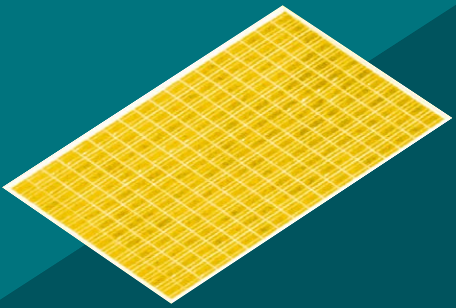

Solar Energy for Multi Family Houses in Lithuania

Potential implementation

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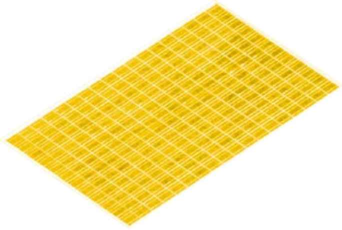
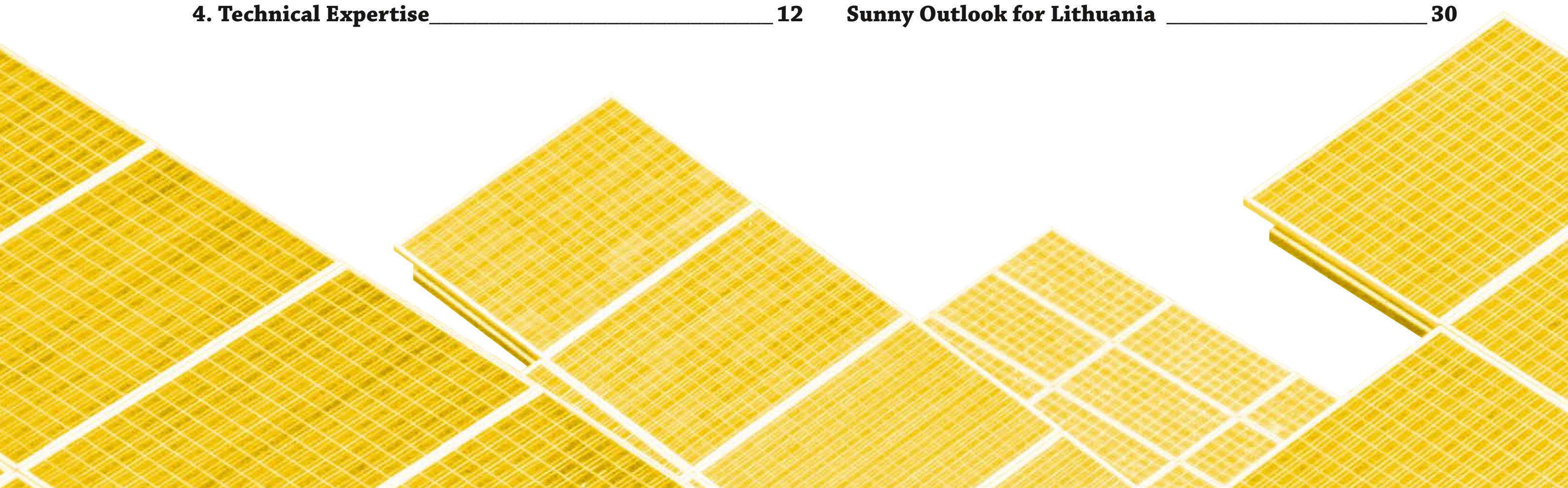


Solar Energy for Multi Family Houses in Lithuania

Potential implementation

Content



Introductory word

An increasing number of people are becoming worried about the consequences of climate change and are taking measures to become more climate and environmentally friendly. This starts with sorting garbage, abandoning plastic and disposable tableware, more frequently cycling or using public transport, and includes energy recovery from renewable energy sources. Until recently, it was hard to even imagine having your own solar power plant. Today, with a dramatic drop in price, photovoltaic modules are becoming more and more accessible. In Lithuania, the owners and residents of residential houses often choose roof-mounted solar power plants. However, apartment owners still view this opportunity with distrust. Through this study, we want to prove that investing in solar modules on the roofs of apartment buildings can be a worthwhile addition to standard renovations and a way of lowering costs, not only for electricity but also for heat when using heat pumps.

Currently, Lithuania imports about 60 per cent of the electricity consumed in the country. This figure shows that the state and electricity consumers are heavily dependent on the economic and political situations of other countries and, in the long run, cannot guarantee best prices. This dependence caused the Ministry of Energy of the Republic of Lithuania to forecast in its National Energy Independence Strategy that by 2050, 100 per cent of the required electricity will be produced inside the country, with 80 per cent coming from renewable energy sources, and that half of all consumers will be producer-consumers[1] (prosumers). This number is very ambitious and will be impossible to reach without the help of even the most modest consumers living in apartment blocks. In order to calculate the potentials and possibilities for installing solar power plants for the residents of apartment buildings, we prepared this publication.

In this study, we examine the current social situation, favourable legal framework conditions and existent as well as future opportunities for consumers to become producers at the same time. Most importantly, we provide a comprehensive technical-economic analysis that underpins the benefits and cost-effectiveness of investing in solar power plants. The Applied Research Institute for Prospective Technologies (Protech), one of our project partners in Lithuania, contributed with an analysis of the renovation practices available in Lithuania and an assessment of the different options. Our German partner Steinbeis-Innovationszentrum energie+, an institute with longstanding experiences in designing and implementing solar energy projects, analysed two unrenovated apartment buildings in Lithuania, modelling their renovation along different scenarios that correspond to the requirements for energy efficiency classes C, B, A, A+ and A++, respectively. Also, the energy consumption was calculated for the case that photovoltaic cells are incorporated and employed as part of a standard apartment renovation aiming at achieving energy efficiency class C.

This study is primarily addressing civil servants and politicians who are in the position to take decisions and have the power to accelerate the development and implementation of renewable energy. However, we hope that the information provided in this study may also be useful and relevant for energy consumers who are taking the possibility of ‘employing the sun’ for their own use into account.

Knut Höller

Housing Initiative for Eastern Europe (IWO e.V.)

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[1] https://enmin.lrv.lt/uploads/enmin/documents/files/Nacionaline%20energetines%20nepriklausomybes%20strategija_2018_LT.pdf

Synopsis

1. Producing solar energy by using photovoltaic cells is becoming more and more popular. One of the most promising areas for applying this technology is the modernisation of apartment buildings.
2. Energy production from renewable energy sources (RES) is being promoted in European and Lithuanian strategic documents. The Lithuanian National Energy Independence Strategy foresees not only the pursuit of full independence from imported energy, replacing it with RES, but also a rapid increase in the number of prosumers.
3. In Lithuania, a large part of the population suffers from energy poverty: many families cannot afford to pay for heating, hot water and electricity. Investing in RES could be one way of tackling this problem.
4. According to the requirements for the energy efficiency classes for buildings, only class A++ requires the inclusion of renewable energy sources. We have analysed cases in which RES are also used in lower energy efficiency classes, and we will provide our calculations herein.
5. The complete modernisation of an apartment building incurs huge costs, which the residents will most likely wish to avoid. Thus, we have compiled a 10-year history of complete renovations – showing that only 6 per cent of apartment blocks have been renovated so far, which reflects the unattractiveness and inefficiency of current approaches.
6. An economically efficient way to save money is to give up the hot water supply from centralised networks in the summer. From May to October, after the end of the heating season, centralised heat production and power supply for heating domestic hot water and towel dryers (coils) are very cost ineffective. Replacing these power supplies with heat pumps would not only reduce consumers' expenditures, but also eliminate the losses incurred by operating boiler-houses and centralised network operations through the warm seasons.
7. Where funds for fully renovating buildings are not sufficient, it is worthwhile to consider partial renovations e.g. of the heating units. A possible result could be that it will be possible to regulate the heating individually per apartment, so that the central heating system could be operated more energy- and economically efficiently.
8. A very efficient way of modernising a building's heating and energy system is to employ a combined heat pump (CHP) linked to a photovoltaic (PV) system and integrate this into a partial renovation of the building. This could save up to 60 per cent of the annual costs for heating and hot water, as compared to a conventional renovation practice.
9. Renovating an apartment building to comply with energy class A++ is the best choice in terms of energy but is economically unattractive and only applicable in particular cases.
10. The comprehensive analysis of the buildings and the simulated renovations have shown that upgrading the building to energy class C along with installing a solar power plant, is the most cost-effective approach.
11. Supporting the establishment of energy communities and a more transparent and accessible legal framework for joint ownership are two of the most important tools available to the state policy to gradually increase the number of prosumers.
12. Solar power plant prices are still as high as to discourage lower-income consumers, which is why state support is an indispensable tool for further developing solar energy.

1. Lithuanian social conditions regarding PV

In the scope of this report, we concentrate on two energy issues. **First**, photovoltaic (PV) technology which is the most obvious technology for producing electricity from solar radiation; the latter is converted into electric power via solar panels (containing solar PV cells made of semiconductors) and then, using inverters, is fed into the [micro]grid. This is the most straightforward use of solar energy in any building, including multi-family houses (MFHs). Solar electricity or **solar photovoltaic** is usually the term used in such cases, or in short, solar PV.

Second, and applied much less, is solar energy used for heating. In the course of the development of solar energy utilisation technologies, solar panels were initially used to collect sunlight and transform it into heat, hence the synonymous name **solar thermal** technology. The panels on the roof function as collectors of sunlight, containing tubes with liquid in it. Solar radiation heats up the liquid in the tubes which is then transported into the heating system ready for use, e.g. for heating water.

As technologies advanced, solar PV saw the steepest drop in prices which made it more competitive in comparison to solar thermal. Sunlight conversion into electricity increased hugely in the last few decades, while the cost of equipment dropped multiple times from what it cost back in 1990 through to 2000. This caused solar PV to spread on a global scale and motivated the introduction of additional incentives as economies of scale made it affordable.

Certain economic and political developments made solar PV even less costly to the end user. Since September 2018, European Union scraped Minimum Import Price regulations for solar panel imports, which led to solar panel prices dropping an additional 30 per cent, with panels selling out at €0.20/Wp – a price considered by many close to the bottom for current production technology[2].

As of today[3], solar PV is more cost-effective and less technically challenging when compared to solar thermal. For this reason, we decided not to consider solar thermal usage for MFHs in Lithuania, which also corresponds with many industry experts' opinion. The main assumption behind that is that electricity is still the most universal form of energy, easily converted into any other form of energy typically used in a household, while thermal (heat) energy is not as universal by far.

When it comes to electricity, the overall picture is suggesting that PV deployment should be increased. Electricity grid prices in Lithuania are among the lowest in Europe – with 0.1097 €/kWh according to the most representative (Eurostat[4]) electricity usage band. Across the EU, electricity for households is cheaper in one EU country only – Bulgaria.

Our own calculations show that the typical PV installation investment will pay off in 8 to 13 years, depending on state support levels and calculation assumptions. For countries with better parity-to-grid ratios like Germany, Spain or Italy, the choice for solar electricity is obvious – self-production and -consumption brings easily visible benefits for both, households and the industry.

In Lithuania, with an average 0.1097 €/kWh, the choice is not so obvious. Comparatively large upfront investment costs hinder consumers' ability to install solar PV for self-production. The number of prosumers ('producer-consumers') is still around 1.000, the absolute number of such installations in place in single-family houses.

With regard to MFHs, huge hurdles exist for private households to produce their own energy. This contrasts with the probability that solar energy self-production and -usage is desirable for consumers in MFHs to help balance social equality issues there and fight energy poverty.

The latter is clearly a problem, insufficiently addressed by the state as well as non-state players. As shown by the European Energy Poverty Observatory[5], Lithuania is among the laggard countries when it comes to its citizens' 'ability to keep their homes adequately warm'. See chart below:

The poorest Lithuanian families spend as much as 50 per cent of their monthly income on heat, electricity and warm water. The problem roots in the Soviet legacy, as is evident from pan-European statistics[6].

Caused by a combination of factors, including low household incomes, high energy costs and energy-inefficient buildings, energy poverty[7] is estimated to presently affect around 50 million people across Europe, with severe consequences for

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[2] In total, the price for installing 1 kWp of solar PV power station is around 1.000 Euros for small installations (in low kW figures range) and between 500-600 Euros per kW peak power for larger installations (hundreds of kW and megawatts). In addition to solar modules, mounting structures and additional electrical equipment is needed, while cost for human labour and administrative workload will also have to be added.

[3] At the time of print of this brochure, March 2019.

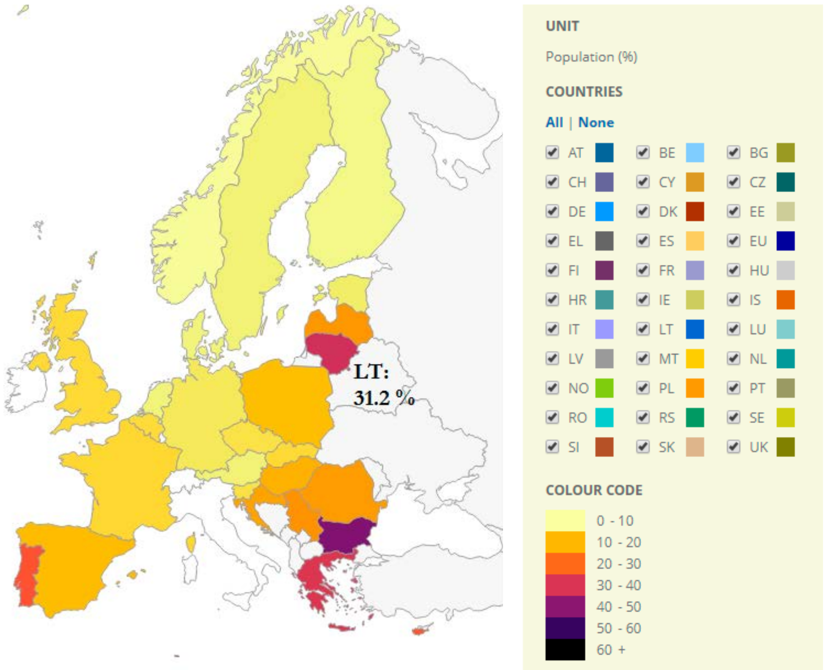
[4] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Electricity_prices,_First_semester_of_2016-2018_(EUR_per_kWh).png

[5] https://www.energypoverty.eu/

[6] Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, „Energy prices and costs in Europe“ {SWD(2019) 1 final}, published on January 9, 2019 (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52019DC0001) states, that across the EU, northern and western European households spend 4-8 % and central and eastern Europeans spend 10-15 % of their income on energy, excluding transport.

