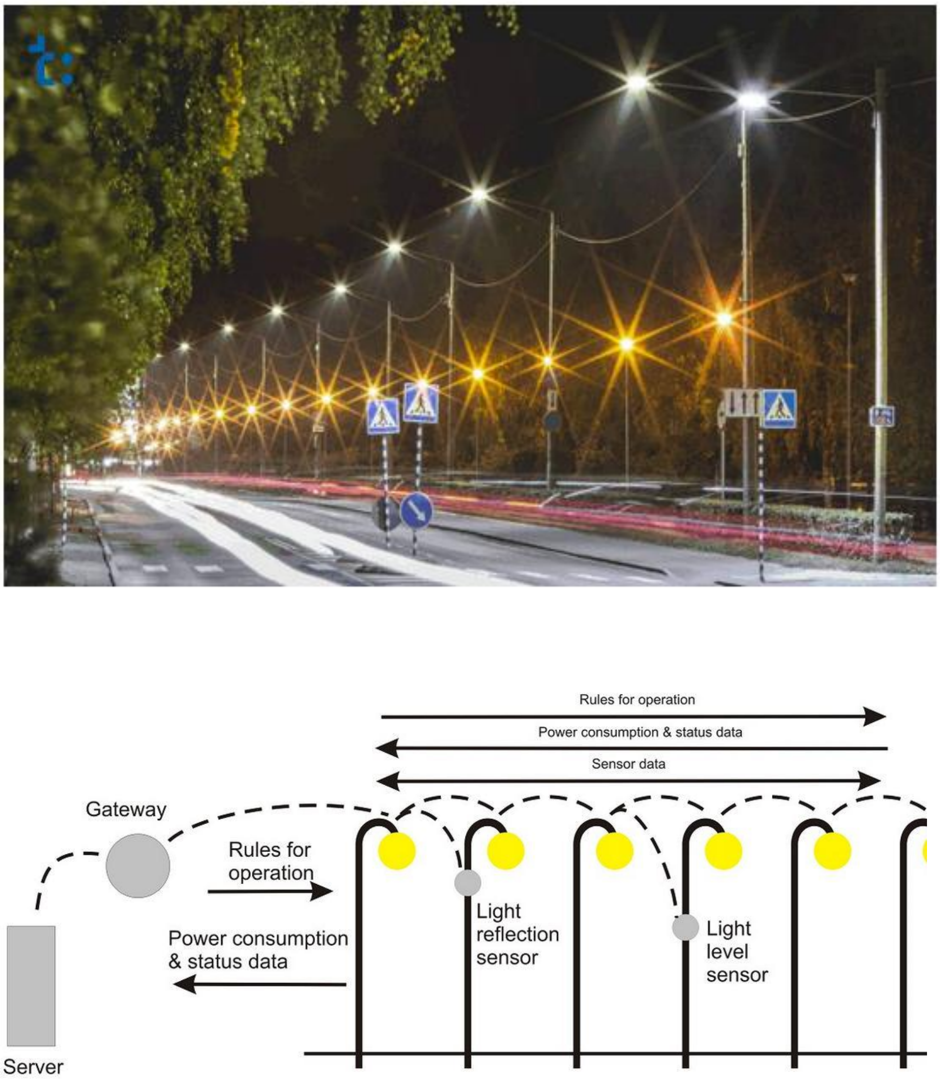

Figure 16. Smart streetlights in Tartu and their sensor scheme [4.]

3.5 Funding

The funding structure of Smartovka pilot project is divided so that the occupants of the building to be renovated pay about 30-35% of the renovation cost, 45% is paid by EU sustainability funds and 25% paid by the national renovation support scheme KredEx. The budget is €9 million. [16.]

The estimated cost of the renovation of Smartovka is 300 €/m², which includes the design and construction works, whereas the average renovation cost of Soviet-era apartment buildings in Estonia is 200-260 €/m². Price is one of the most important factors in terms of project replicability. As the average price for new apartments in Soviet-era buildings varies between 1 000-1 300 €/m²,it is challenging to explain the benefits of retrofitting projects to the average occupants and try to encourage them to take a loan for such projects. Smartovka project papers state that even with a scheme where the EU and local authorities have paid 70% of the total renovation costs it has been difficult to involve residents. [16.]

Although it is unclear if the EU will fund the same type renovation projects as Smartovka in such a scale in the future, the Smartovka project pages say that they consider a future scenario where a retrofitting project is financed with 45% of state funding and 55% of the residents' funding. It means that the price will be significantly higher for the residents compared to the pilot project in Tartu. In a real- life situation it means that if someone has payed 36 000 euros for a 30 m² non- renovated *hrustsevka* apartment in Tartu and the building undergoes a *hrustsevka* to *smartovka* renovation, the householder will need to pay an additional 5 000 euros which they might consider to be too much. Quite a different situation might be seen in cities like Tallinn, where the apartment prices are higher, and an additional 5 400 eu may seem more acceptable. Slow bus stable decrease in Tartu population might also play its role in building's occupants' behaviour and they will to renovate. [16.]