[7] Energy poverty refers to a situation where households struggle to maintain a necessitated level of domestic energy services to guarantee a decent standard of living, like adequate warmth and cooling (18-21 °C in the winter and 25 °C in the summer according to the World Health Organization).

Inability to keep home adequately warm



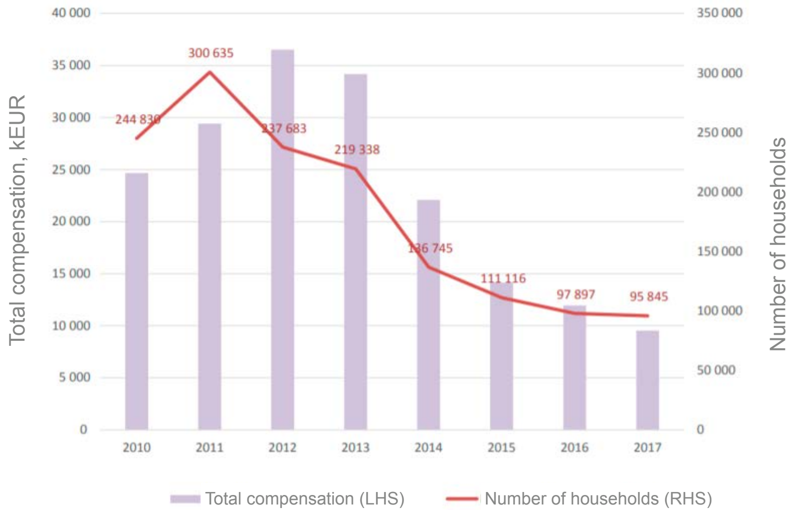
citizens' health and wellbeing. For Central and Eastern Europe, the combination of the aforementioned factors creates a self-reinforcing vicious cycle: low incomes (and consequently low or non-existing[8] savings) hinder the residents' ability to invest into energy efficiency measures for the house or apartment they live in.

Extensive and unsustainable privatisation campaigns in the 1990's turned out to produce 'poisonous gifts' – people were given dwellings which they would normally not be able to afford buying or renting, and which they struggle to maintain today, given that the building condition and infrastructure was often outdated at the time of privatisation already: Families with low income and hardly any savings are not able to bear the cost of required building improvements, let alone additional ones – hence, state-supported instruments are in place to run the massive MFH modernisation programme.

Global climate impacts and the drive to consolidate European energy policy have added urgency but some fundamental and complex issues remain unresolved, and further progress is hindered. Without further dedicated action, the 2030 and 2050 climate and energy targets will be very difficult to meet. The potential is there for reducing the energy consumption in existing buildings by 5 to 6 per cent and lower their carbon emissions by about 5 per cent. However, with only 0.4-1.2 per cent of the EU building stock renovated or subject to renovation every year, it is obvious that efforts need accelerating on a European and global scale.

In 2015, around 15.2 per cent of the EU population lived in homes with structural damages (such as leaking roofs, damp walls, floors or foundation, or rot in window frames or the floor). The relevance and importance of energy efficiency measures is self-evident. The Energy Efficiency Directive (EED) has the potential to constitute a major step in the right direction by steering energy efficiency measures and respective support towards low-income households and the energy poor. The emerging EU regulatory framework therefore may help to fight energy poverty more effectively. Transposition into national law should be taken very rigorously to ensure measures are put in place to tackle this serious and multi-layered issue.

Compensation for heat and hot water provided to state-support eligible consumers, 2010-2017



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[8] For 2017, 12 per cent of Lithuanian households stated that they had no savings at all, as research conducted by Spinter tyrimai showed. Another 27 per cent stated to have savings equalling one month's household expenses (or less). Source: https://ziniuterasa.swedbank.lt/spaudos-pranesimai/tyrimas-be-pajamu-2-3-lietuvos-gyventoju-issiverstu-iki-3-menesiu.

2. Conditions and opportunities for the PV market to expand in Lithuania

2.1. Average level of solar radiation in Lithuania

The radiation level in Lithuania is between 900 kWh/km^2 and 1100 kWh/km^2 per year. Average radiation levels in the major cities of Lithuania (kWh/m^2/year) are as follows: Vilnius – 990, Kaunas – 1058, Klaipėda – 1062, Šiauliai – 974, Nida – 1073. Under these conditions, it is possible to produce an average of 950-1050 kWh of electricity per year by using the latest PV technologies.

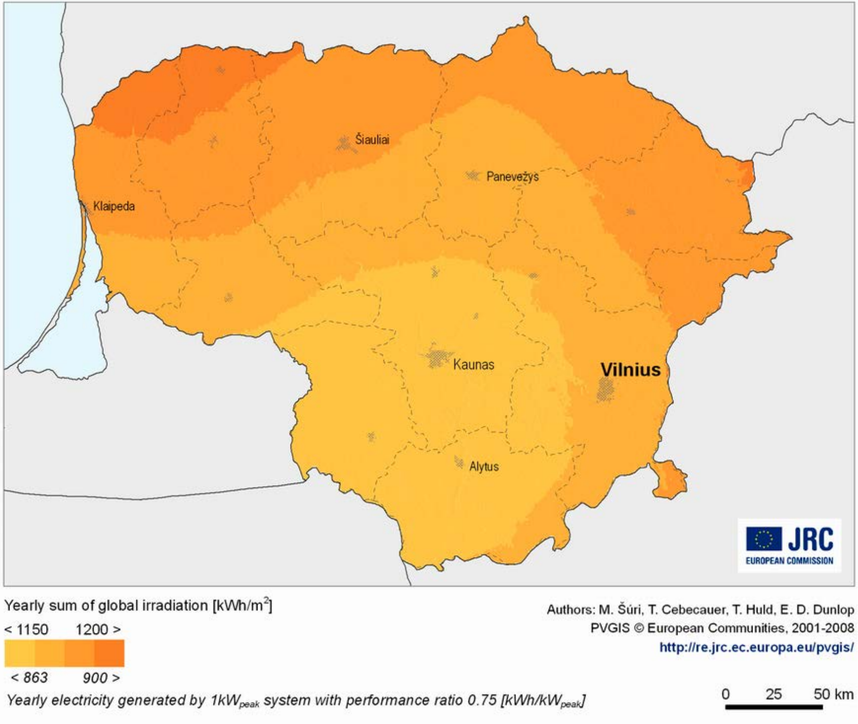
At such a level of radiation and by offering a 30 per cent support for the equipment, solar electricity production is cost-effective. Therefore, it will surely develop. The Lithuanian Energy Independence Strategy has foreseen that by 2020, 30 per cent of the country's electricity will be generated from renewable energy sources, whereof the share of solar energy will be 6 per cent. In 2030, 45 per cent of all energy will be produced from renewable sources, and the share of solar energy therein will be 25 percent to satisfy approximately 12 per cent of the country's electricity needs.

2.2. PV market assessment

The more active development of the solar photovoltaic market in Lithuania began in 2009, when the feed-in tariff was introduced, and the first commercial projects were launched. Soon afterwards, in 2011, the Law on Energy from Renewable Sources was adopted. This has created favourable conditions for solar power, and especially for smaller installations (up to 30 kW). Within three years, the total volume of photovoltaic installations reached 60 MW. In 2012, when the authorities did not respond in time to the dramatic fall in the price for solar modules, the feed-in tariff became very attractive, leading to a 'solar energy boom'. The new government then drastically cut all the benefits; therefore, there weren't any new solar power plants installed in Lithuania for two years.

In 2014, a double net metering system for solar electricity was developed. This system allows electricity to be produced at the most favourable time, i.e. during the day and in summer, to immediately transfer the unused surplus to the distribution network operator, and to withdraw this electricity at times of shortage, i.e. in the evening and in winter. At the

Average level of solar radiation in Lithuania



same time, households started becoming not only electricity consumers but ‘producing consumers’ (prosumers), which resulted in major economic and social consequences. Although the production is limited to 10 kW for home users and 50 kW for public authorities, this change revived the market and in 2018, the total power reached 80 MW. Consumers were able to receive support of up to 30 per cent of the equipment’s price, and public bodies up to 100 per cent.

At present, the legal and economic conditions are more favourable than ever for ‘producing consumers’, and consequently the number of new plants is steadily increasing. The Ministry of Energy’s programme foresees 34,000 new production bodies by 2020, with a total capacity of up to 200 MW. However, this ambitious goal can only be achieved by involving the residents of apartments buildings. Additional favourable conditions are provided in an amendment to the Law on Energy from Renewable Sources, which is currently under consideration by the Seimas (Lithuanian parliament). It is envisaged that a 500 kW power limit will be applied to double net metering, as well as allowing for electricity generation not only at the place of consumption, but also at any other location chosen by the producer. At the same time, excellent conditions for using solar electricity for domestic purposes, with the help of modern air-to-water heat pumps, will make this type of electricity an economical choice for heat production. For this reason, we have prepared this feasibility study, in which we calculate the possibilities for introducing solar energy into apartment renovation actions and programmes in Lithuania.

3. Situation of renovations of apartment buildings in Lithuania

The scaled process of renovating apartment buildings in Lithuania started in 2004, after the Government of the Republic of Lithuania passed the resolution “On Approval of the Programme for the Renovation (Modernisation) of Multi-Apartment Buildings”. This resolution set the conditions for renovations and the promotion mechanisms and established the Housing Renovation Agency which became the coordinator and supervisor of this process. The renovation mechanisms have been constantly improved since then.

The latest amendment to the resolution of the Government on the wider use of renewable energy for the renovation of residential buildings was adopted in December 2018. Thanks to this, renewable energy will be an integrated part of the modernisation process of apartment buildings: the use of solar, wind, geothermal and aerothermal energy is being provided favourable conditions. This allows for more diverse approached and possibilities in the process of renovating multi-apartment buildings, and thus a more active pursuit of climate change management objectives.

In Lithuania (according to data from 2010), there are 37,300 Soviet-era apartment buildings with 3 or more apartments that need to be renovated. By the end of 2018, only 1,650 buildings, or 6 per cent of all apartment buildings, had been renovated. 450 buildings are currently undergoing renovation. Therefore, approximately 35,000 buildings are still waiting for their turn. This continuously high number makes it clear that we need to look for simpler, cheaper and more efficient ways to modernise these buildings.

3.1. Energy modernisation of multi-apartment buildings – options, advantages and disadvantages

In Lithuania, typical renovation practice involves insulating the walls, roof and basement of the buildings, as well as replacing the windows and exterior doors, insulating pipelines and replacing radiators. More dedicated energy efficiency measures that integrate and apply solar, aerothermal or geothermal energy are very rare. Making use of them, though, could lead to the same energy saving results, only at significantly lower costs. Most importantly, such measures help achieving better results in reducing carbon emissions and making a significant contribution to the implementation of the Lithuanian climate change programmes.

Particularly favourable conditions for the use of renewable energy, mainly for solar power generation, can be found in a very advanced double net metering system in place in Lithuania. The essence of this system is that solar power can be produced at a time favourable for energy generation, i.e. during light days or in summer; for a small fee, it can then be passed to the grid for storage and used at the time when it is needed most, i.e. during gloomier times of day or in winter.

This system is particularly suitable to produce thermal energy using air-to-water heat pumps. The pumps use environmental aerothermal energy for this purpose and sunlight for electricity.

3.1.1. Partial modernisation

The complete modernisation of an apartment building ensues huge costs, which the residents will most likely wish to avoid. Thus, we have compiled a 10-year history of complete renovations – showing that only 6 per cent of apartment buildings have been renovated, while also looking at the effectiveness of the renovations.

It turns out that re-thinking renovation practice and approaches is worthwhile – taking small and very cost-effective steps could be the key. A possible step is to use innovative means to modernise the heat distribution units of the apartment building and reduce heat consumption per apartment by up to 15 per cent, incurring only low costs. Another very cost-effective measure is to give up hot water supply from centralised networks during the summer. From May to October, after the end of the heating season, centralised heat production and the power supply for heating domestic hot water and towel dryers (coils) are very cost ineffective.

3.1.2. Modernisation using solar power and heat pumps

This modernisation method is attractive because the targets of the modernisation, such as reducing the amount of heat supplied centrally, can be achieved by reaching an indicator of 60 per cent. It involves a typical renovation task, whereby the building's energy efficiency class is increased from F to C. This goal can be achieved in a much more economical way by using aerothermal and solar energy.

3.1.3. Traditional renovations

Traditional renovations include the thermal insulation of all exterior structural elements of a building in order to significantly increase their thermal resistance, i.e. avoiding losses of thermal energy. At the same time, the energy system of the building is partially renovated. This is an obvious and understandable way of modernising a building; however, it is an expensive one, which makes it difficult to convince the residents of the building to undertake it.

3.1.4. Traditional renovations combined with the use of renewable energy

This method allows the building to use almost no central heating power and to become a 'nearly zero-energy building'. To achieve this, it is necessary to use autonomous heat production facilities. As a rule, such facilities are photovoltaic cells for power generation and geothermal or aerothermal air-to-water heat pumps to produce heat and hot water.

3.2. Application of energy modernisation models – example of a building on Taikos Street, Utena

For a more detailed study of the modernisation of different buildings, a typical Soviet-era residential apartment house in Utena, located at Taikos Street 27 (hereafter referred to as the Utena building) was selected.

Its main general parameters are as follows:

- Number of apartments – 38
- Usable area for apartments – 2,043 sqm
- Usable area for non-residential purposes – 101 sqm
- Total area – 2,144 sqm

Key energy and economic parameters:

- Heat consumption per one sqm per year – 189 kWh
- Total heat consumption per year – 405,400 kWh
- Heat amount for hot water preparation per one sqm per year – 54 kWh
- Total heat amount for hot water preparation per year – 110,000 kWh
- Electricity consumption for domestic purposes per one sqm per year – 30 kW
- Total electricity consumption for domestic purposes per year – 64,300 kW
- Energy Efficiency Class – F
- Estimated cost of construction work for the transfer of a building from Class F to Class C – EUR 378,000
- Estimated cost of construction work for the transfer of a building from Class F to Class A++ – EUR 667,000

These parameters were used to simulate the energy system modernisation of this building.

The Utena Building is not typical from the point of view of a renovation, because its initial energy efficiency class is F, while the average energy efficiency class of a multi-apartment building in Lithuania is E. Having all energy-related data of an apartment building before and after the renovation as well as collecting information on the energy consumption after the renovation make it possible to compare the various renovation measures first in the simulation and then in reality after final implementation.

3.2.1. Renovation of the heating unit along with the summer hot water system: partial renovation

The purpose of this kind of renovation is to modernise the heating unit of the building so that it stops supplying hot water during the warm (summer) period.

The heating units of old buildings like the Utena one are operated very inefficiently, as it is difficult to control and manage the temperature of the water according to the demand and need as the heating units are managed centrally throughout the heating network. It is not possible to regulate the heat consumption quickly in the building to correspond to changes in air temperature during the day and thus changes in demand. Of course, every building is different as are the needs of their inhabitants. After the modernisation of the heat substation, possibilities arise which allow for approximately 15 per cent of the thermal energy to be saved. The cost of such modernisation would be approximately EUR 20,000 for the Utena building.

Another possibility to increase energy efficiency is to give up hot water supply from the central heating system. Economic indicators of such a move would be as follows:

- Hot water consumption from May to October – 1,100 cubic metres
- Heat energy needed for preparing such an amount of hot water – 55,000 kWh
- Power needed for running a heat pump for that much heat energy – 42 kW
- Electricity consumption of the heat pump to produce that much heat – 18,000 kWh
- Power of the solar power plant needed to produce that much electricity to run the pump – 19 kW
- Price for the solar plant – EUR 19,000
- Price for the heat pump including installation – EUR 11,000

- Price for solar electricity using double net metering – 0.03 EUR per kWh

Based on these indicators, the following calculations were made:

- Price for heating one cubic metre of water using solar electricity and a heat pump – 1.5 EUR/cubic metre
- Price for one cubic metre of hot water from the centralised network – 4.52 EUR/cubic metre
- Difference – 3 times

In this case, the investment costs are not included. They are composed as follows: EUR 20,000 for modernising the heat substation and EUR 30,000 for producing hot water. This estimation, however, does not consider the real costs of a centralised boiler room, which generates heat at a capacity 3 times lower than in winter. In the case of a partial renovation including the usual 30 per cent support, the following payback time is achieved: for the renovation of the heating unit – 4.7 years; for the hot water preparation – 6.5 years.

Thus, the partial or 'small' renovation is much more cost-effective than a traditional renovation where the insulation of the entire building is involved.

3.2.2. Transfer of a building from Energy Class F to C without insulation

This type of modernisation is carried out using solar power and heat pumps.

As was mentioned earlier, the purpose of the renovation and modernisation of old buildings is to reduce the energy consumption of the buildings and the cost of providing heating and hot water for the residents. At the same time, such actions aim at reducing carbon emissions and contributing to the protection of the environment from the greenhouse effect. For this purpose, the traditional way of insulating the walls of a building is usually employed, which involves changing the windows and doors, and using other passive means.

However, there is another way to achieve the same result: to replace the heat 'contaminated' with CO2 (gas or even biofuel) with clean solar and aerothermal energy coming from photovoltaic solar modules and air-to-water heat pumps. The legal, technical and administrative possibilities for this modernisation method in Lithuania are due to be finalised very soon, whereby it will be possible to use a net metering system of solar electricity for solar power plants up to 500 kW, and to apply this system to power plants at other sites than the place of power consumption.

Below, the economic effect of applying such a modernisation approach to the example of Utena Building is described using the building data compiled above.

Thanks to the renovation from class F to C, 253,100 kWh of heat is expected to be saved.

This renovation and upgrade in energy class would cost EUR 378,000.

Let's calculate the cost of the same heat savings in another way, this time assuming the employment of a solar power plant and an air-to-water heat pump. The pump has an annual efficiency indicator SCOP of 3, i.e. 1 kWh of electricity is converted to 3 kWh of heat. This will require 253,000 : 3 = 85,000 kWh of electricity to achieve the same savings as with renovation to class C.

The heat output of a heat pump producing 253,000 kWh per year, should be 125 kW with a total installation cost of EUR 80,000.

The power of a solar power plant producing 85,000 kWh of energy per year should be 90 kW and comes with a total installation cost of EUR 90,000. When using this method, it would also be helpful to replace the radiators, which would cost EUR 10,000.

Therefore, the total cost of modernising the building's energy system installing a solar power plant and heat pump is EUR 180,000. For an investment project for a traditional renovation, construction work costs of EUR 378,000 would apply.

It should be concluded that modernising the building's energy system by replacing 'contaminated' heat energy with green energy and thus allowing for savings of 62 per cent of heat energy (as provided for in the renovation investment plan for transfers from Class F to C) would result in **a heating method that is 2.1 times cheaper than the current one**.

3.2.3. Traditional renovations

Traditional renovations include insulating all the external constructions of a building, as well as replacing the windows and exterior doors, and modernising the heating units and elements of the heating system.

In this study, this method has not been explored in more detail since such renovations are not new, and studies have already been carried out by various institutions on many buildings.

As was already mentioned, in the case of the Utena building, its thermal energy consumption shall be reduced from 405,000 kWh/year to 152,000 kWh/year, i.e. by 253,000 kWh/year. At the same time, the energy performance class of the building would be upgraded from Class F to C.

The cost of this action is 378,000 EUR.

Since the cost of central heating in Utena is 4.72 EUR ct/kWh, the renovation would save 11,950 EUR per year. The estimated **payback period for such a renovation is 31 years**.

So far, however, social and aesthetic results of such a renovation have not been mentioned: the exterior of house will be upgraded, and it will be nicer to live there. Such factors are very important, but it is hardly possible to estimate and consider them economically.

3.2.4. Traditional renovations combined with the use of renewable energy

In Europe, the drive to install passive zero-energy buildings with Energy Efficiency Class A++ is increasing. Such buildings are undoubtedly the future for residential and non-residential buildings. Realising an A++ building, however, is not possible without integrating locally produced energy, which means in the case of renovations that the building' energy system must be renovated, too. Piloting such technically advanced buildings is necessary, because both, scientists and practitioners, need to understand the specific requirements of such building houses and learn how to equip and operate them in economical and technically efficient ways.

This method was also calculated for the Utena building. Here, beside insulation measure, installing a solar power plant connected to a geothermal heat pump is also part of the planned action.

To comply with Class A++ standards, the building's heat energy consumption needs to be reduced by 371,000 kWh/year, from 405,000 kWh/year to 34,000 kWh/year. In this case, 1.62 kWh/year would be suffice to heat 1 sqm, while for the unrenovated house, this figure is 188.86 kWh/year – which means that the heat consumption would be reduced by as much as 99.1 per cent. In order to achieve this result and in addition to insulation measures, a 18 kW solar power plant, as well as a 24 kW heat pump and a set of 8 kW solar thermal collectors for hot water production need be installed.

This renovation approach would be very desirable and effective for multi-apartment buildings, but implementation costs are as high as 667,000 EUR, excluding the design and additional work. Such a project's net payback period is **35 years**. Thus, without additional state or other support, this method will not be attractive to the residents. We hope that, based on the foreseen implementation of the Utena building's project, we will be able to calculate specifically whether the renovation of a building to reach the highest energy class is beneficial in terms of financial and environmental aspects.

4. Technical Expertise

The purpose of this project is to examine conditions under which it is feasible to invest in equipping apartment buildings with photovoltaic units. At the first stage, two typical apartment buildings were selected: one made of reinforced concrete (panel house) and one solid-cast one (brick house).

There are about 20,000 buildings of these types in Lithuania (cf. Illustration 1).

As part of the first stage, thermal modelling of the selected buildings was carried out in the EnergyPlus program in order to determine the heat demand. Based on this and on the measured energy consumption for heating water, the total demand for heat and hot water was determined. Losses in hot water pipelines were assumed to be approximately 20 per cent, in heating pipelines approximately 10 per cent. The demand for additional power was 2 per cent of the consumed heat. Indicators of electricity consumption are based on measured values.

Combining these values made it possible to determine the total building energy demand. The procedure is shown in Illustration 2.

In addition to the model of the two existing buildings, three models with different envelopes were made for each of the buildings. The requirements for heat-transfer coefficients were considered in accordance with Lithuanian energy efficiency classes. In addition, airtightness requirements were also examined. The requirements for final and primary energy as indicated in the energy efficiency classes, including not only the building envelope but also energy generation

Illustration 1: Selected buildings

Typical MFH „brick house"
(~ 2/3 of building stock)

~ 14.000 units in total

simple brick construction

district heating system

Typical MFH „panel house"
(~ 1/3 of building stock)

~ 6.000 units in total

simple ferro concrete construction

district heating system

Illustration 2: Energy demand calculation process

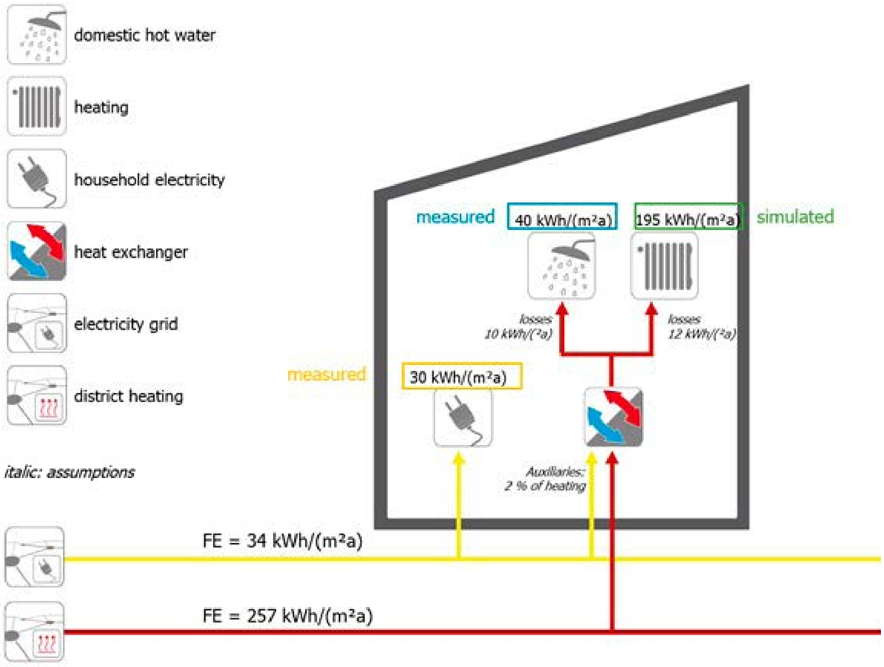


Illustration 3: Basic data for a brick house

	W/(m²K)
U_{Wall}	1,27
U_{Window}	2,5
U_{Roof}	0,85
U_{Floor}	0,93
n_{50}	3 h^{-1}

2760 m² living area
55 flats
ground area 63,4 m x 11,05 m
5 storeys
~ 30 % window area ratio on „long side"
measured total heat consumption: 156 kWh/(m²a)
measured total DHW consumption: 70 kWh/(m²a)
measured total electr. consumption: 21,3 kWh/(m²a)

Illustration 4: Basic data for a panel house

	W/(m²K)
U_{Wall}	1,27
U_{Window}	2,5
U_{Roof}	0,85
U_{Floor}	0,71
n_{50}	3 h^{-1}

2043 m² living area
38 flats
ground area 40 m x 15,5 m
5 storeys
~ 30 % window area ratio on all sides
measured total heat consumption: 189 kWh/(m²a)
measured total DHW consumption: 55 kWh/(m²a)
measured total electr. consumption: 30 kWh/(m²a)

Table 1: Building envelope and infiltration conditions

Heat-transfer coefficient [W/(m²K)]	Floor	Class C	Class A	Class A++
Roof	0.85	0.16 → **18 cm of ins.**	0.10 → **31 cm of ins.**	0.08 → **40 cm of ins.**
Wall	1.27	0.25 → **12 cm of ins.**	0.12 → **26 cm of ins.**	0.10 → **32 cm of ins.**
Floor	0.93	0.25 → **9 cm of ins.**	0.14 → **20 cm of ins.**	0.10 → **30 cm of ins.**
Window	2.5	1.6 → double glazing	1.0 → double glazing	0.7 → double glazing
n_{50} [h^{-1}]	3	2	1	0.6

parameters and energy sources, were omitted. The reason for this is that the project compares building insulation and photovoltaic systems integration and analyses their impact on energy costs.