Possible solution can be renovation cost reduction which might be achieved by use of same- type renovation solutions and designs, which would not need new energy assessments, plans and design. Such a solution might be also combined with an increased

EU funding part and rising the occupants' awareness of the benefits they could have from such renovations.

3.6 Retrofitting packages and community solutions in other lighthouse cities

In Sonderborg, Denmark, seven social housing (figure 17) districts with a total of 51 buildings and 815 apartments were retrofitted using different solutions for different districts. The Retrofitting baseline is similar to that of the Tartu package-improving the energy efficiency of the building envelope by installing new low energy doors and windows, improving facades, roofs, air tightness, installing new ventilation systems with heat recovery, indoor LED lights, automatic heating control system and 4950 m² of solar panels in six housing districts integrated into the roof and façades. As output result, the energy demand of the buildings was reduced from 114-139 kWh/m²/year to 61- 118 kWh/m²/year, or by 21-47%. The result is better than that in Tartu, but the energy demand of the buildings in Tartu was significantly larger before the renovation and the difference between before and after renovation in Tartu is 67%. The citywide solutions in Sonderborg are very similar to the ones used in Tartu. [18.]

Figure 17. Social residential buildings before renovation in Sonderborg, Denmark [18.]

In Vitoria-Gasteiz in Spain, 750 dwellings were connected to the district heating network and the envelope of the buildings was retrofitted, but there is no data available about the energy savings yet (figure 18). The main aim of the project was to improve the quality of living in a socially susceptible part of the city. [19.]

Figure 18. Vitoria- Gasteiz before and after renovation [19.]

4 Conclusion

The impact of residential buildings on the environment and on CO_2 emissions is significant. The fact that renovation of buildings like the Soviet panel buildings can lead to a 70% reduction in their energy consumption makes the search for cost-effective ways of renovation an important topic for community planning strategies. Estonia is seen to have implemented efficient renovation practices like getting people involved in the renovation by significantly covering the renovation costs. However, the pace, and scale could be larger. The KredEx and SmartEnCity retrofitting projects done in Tartu (table 4) may result in significant energy consumption reductions for a relatively low increase in monthly payments. Both projects demonstrate that it is economically efficient to have a major renovation rather than an average one as saving more energy also reduces the monthly bill for an apartment.

Table 4. Comparison of outcomes of Kredex and SmartEnCity project.

	Min. U-values(Kredex 25%) W/(m²·K)	Min. U-values(Kredex 40%) W/(m²·K)	U values (Smartovka) W/(m²·K)	U values (non-renovated) W/(m²·K)
Wall	0.25	0.22	0.149*	0.8- 1.1
Roof	0.15	0.11	0.076	0.9- 1.1
Windows	1.1	1.1	0.9	2.9
Cost of examined projects (total) euro/M2	192	265	300	
Cost of examined projects for occupants euro/M2	143	158	105**	
Delivered energy after renovation	167	111	90	
Difference (savings) (kWh/ m2 * a)	46	100	180	
Difference (savings) (%)	22%	47%	67%	
Price of saved kWh/ m2 * a	4.20 €	2.60 €	1.70 €	

**Plinth wall has U value of 0.21 W/ m^2 *K*

*** Small costs for residents are due to 70% financing by EU/ local funds*

The European Union is working on both efficient renovation practices and sustainable community planning strategies implementation by funding cost-effective renovation and pilot city projects. It is impossible to underestimate the meaning of such promising projects for the environment. It seems that the EU community is at the beginning of its path to implementing EU-wide guidelines, searching for the best solutions by investing in pilot projects in order to evaluate the outcomes.

Studies show that in order to achieve better energy efficiency results, more expensive solutions should be applied under the supervision of independent professionals, and that getting people involved into the process in also an important part of sustainability. It is important for projects like SmartEnCity and KredEx to continue and to be as transparent as possible so we could learn the experience of one another and achieve energy efficiency goals together, which is more effective than doing so alone. Original solutions like art works on Tartu project facades look more attractive on project overview pages than if there was no art involved. Those are small details among up to date, professional technical solutions that are pushing our society towards a more sustainable future.

However, it is clear that it will be impossible to renovate all old buildings because it is not possible to gain such speed of renovation that all of the buildings could undergo a major renovation before the end of their service life. It would require both money and many companies working on a renovation at the same time. For Estonia this would mean renovating about 1 000 buildings per year, which is not reachable, neither from a financial nor a constructional capacity point of view.

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