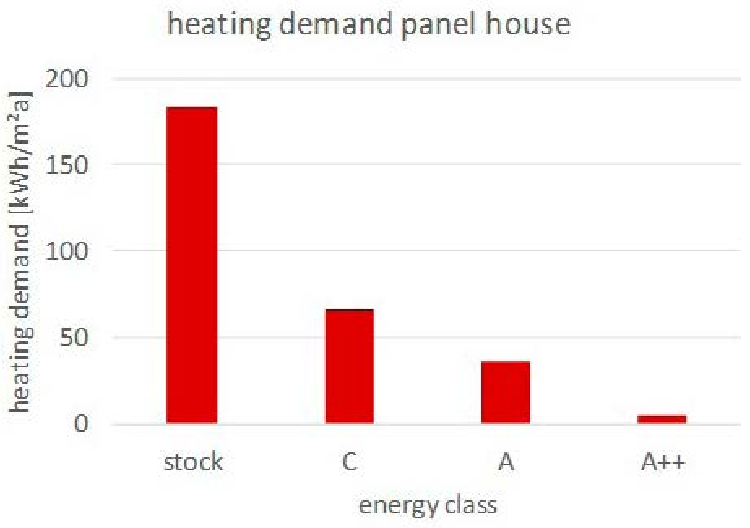
After determining the demands for electricity and heat, a model was compiled to calculate electricity generation and the share of individual use of electricity generated by a photovoltaic unit, depending on its direction and the location of the panels on the roof.

Based on these indicators, the profitability was calculated in accordance with VDI 2067 (including total costs). Recommendations are made in accordance with the results obtained.

While legal requirements do not address this aspect, the project also considers household electricity.

Illustration 5: Heat demand of a brick house for different Energy Efficiency Classes

Illustration 6: Heat demand of a panel house for different Energy Efficiency Classes



4.2 Building and Modelling Conditions

Two unrenovated buildings were selected for the project, corresponding to typical buildings in Lithuania. Both are five-story buildings. Photos and data on the areas and envelopes of the buildings are shown in Illustrations 3 and 4.

The thermal model is compiled in the EnergyPlus programme. For assuming weather conditions, data from the Kaunas' Meteonorm system was used. The heat-transfer coefficients correspond to simple structures of brick or reinforced concrete. The energy permeability of glazing is 0.5. To determine infiltration air exchange, the air exchange value is used at a pressure difference of 50 Pa and Gl. 61 and Gl. 62 of DIN V 18599, part 2 [1]. Internal loads and airing through the windows are taken into account based on the usage profiles from DIN V 18599 or the standard BDEW load profile.

To model renovated buildings, the requirements for heat-transfer coefficient and air exchange n50 of the respective energy efficiency classes in Lithuania was taken into account. Table 1 shows general conditions as well as the required insulation thickness when using typical insulation material of thermal conductivity group 035.

4.3 Heat Demand Simulation Results

Models of both buildings were made applying in the EnergyPlus programme. To test the influence of building orientation, a grid with a spacing of 15° was used. This influence could be neglected. Exact results are provided in the appendix.

The average heat demand of a building of brick: 144 kWh/(m²a) for an unrenovated state, 65 kWh/(m²a) in energy efficiency class C, 44 kWh/(m²a) in energy efficiency class A and 10 kWh/(m²a) in energy efficiency class A++. It should be noted that for energy efficiency class A++, a ventilation system with heat recovery is considered. In our case, a ventilation system is absent to save costs. Illustration 5 above shows a heat demand model for a brick house.

Illustration 6 shows the heat demand for a panel house. In this case, energy efficiency class A++ also considered a ventilation system with heat recovery. Average heat demand is 184 kWh/(m²a) for the unrenovated state, 67 kWh/(m²a) in

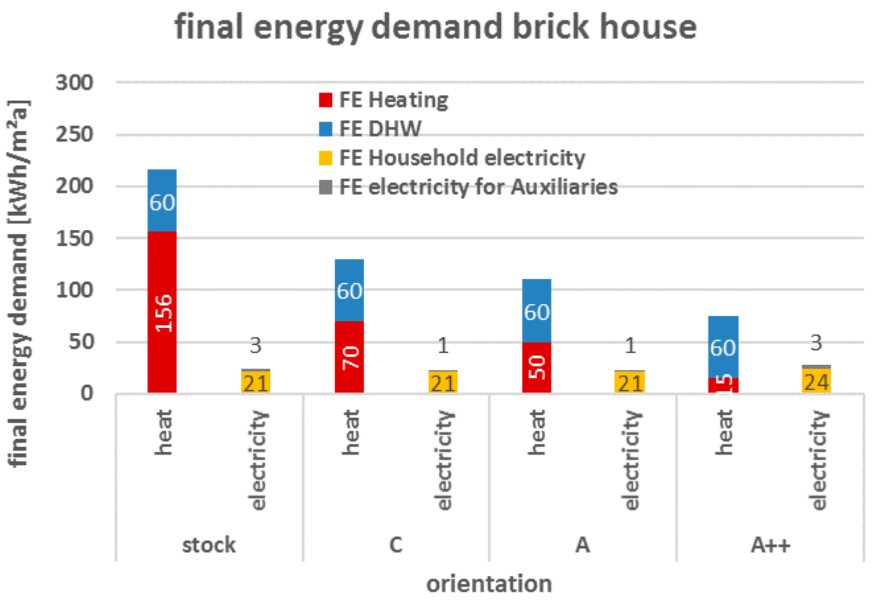


Illustration 7: Final energy demands including electricity consumption in a brick house

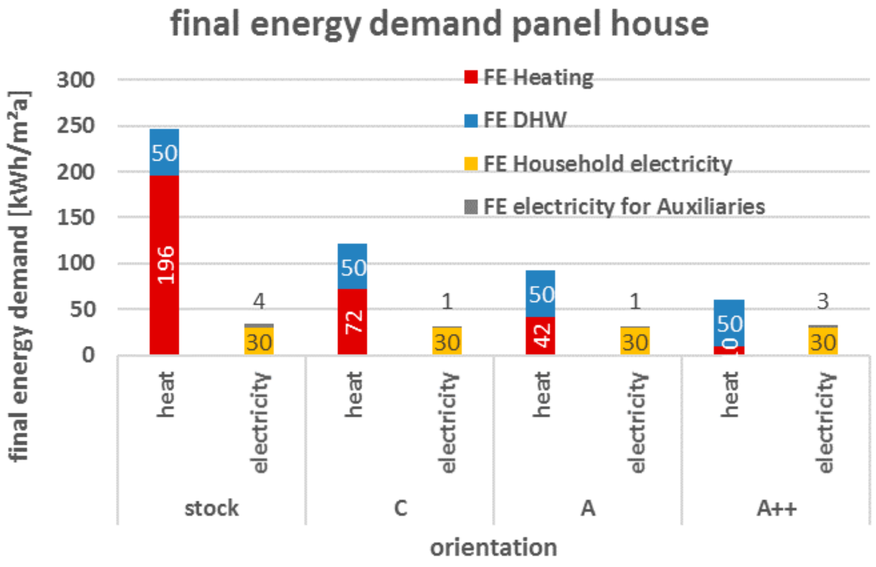


Illustration 8: Final energy demands including electricity consumption in a panel house

Illustration 9: Energy costs (without Base Rates) in a brick house

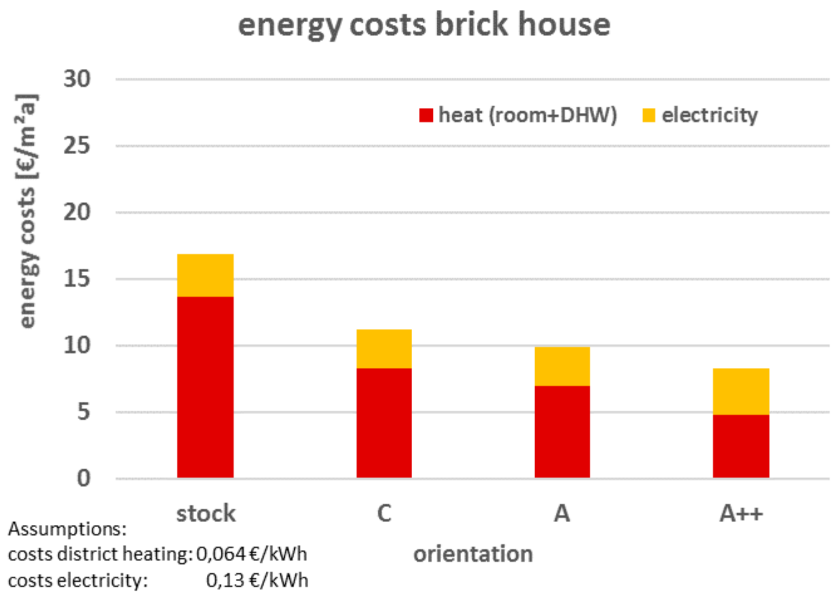
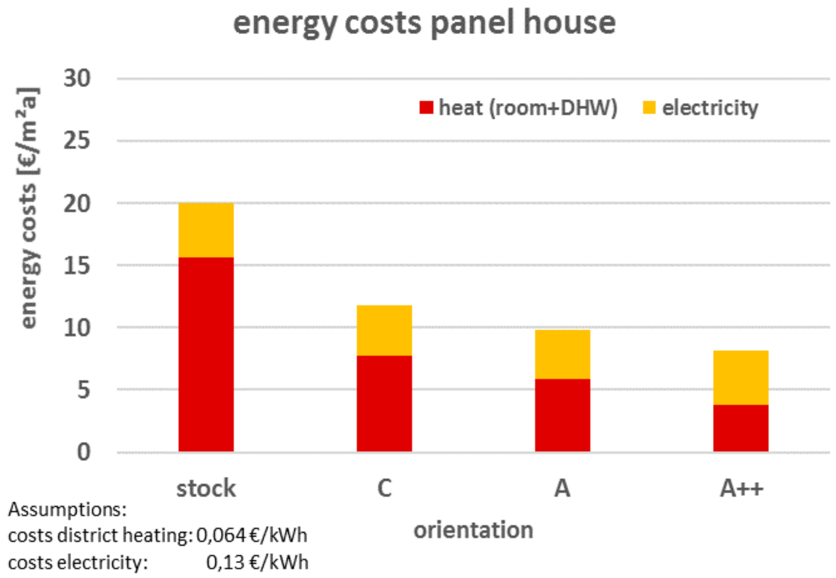


Illustration 10: Energy costs (without Base Rates) in a panel house



energy efficiency class C, 37 kWh/(m^{2}a) in energy efficiency class A and 8 kWh/(m^{2}a) in energy efficiency class A++.

4.4 Building energy demands and energy costs

Illustrations 7 and 8 show the energy demand of the entire building. This also includes electricity consumption for household needs in apartments, which affects the cost of electricity in apartments. Losses in the heating network in an unrenovated building amount to 12 kWh/(m^{2}a), in a renovated one to 5 kWh/(m^{2}a); losses in water pipelines are 10 kWh/(m^{2}a). It is assumed that also after energy-efficient renovation, the consumption of drinking water will not change. Only heat distribution losses that occur in the thermal envelope and reduce the demand for heating will be minimized. For this reason, it is assumed that energy requirements for heating water will not change.

The higher the energy efficiency class, the larger is the share of electricity needed in the total energy demand. In addition, it is obvious that the cost of heating water decisively affects the total heat consumption.

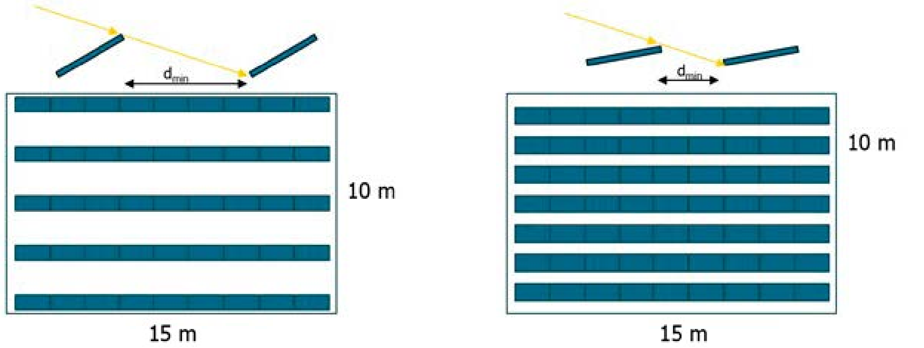
Looking at the rates for central heating and electricity, as per January 2019, the share of electricity increases even further (cf. Illustrations 9 and 10).

Based on these indicators, the feasibility of a photovoltaic unit is analysed from both, an economic and environmental point of view, comparing also the effects of insulation reinforcement.

4.5 Photovoltaic System Simulation Results

To determine the economic and environmental potential of photovoltaic systems in apartment buildings, one should first determine the rate of their production. To this end, the TRNSYS program calculates a model of possible electricity generation by a photovoltaic system, depending on its direction.

Illustration 11: Comparing different angles of panels placed on the roof on an example building in Berlin



incline of PV:	30 °	incline of PV:	10 °
installed PV:	8,755 kWp	installed PV:	12,28 kWp
distance between two strings:	1,50 m	distance between two strings:	0,52 m
total annual production:	7.878 kWh/a	total annual production:	9.921 kWh/a

Illustration 12: Photovoltaic modules electricity production, use for individual needs and supply to the network with a different number and orientation of the modules on the roof, brick house

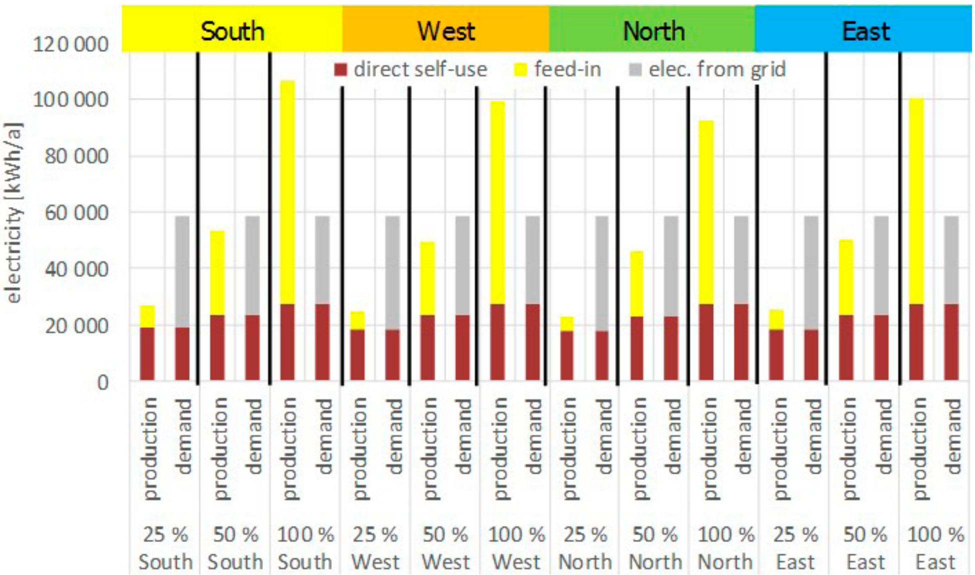
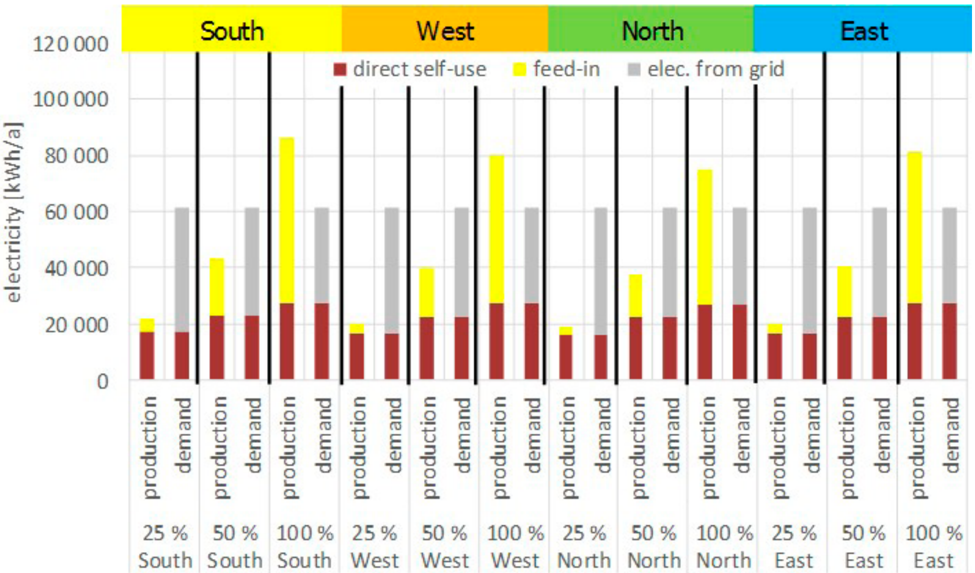


Illustration 13: Photovoltaic modules electricity production, use for individual needs and supply to the network with a different number and orientation of the modules on the roof, panel house



The panels are assumed to be installed at an angle of 10°, since in this case, more panels can be installed across the same area. The specific production decreases due to a non-optimal slope, but the total production increases due to an increase in capacity that can be installed on the same roof (cf. Illustration 11).

The model was made for both buildings, for four directions (north, east, south, west) and three options for panel numbers on the roof (25, 50 and 100 per cent of the available roof area). The roof area available for the installation is assumed to be 80 per cent of the total. In addition, the specific area is taken as 5 m²/kW-peak (for high power panels).

Thus, the maximum installed power of a photovoltaic unit is 112 kW-peak (for the brick house) and 91 kW-peak (for the panel house).

For each building, there are 12 profiles of solar energy production.

Since it is more profitable to use generated energy individually and feeding surplus energy to the grid and measuring net consumption than to supply all the energy into grid, it is important to calculate the individual share of consumption. This requires a consumption profile. As a base, profile H0 compiled by BDEW is used, which can be scaled according to the building's electricity demands. The share of individual consumption can be determined according to the ratio between production and demand on a 15-minute basis. Illustrations 12 and 13 show energy balances with a different number of modules on the roof and their different orientation, the modules tilted at an angle of 10°.

It can be seen in both cases that up to 40 per cent of individual energy needs can be covered by a photovoltaic unit. It is also obvious that to cover this need, the panels should occupy about 60 per cent (in the brick house) or 80 per cent (in the panel house) of the available roof area.

From an economic point of view, it is not reasonable to cover the entire roof with panels, as the legislation provisions imply that generating electricity in excess of individual needs does not provide financial advantages.

4.6 Profitability Analysis

In the previous chapters, energy demands were determined and the potential of a photovoltaic system installation was analysed. The findings serve as the basis for the economic analysis. It is grounded on total costs, by analogy with VDI 2067, which means that capital investments, current costs (for maintenance and repairs) and costs (for energy) associated with needs over a 20-year period are determined.

It is assumed that the building is still connected to the district heating network (see Figure 15). A further assumption is that distribution and transfer losses are going to be reduced.

To analyse the effectiveness of photovoltaic systems, ten scenarios were investigated:

13) without reconstruction, without a photovoltaic unit
14) without reconstruction, 25 per cent of the available roof area occupied by a photovoltaic unit
15) without reconstruction, 50 per cent of the available roof area occupied by a photovoltaic unit
16) without reconstruction, 100 per cent of the available roof area is occupied by a photovoltaic unit
17) reconstruction of the building envelope according to class C requirements, without a photovoltaic unit
18) reconstruction of the building envelope according to class C requirements, 25 per cent of the available roof area occupied by a photovoltaic unit
19) reconstruction of the building envelope according to class C requirements, 50 per cent of the available roof area occupied by a photovoltaic unit
20) reconstruction of the building envelope according to class C requirements, 100 per cent of the available roof area occupied by a photovoltaic unit
21) reconstruction of the building envelope according to class A requirements, without a photovoltaic unit
22) reconstruction of the building envelope according to class A++ requirements, without a photovoltaic unit

Illustration 14: Investments in a brick house

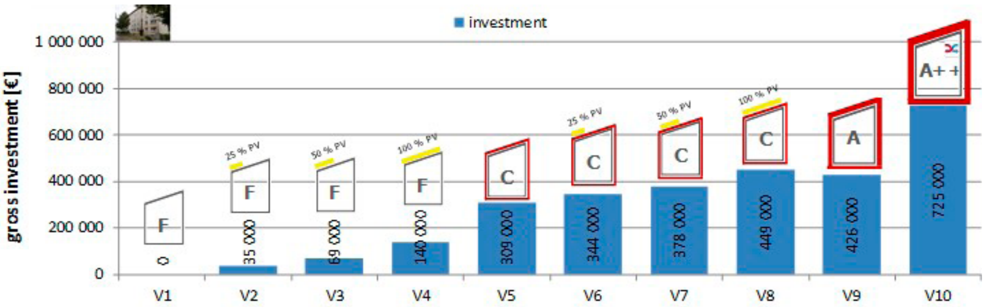


Illustration 15: Investment in a panel house

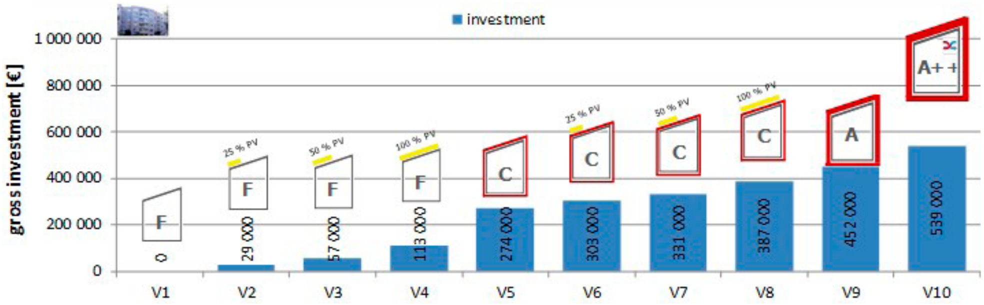


Illustration 16: Total costs for a brick house for the first year

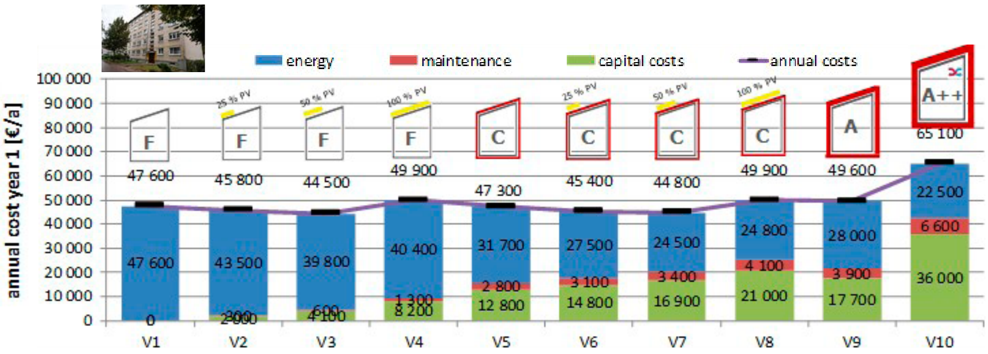


Illustration 17: Total costs for a panel house for the first year

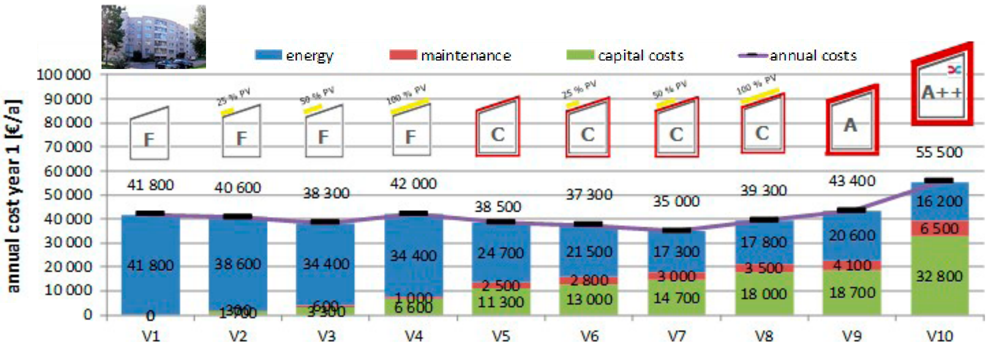


Illustration 18: Total costs for 20 years for a brick house

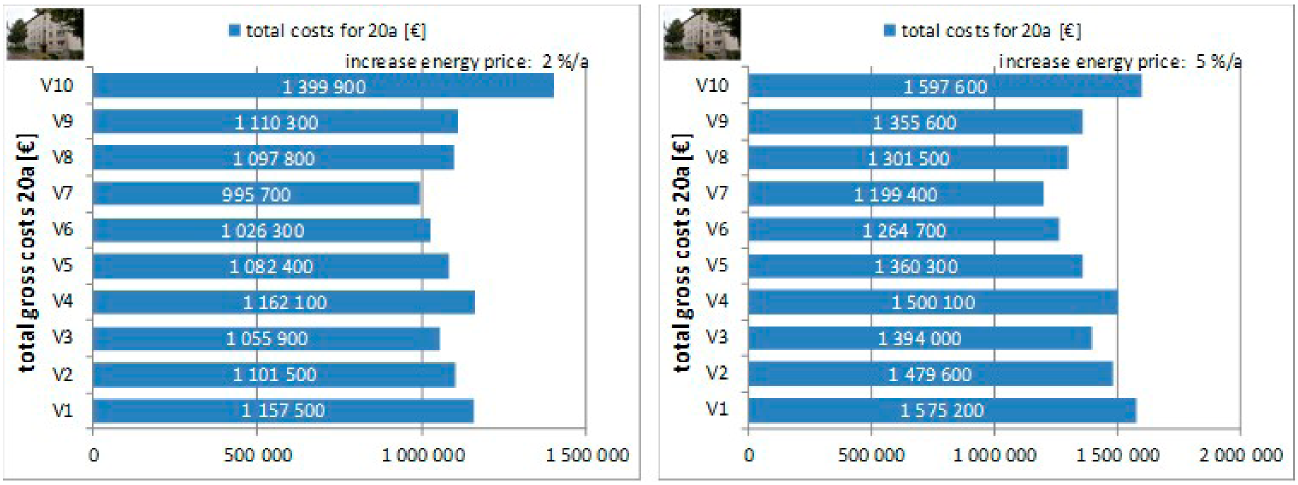
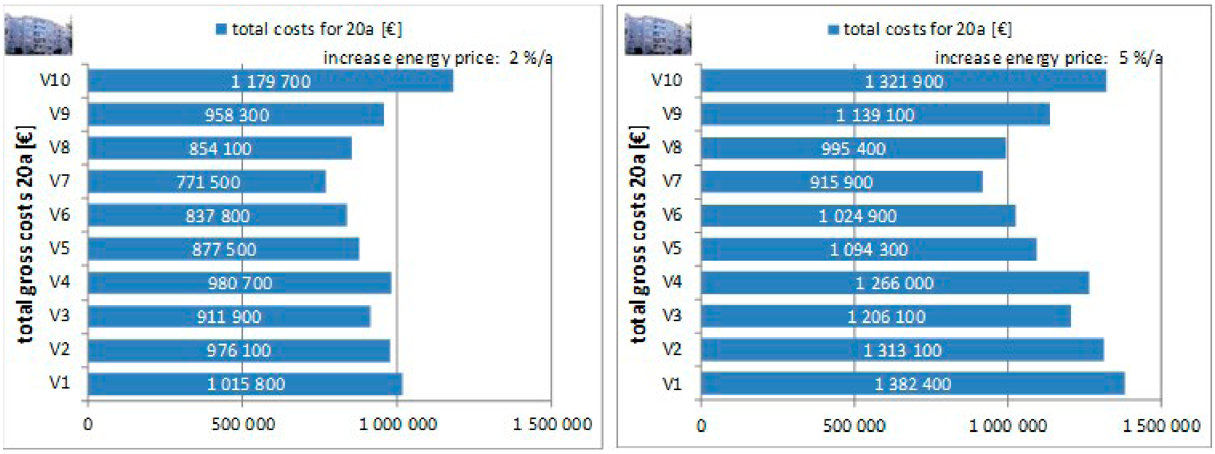


Illustration 19: Total costs for 20 years for a panel house



As a basis for calculations, specific indicators of investments per cm and m² of insulation are applied, as well as per photovoltaic unit (1100 EUR/kW-peak net). For the building envelopes, only extra energy costs are considered.

The service life of a photovoltaic unit is assumed to be 25 years, that of the building envelope to be 50 years. A ventilation system with heat recovery which required for class A++ is designed to last for 20 years. The theoretical interest rate is 3 per cent. In terms of rising electricity prices, two cases were analysed: annual price increases of 2 per cent and of 5 per cent. An overview of the boundary conditions is given in the appendix.

The principle of net counting applies, that is, feeding excess electricity into the grid, and purchasing provided electricity on more favourable terms (~ 4 EUR ct/kWh) at times when the production of the photovoltaic plant is not sufficient. The maximum amount of energy that can be bought from the grid on preferential terms corresponds to the amount of fed-in energy or, in case of excess power of a photovoltaic unit, (meaning production is higher than demand) of the electricity demand. Illustrations 14 and 15 show the required investment for the respective options.

The required investment is from 12.70 EUR/m² or 636 EUR/RU to 262.68 EUR/m² or 13,181 EUR/RU for a brick house and from 14.19 EUR/m² or 763 EUR/RU to 263.83 EUR/m² or 14,184 EUR/RU for a panel house. The difference is striking. Capital expenditures are increasing especially when a ventilation system with heat recovery is installed subsequently (V10).

Illustrations 16 and 17 show the total expenses for the first year (without an increase in energy prices). It can be noted that despite renovation to class A+, the total expenses differ by 10 per cent for brick houses and by approximately 15 per cent for panel houses. It can also be seen that with renovation to class A++ energy, costs are minimal, however, the total costs over the year are maximal due to large investments. Minimal total annual costs arise in version V7 with renovation to class C and covering 50 per cent of the roof with panels. Somewhat higher total costs with 100 per cent of the available roof area used – compared to using only 50 per cent – can be justified with a net counting system. If more energy is produced than a building requires during the year, the difference or surplus is fed into the network for free; as a result, the additional area occupied by solar panels and generating excess energy is economically useless.

It is clear that energy-efficient renovation is more economical than a photovoltaic unit (see comparison of V5 and V2-V4). Increasing the insulation standard leads to more efficiency for purely physical reasons (see comparison of V5 and V9-V10). Installing a photovoltaic unit in combination with a renovation to meet energy efficiency class C is more econom-

Illustration 20: Electricity costs in a brick house

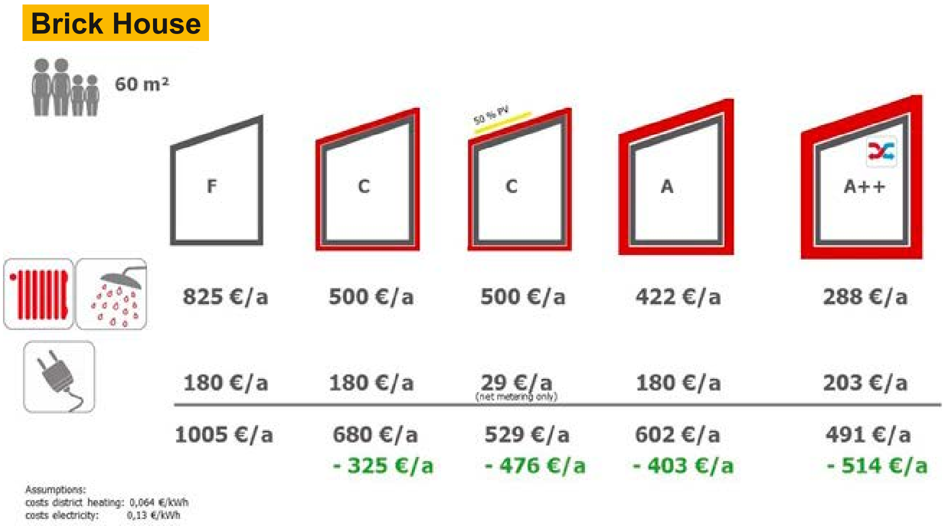


Illustration 21: Static depreciation period of a brick house

Illustration 22: Electricity costs in a panel house

Illustration 23: Static depreciation period of a panel house

ical than solely renovating to meet classes A or A++ (see comparison of V7 and V9-10).

If we assume an annual increase of prices for electricity and heating by 2 per cent or 5 per cent and constant electricity prices in the net metering system, the total costs for 20 years will be from 1.0 (V7, 2 per cent price increase per year) to 1.6 million EUR (V10, 5 per cent price increase per year) for the brick house (cf. Illustration 18) or from 0.8 (V7, 2 per cent price increase per year) to 1.4 million euro (V10, 5 per cent price increase per year) for the panel house (cf. Illustration 19).

For both buildings, it becomes clear that version 7, that is, renovation of the building envelope in accordance with energy efficiency class C requirements and use of a photovoltaic unit, is the most profitable; therefore, it should be preferred.

With a view to energy shortages, the impact of energy costs after renovation and use of photovoltaic units is relevant as well and analysed in the following. In the analysis, the example of a family of 4 living in a 60 sqm apartment was used.

Illustrations 20 to 23 show energy costs in the first year after renovation per energy efficiency class, as well as investments by this family and static depreciation excluding maintenance and repairs.

What can be seen from this is that combination of renovating to meet class C and using of photovoltaic system is characterized by the shortest depreciation period and also the highest impact on annual energy costs. Lower energy costs are reached only by renovations up to class A++, which comes with higher capital investments though.

4.7 Conclusions and Recommendations

The results from the economic analysis show that for unrenovated buildings, renovation should primarily consider the factor of energy consumption. On the one hand, the comfort inside the building will increase, on the other, construction-physical problems like heat bridges will be reduced. What’s more, energy costs will turn out to be significantly lower.

When renovating, however, it should be observed that as the insulation thickness increases, the specific efficiency of additional layers constantly decreases – that is, if insulation with a thickness of 20 cm reduces heat demand by 70 per cent, the next 20 cm (adding up to an insulation layer of 40 cm) reduce this need only by another 20 per cent. Consequently, the effectiveness of insulation is gradually reduced.

Calculations showed that in terms of energy costs, renovation to meet class C is more cost-efficient than reconstruction to meet classes A or A++.

In addition, it turned out that in a renovated building of class C standard, the use of a photovoltaic unit is more profitable in terms of total energy costs than installing additional insulation.

An additional advantage of a photovoltaic plant is its increasing independence from changes in electricity prices. Up to 40 per cent of the need for energy can be covered directly by a photovoltaic unit.

As a consequence, it is preferable to renew a building to meet class C and install solar panels with an annual output approximately equalling the annual energy demands of the respective building.

When designing a photovoltaic unit, the static requirements and the required area shall be considered; it may turn out that is will be impossible to use the entire roof. In this case, the maximum available area shall be used.

4.8 Future Expectations

Calculations showed that the use of photovoltaic systems is rational. It is also obvious that photovoltaic systems with a capacity higher than the consumption of the respective building, are economically unprofitable due to the net metering principle. If we assume the case that excess energy can be sold at current exchange prices, this would mean obtaining an additional source of income.

We tried to figure out how large such income may be. In the brick house, when using the entire roof area, 106 MWh per year can be produced, of which 78 MWh per year is fed into the network and 31 MWh per year is returned via the net metering system. This means that 47 MWh per year are produced for free and could potentially generate income. Based on annual changes in stock prices, we can assume that the average price during periods when energy is fed into the network is 4.82 EUR ct/kWh. The average price per year is 4.03 EUR ct/kWh. If we assume that the annual surplus of 47MWh will be sold at the price of 4.82 EUR ct/kWh, the additional income will amount to 2,256 EUR per year. To generate 47 MWh per year, a power of about 47 kW-peak is required. Including subsidies, the investment needed will be around 37,000 EUR. With the income from sales at stock price, the photovoltaic plant will pay off within 16.5 years.

Dedicated legal provisions would be necessary to make such a case work. Additional income can also help to address energy poverty issues.

It will be necessary to create transparent legal frameworks so as to decide which homeowner associations would be able and eligible to install and operate photovoltaic units.

Appendix

Results of modelling existing buildings and buildings after renovation to meet energy efficiency class C

Illustration 24: Heat demand in a brick house, North-South direction, before renovation

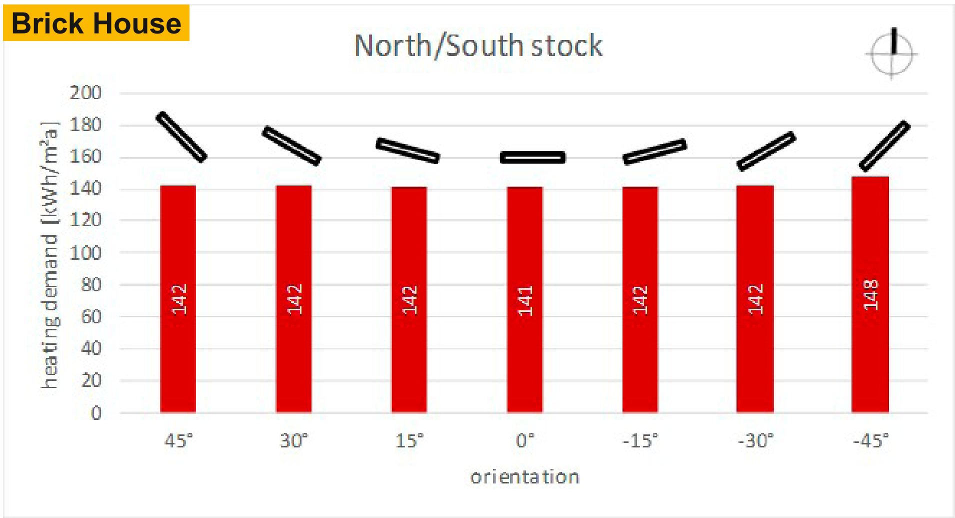


Illustration 25: Heat demand in a brick house, East-West direction, before renovation

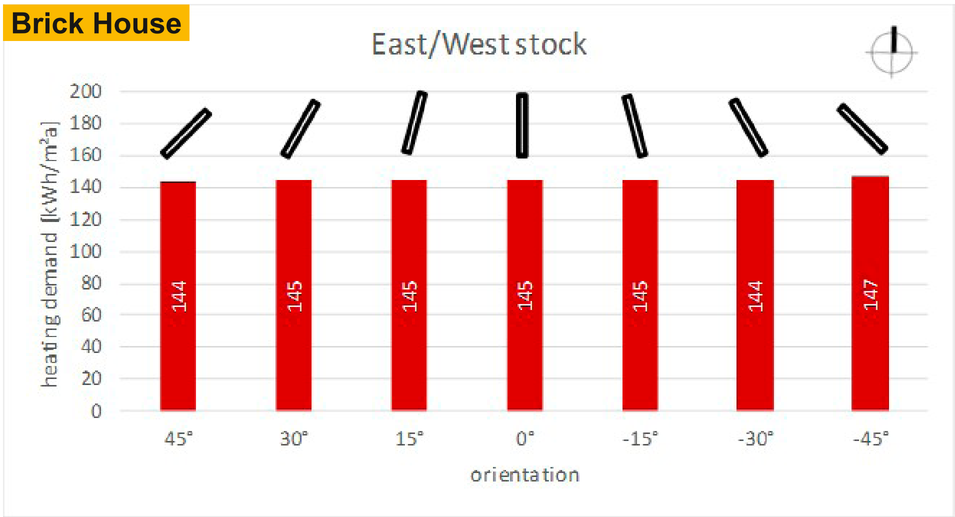


Illustration 26: Heat demand in a brick house, North-South Direction, after renovation to meet class C

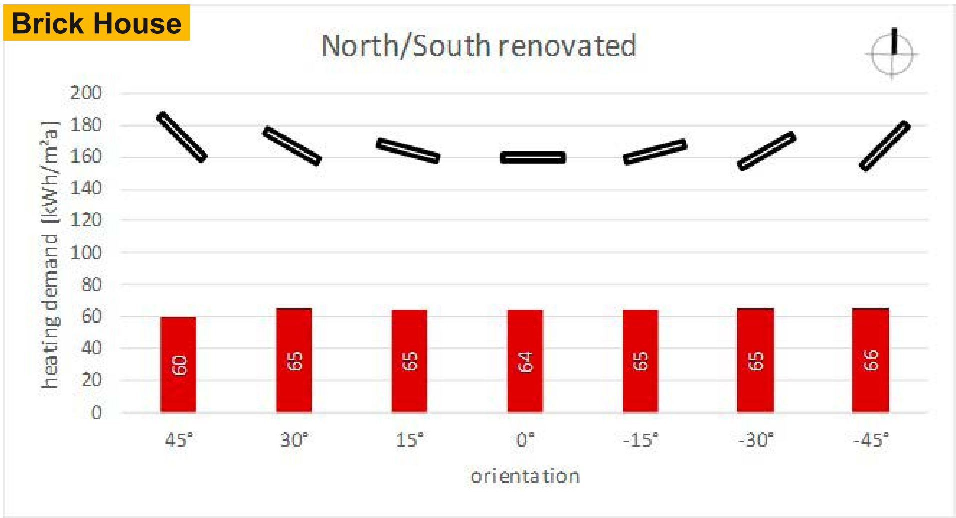


Illustration 27: Heat demand in a brick house, East-West direction, after renovation to meet class C

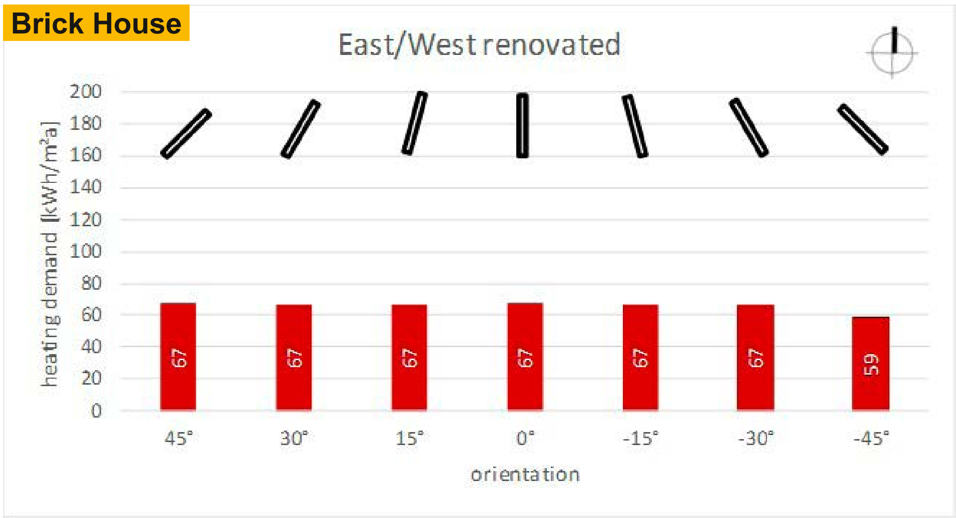


Illustration 28: Heat demand in a panel house, North-South direction, before reconstruction

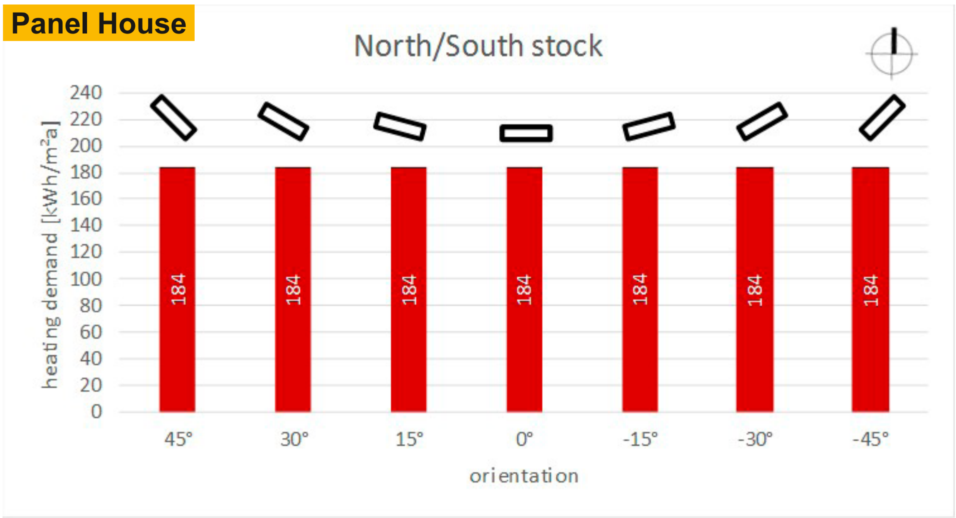


Illustration 29: Heat demand in a panel house, East-West direction, before reconstruction

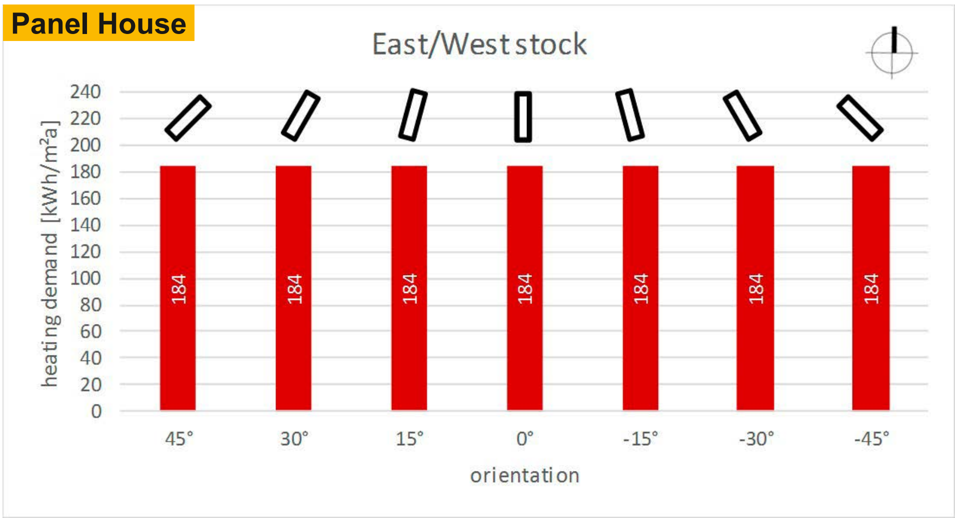


Illustration 30: Heat demand in a panel house, North-South direction, after renovation to meet class C

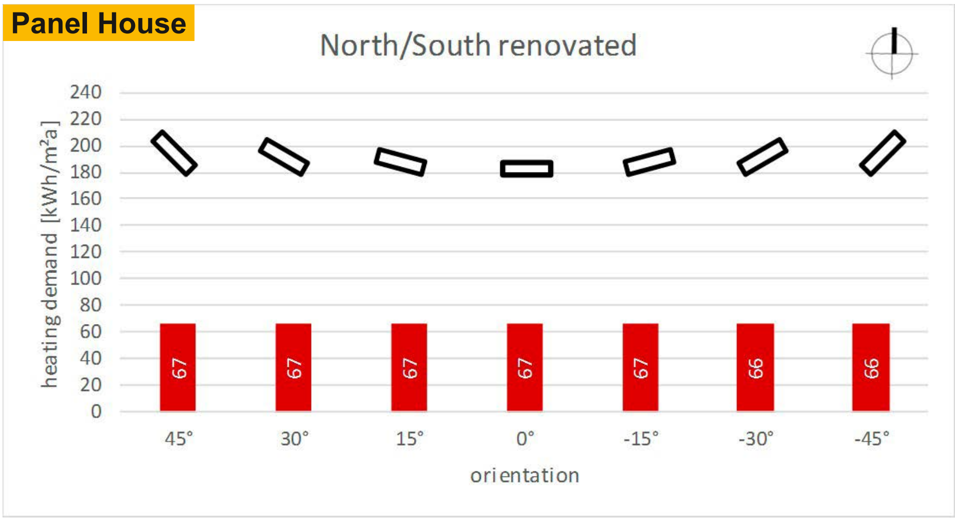
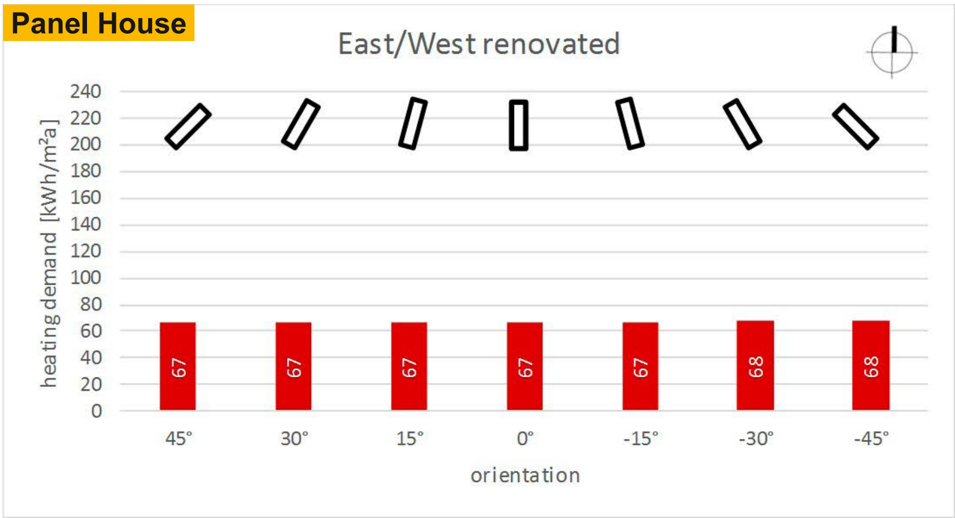


Illustration 31: Heat demand in a panel house, East-West direction, after renovation to meet class C



Profitability Analysis Conditions:

Building envelope (additional energy costs, net):

Table 2: Building envelope costs

Source: Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS).

Net investment costs insulation	
Additional costs per cm ir m^2 insulation wall	2.39 €
Additional costs per cm ir m^2 insulation basement ceiling	1.35 €
Additional costs per cm ir m^2 insulation steep roof	2.18 €
Additional costs per cm ir m^2 insulation flat roof	1.15 €
Insulation double-glazed windows per m^2	269 €
Additional costs triple-glazing to double-glazing per m^2	50 €

Maintenance and repair approach: 1 per cent of investment per year

Utility systems:

- Photovoltaic systems with peripheral devices (inverters, cables, wiring): 1,100 EUR/kW-peak (net)
- Subsidy: 332 EUR/kW-peak (gross)
- Heating, ventilation and air conditioning with heat recovery: 75 EUR/sqm (gross)

Maintenance and repair approach: 1 per cent of investment per year

Energy Costs:

- Electricity: 10.74 EUR ct/kWh (net)
- Heating: 5.82 EUR ct/kWh (net)
- Net measurement: 3.82 EUR ct/kWh (net)

VAT for heating: 9 per cent
Other VAT: 21 per cent

5. Assessment of the legal and financial conditions

5.1. Legal regulations

When faced with the use of solar installations in residential areas with multiple houses, there are quite a number of uncertainties. This is because the legislation is not clear enough to regulate their application, especially in the case of residential areas with multiple houses. This raises the question of whether or not it would be appropriate for Lithuania to adopt a specific law on energy communities defining specific aspects of the collective energy production and distribution.

We would like to summarise the main reasons and barriers to scaling up the use of solar power plants in multi-apartment buildings.

First, there is the problem of **joint ownership**. In accordance with the Civil Code of the Republic of Lithuania, it is a general rule that the property under joint ownership is managed, used and disposed of by mutual consent of all co-owners. This provision shall not apply if the use of the building's common premises or facilities is subject to statutory and regulatory requirements for the use and maintenance of buildings.

In such cases, there is a provision that the decision on the use of the common property is taken by the votes of half of the members of the community plus 1 vote. Since the installation of a solar power plant is not necessary for the operation of the building, the authorities responsible for issuing permits for the installation of solar power plants often comply with the general provisions of the Civil Code, which requires the consent of all members of the community. Therefore, there is a need for clarity in the legislation as to the number of the members of a community required for issuing a consent for the installation of a solar power plant on the roof or walls of the building to be used for electricity purposes.

From 1 November 2017, communities can take advantage of the provisions in the laws of the Republic of Lithuania not only for installing a solar power plant. They can also profit from provided benefits for producing consumers (prosumers) i.e. using the possibility of feeding excess energy for storage into an electricity supplier, provided that the power of the plant does not exceed 100 kW (this threshold is expected to increase to 500 kW from Autumn 2019). The essence of this storage strategy is that the producer can transfer part of the solar electricity that was not consumed immediately into the grid, and can then retrieve it when solar energy production is not sufficient (at night or during autumn-winter periods). It has to be noted, however, that this service incurs a network maintenance fee set by the National Commission for Energy Control and Prices, which amounts to approximately 4 EUR ct including VAT.

The new law on energy partnerships or communities could establish a provision that would prevent any doubt as to whether a consumer using solar energy through a collective legal entity can use the 'storage' service. It would also be important to abolish the provision that the introduction of renewable energy sources in the heating sector automatically entails the introduction of a binary tariff; the latter factor is very discriminatory, as the multi-apartment buildings that formerly installed solar collectors became 'victims' of the binary tariff for heat, while the poorest apartment owners and those affected by energy poverty (receiving state support) lost out on compensation. This situation requires a more detailed study and is one of the problems that would need to be addressed by a separate law.

Secondly, a major part of multi-apartment buildings is characterised by **low levels of electricity consumption for general house needs**. The system and the cost allocations are clear enough when the community uses solar power for general purposes: for lifts, corridor lighting, water pumps and other common property facilities. However, in rationally arranged common areas and facilities, the energy demand is not high and low-power solar power plants are not economically attractive. Therefore it would be rational to install solar power plants on the roofs and, where appropriate, on the walls, and to produce electricity in these plants not only for general use, but also for individual consumption by the members of the community.

Thirdly, it is not clear how **the amount of energy consumed internally for individual needs should be accounted for**. Such an accounting process and system will require a special meter. Unfortunately, there are many legal and technical issues to be addressed in this regard. At present, each member of the community has an individual contract with the electricity supplier. Usually, the building does not have (and was not required to have) a general accounting of the cost for the entire building, which would account for the total energy consumption of the individual consumers. Therefore, the legal and technical conditions for feeding in solar power to the general inlet of the building, for the installation of electricity meters that will account separately for the consumption in the common facilities and the total consumption of individual consumers, must first be provided. The question of who is supposed to be responsible for this and who should pay remains.

The issue is complicated by the fact that, in the near future, the energy operator ESO, in fulfilling the requirements of the EU Third Energy Package, must abandon its electricity supply function and retain only its function of providing electricity distribution and network maintenance. At the same time, the power supply function must be passed on to free market suppliers. In this case, each member of the building community is free to choose their electricity supplier, and the installation of a total electricity accounting device becomes very problematic, as each electricity supplier should also have separate accounts.

The fourth problem is that the freedom to choose a supplier reduces the attractiveness of PV. A legal provision could be introduced to allow a single independent supplier to be chosen by the majority of the building's community for all members of the community, while limiting the right of the members of the community to choose. But such a situation may be complicated in cases where a member of the community sells his apartment to a non-community member, who will want to come with his own electricity supplier. In such a case, to take advantage of a solar plant held in joint ownership, the right to choose a supplier should be restricted even further. Such questions will trigger sharp discussions between lawyers, energy professionals and consumers, that is, members of the community, but they should undoubtedly be legally regulated.

The distribution of solar power to individual customers, as well as who will perform that distribution with each consumer having an individual contract with the electricity supplier, would also require legal regulation. The easiest way would be to distribute the generated solar electricity by consumption. An algorithm for such a distribution method would be easy to implement. However, in this case, a situation would result where a consumer that uses electricity the most would get the maximum total benefits, which is likely to be unacceptable for families consuming less energy. The decision in this case would be facilitated by a community agreement, to ensure that the coverage of the members' investment in solar power is proportional to their electricity consumption. Such an agreement would probably be difficult to implement.

Sixthly, there is a dilemma concerning the **'storage' tax allocation**. The situation would be complicated by the specificities of solar energy production during the daily cycle. Naturally, solar power is produced in daylight, that is, during the daytime. If it is consumed during the day, such consumption is highly desirable, as the storage of unused energy and, at the same time, the cost of this storage is reduced. A total accounting method dividing the cost of the 'storage' in proportion to electricity consumption has the following effects: for those who use electricity during the daytime, total costs are relatively higher than for those who use the more "expensive" electricity in the evening. Thus, while the use of electricity during the daytime should be encouraged, a straightforward allocation of the 'storage' costs would demotivate the daytime users. It is therefore advisable to change the 'storage fee' system to pay for this service in kind, rather than in cash. This way, if the community does not consume the electricity it generates during daytime, it would recover less electricity than it produced in the evening and at night, and would need to buy the missing amount at the market price. This would resolve the partially unfair taxation of daytime consumers.

5.2. Economic factors

Unfortunately, the payback time for solar power plants is still too long. Although the cost of solar power plant equipment is steadily declining, it is not yet possible to install a small power plant at a price below 1,000 EUR/kW. If electricity costs more than a dozen EUR ct per kWh, then the payback time for a solar power plant will not be less than 10 to 15 years. Such a payback time will certainly not be acceptable for many consumers. To become more attractive, the term should not exceed 8 years. Given this scenario, the installation of solar power plants requires investment support of at least 30 per cent. Respective investments should be included under the most favourable conditions in the Lithuanian renovation programme for apartment buildings. (However, even in this case, the aspect of the distribution of electricity incurs challenges, as described above.)

There are suggestions from foreign examples that a community's prosumers might use various preferential leasing or credit programmes, instead of receiving direct support. Many of these programmes have been effective, but only in those countries where the retail price of electricity for household customers is much higher than in Lithuania, which leads to other economic conditions for activities as 'producing consumers'.

Also, the use of solar energy should not be limited to the energy aspect. For example, a community that has installed a power plant producing 60 kW would reduce its annual carbon emissions by 30 tons. This way, communities in residential homes can make a significant contribution to meeting the country's climate change commitments.

It should also be borne in mind that, even if a community receives 30 per cent support for a typical 60 kW plant, the members of the community would still need to contribute 42,000 EUR at their own expense. This would represent the financial contribution of citizens to the development of local electricity generation, as provided for in the Lithuanian Energy Security Strategy. By creating appropriate promotional tools, and by such supporting an expansion of prosumer activities, the state would save tens of millions of Euros while increasing its energy security and independence.

Furthermore, since almost all required solar energy equipment is produced in Lithuania, scaling up the development of solar power plants would create hundreds of jobs in the manufacturing companies, as well as in the design, installation, operation and maintenance companies, which would mean a significant contribution to the economic development of Lithuania.

Consequently, future activities of Lithuanian residential (or energy) communities and their use of solar energy would be a significant factor for the country's progress in the fields of energy, the economy and environmental protection.

5.3. Support programmes

Funds from the Climate Change Programme amounting to 17 million EUR are foreseen for the promotion of solar energy to be used in for apartment buildings in 2019 and 2020.

The programme is being prepared by the Ministry of Energy of the Republic of Lithuania. However, the guidelines for the promotion programme have not yet been published. The Ministry has also not yet outlined how the programme will work.

In our opinion, the following principles should be respected when designing the programme:

- **Non-discrimination.** There should be no exceptions or limitations that will prevent persons or communities in buildings from receiving support. On the contrary, there are cases where, according to the Government's priorities (which were discussed with representatives from the non-governmental sector and business associations as part of the project), there is a tendency to promote a particular segment of apartment buildings – for example, houses for which renovation possibilities are typically limited (e.g. in old town areas).
- **Minimised bureaucratic procedures.** Minimised requirements for applications must be provided by the ministry and the institutions responsible for implementing the possible support programme – an over-bureaucratic

process will otherwise cause many apartment buildings to be reluctant to apply.

- **Complexity.** Synergies can be tapped by combining solar energy promotion programmes with other important elements of sustainable development. For example, clean mobility using solar power is sustainable both in terms of energy production and in the context of solving transport-related pollution problems. Therefore, the Ministry of Energy and the Ministry of Environment and the Ministry of Transport and Communications should jointly take specific measures to promote not only photovoltaic installations, but also the use of the generated electricity for electric car charging. Suppose, for example, the following scheme: the installation of a solar power plant is carried out as a separate project without additional elements with a compensation rate is X percent; in case additional heat pumps are installed, the compensation rate reaches X+10 percentage points; and if an electric car charging station open to the apartment building's residents is installed for the direct use of solar electricity (or in the absence of it, from the network) – the amount of the compensation is increased by another 10 percentage points, and so on. State provisions like this would significantly increase the susceptibility of the 'producing consumers'' ecosystem to future demand-response schemes, as well as promote the use of electric vehicles to store unused energy, stabilising the overall system.

Conclusions

With this study, we wanted to analyse the different factors that will determine solar energy development in the residential housing market. Residents in apartment buildings in Lithuania are statistically more likely to have lower incomes, and heavily affected by the volatility of heating, hot water and electricity costs. Lithuania is a country where a majority of people suffer from energy poverty, i.e. they are struggling or unable to pay their heating, hot water and electricity bills.

The technical and economic simplification of the conditions for the purchasing and use of solar photovoltaic power plants makes it worthwhile to re-consider the installation of these power plants for the citizens' own electricity production. The new concept of 'prosumers' is gaining popularity worldwide. In Lithuania, the government has been working for years to improve the conditions for those 'producing consumers'. The problem of global warming becoming more and more relevant also in Lithuania, is very important, too.

After analysing the geographical, social and economic situation in Lithuania, we can firmly conclude that there are favourable conditions for investing in solar energy for the residents of apartment buildings. The amount of sunlight in Lithuania is enough to satisfy most of the country's electricity demand. Creating an attractive double net metering system will also encourage the choice of PV systems. An electricity generation subsidy programme has been developed that could help to recover up to 30 per cent of the investments in power plants.

Based on technical calculations for partial and complete renovations without integrating renewable energy sources, the same results are obtained: installing a solar photovoltaic power plant reduces the energy costs in all cases. The decision on a particular option should be made on a case-by-case basis, considering the needs and financial situation of the residents.

Our project partners recommend allocating part of the Climate Change Programme's funds to demonstration projects in different regions of Lithuania, in which the actual benefits of renewable energy would be tested and illustrated in multi-apartment buildings.

At present, there is still a great deal of public scepticism about renewable energy sources, as they are perceived as too expensive and overvalued technologies. A lack of information and persistent stereotypes are preventing this area from developing quicker. Stakeholders should therefore be concerned about informing the public and gradually changing perceptions and attitudes. Demonstration projects could contribute to this goal.

The low purchasing power of many residents in apartment buildings leads to reservations regarding investments in instruments whose performance and effectiveness are not entirely clear to the residents. People with lower incomes are not inclined to risk their property and prefer to use time-tested tools such as window replacement and wall insulation. In addition, the relatively low price of electricity (received from the general grid) in Lithuania does not encourage energy consumers to become producers, because currently, the benefits would be insignificant.

We recommend continuing to encourage people to choose renewable energy sources on all levels available. It is necessary to create a more favourable and flexible legal framework for joint ownership. The creation of energy communities is one of the tools that could be a great incentive for energy consumers to become producers as well.

Sunny Outlook for Lithuania

The EUKI project “SOL” advocated an increased use of solar energy in multi-family houses in Lithuania. In April, the project ended with a final conference in the Lithuanian parliament, the Seimas. The project partners also presented the final study of the project, which sees great potential for solar energy in the country. Besides parliamentarians, representatives of government and other public institutions, energy supply companies, administrators of the multi-family houses, the event was attended by the Lithuanian Minister of the Environment and the Lithuanian Minister of Energy. The conference was organised jointly with the EU project “Heroes – Connecting Communities“.

The study, which was presented by the project partners in Vilnius, shows the economic efficiency of photovoltaic systems on multi-family houses in Lithuania. To date, comparatively few solar modules have been installed on Lithuanian houses. The authors of the study attribute this primarily to a poor knowledge base and fears of economic risks. In addition, there is a lack of legal framework conditions for a stronger expansion. In the case of multi-family houses, the purchasing power of the residents is often low and energy poverty is also a serious problem. Many low-income earners avoid the risk of an investment with an uncertain return.

Overcoming old standards

At the conference in Vilnius, government and parliament representatives welcomed the project’s initiative. They highlighted the added value of the report, which provides concrete data and figures on the potential of solar energy. The findings could help to take greater account of solar energy for private consumption in the long-term prioritised energy modernisation of residential buildings in Lithuania and to provide appropriate subsidies. Both the Lithuanian Environment Minister, Kęstutis Mažeika, and the Lithuanian Energy Minister, Žygimantas Vaičiūnas, emphasised the need to overcome old standards in the energy sector and to move rapidly towards EU requirements and open-technology trends in sustainable energy production and supply.

Kestutis Kupšys represents the consumer organisation LVOA, which is one of the project’s partners. Office of Lithuanian Parliament (aut. Džoja Gunda Barysaite)

Parliamentarians and ministers participated in the event, including the Lithuanian Minister of Energy Žygimantas Vaičiūnas (r.) and MEP Virgilijus Poderys (l.). Photo: Office of Lithuanian Parliament (aut. Džoja Gunda Barysaite)

The discourse on renewable energies in Lithuania had already gained considerable momentum during the term of the EUKI project. For example, renewable energies have been included in the national recovery plan, which makes further subsidies possible. The project partners also want to work towards further improvements after completion of the EUKI project “SOL”. At the same time, a further project of the implementing agency Initiative Wohnungswirtschaft Osteuropa (IWO) for the further training of neighbourhood rehabilitation managers in Lithuania is underway, which will contribute to the dissemination of the results.

The project “SOL – Solar Energy for Multi-Family Houses in Lithuania” involved the Initiative Wohnungswirtschaft Osteuropa, the consumer organisation LVOA, the Steinbeis Innovationszentrum energie+ and the Protech research institute. The project was financed by the European Climate Initiative (EUKI) of the Federal Environment Ministry (BMU). Within the framework of the EUKI, there are also numerous other projects and publications in the field of building refurbishment.

Article written and publicated by EUKI

Acronyms

EED	Energy Efficiency Directive
EUR (EUR ct)	Euros (Euro cents), European currency
kWh	kilowatt-hour
kWp	Peak kilowatt-hour
MFH	multi-family house. According to Lithuanian laws, a residential building with more than 2 apartments is considered an MFH.
PV	photovoltaic
RU	Residential Unit
sqm	square meter (equivalent to m^2)
TFA	total floor area

List of Illustrations