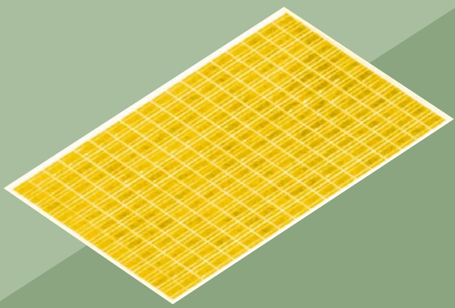
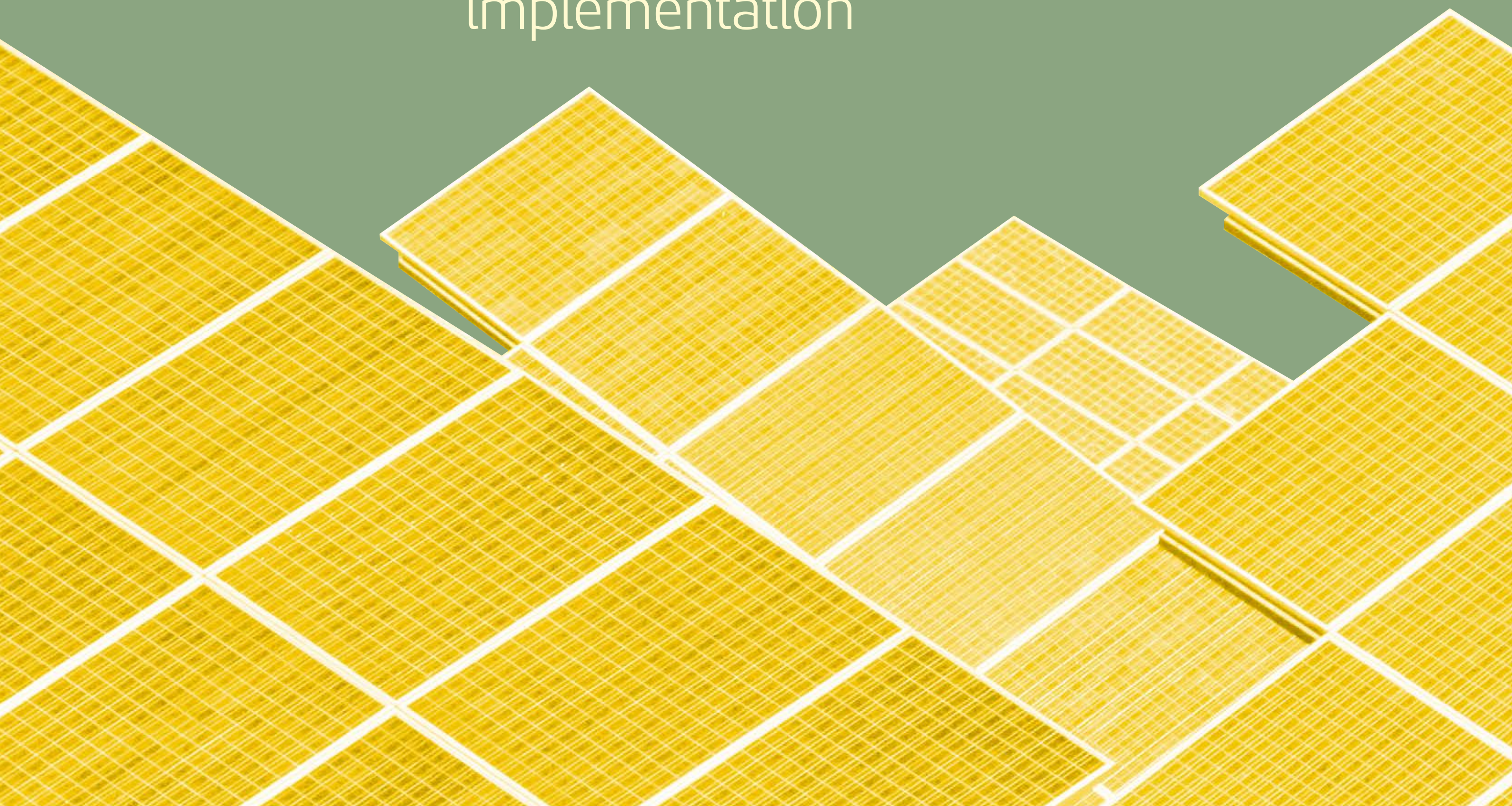


Solar Energy for Multi Family Houses in Lithuania

Potential implementation



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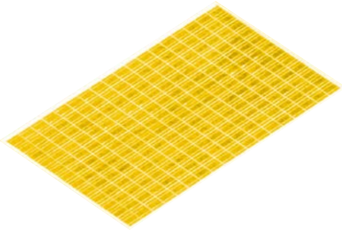
Im Auftrag des:

Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit

Europäische Klimaschutzinitiative EUKI

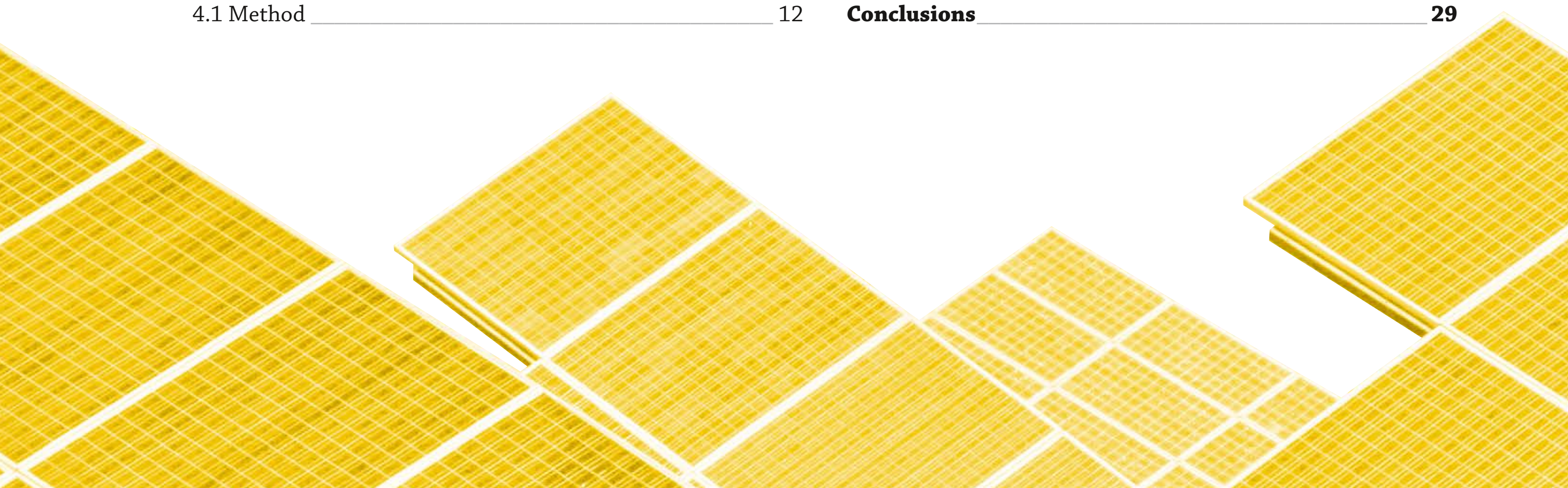
EUKI SOL project is part of the European Climate Initiative (EUKI). EUKI is a project financing instrument by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The EUKI competition for project ideas is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.



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 ends with energy recovery from renewable energy sources. Until recently, it was hard to even imagine having your own solar power plant. But now, with a dramatic drop in the prices of photovoltaic modules, they are becoming more and more accessible. In Lithuania, the owners and residents of residential houses are often choosing roof-mounted solar power plants. However, the owners of apartments still view this opportunity with distrust. Through this study, we want to prove that investing in solar modules on the roofs of apartment houses can be a great addition to normal renovations and a way of lowering costs, not only for electricity but also for heat by using heat pumps.

Currently, Lithuania imports about 60% of the electricity that is 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 the best prices. This dependence means that the Ministry of Energy of the Republic of Lithuania, in its National Energy Independence Strategy, has forecast that one hundred percent of the required electricity will be produced inside the country by 2050, 80% of which will come from renewable energy sources, and that half of all consumers will be producing consumers[1] (prosumers). This number is very ambitious and will be impossible to implement without the help of even the smallest consumers living in apartment blocks. In order to calculate the possibilities for installing solar power plants for the residents of apartment buildings, we have prepared this publication.

In this study, we will discuss the current social situation, the legal framework and the opportunities for consumers to become producers. Most importantly, we will 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), a project partner in Lithuania, has presented an analysis of the renovations available in Lithuania and an assessment of the different options. Meanwhile, our partners in Germany, Steinbeis-Innovationszentrum energie+, with many years of experience in designing and implementing solar energy projects, have analysed two non-renovated apartment buildings that are currently standing in Lithuania, and have modelled their renovation ideas for different scenarios according to the requirements for Energy Efficiency Classes C, B, A, A+ and A++. It was also calculated what the energy consumption would be if photovoltaic cells were incorporated into a standard apartment renovation to achieve Energy Class C.

This study is primarily aimed at civil servants and politicians, who have the right to make decisions and the power to accelerate the process of developing renewable energy. In addition, the information provided in this study may also be useful and interesting for each energy consumer who is considering the possibility of 'employing the sun' for their own use.

Knut Höller
Initiative Wohnungswirtschaft Osteuropa (IWO e.V.)

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

Synopsis

Solar energy produced using photovoltaic cells is becoming more and more popular. One of the most attractive areas where this technology could be applied is in the modernisation of apartment buildings.

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, but also a rapid increase in the number of prosumers.

In Lithuania, a large part of the public suffers from energy poverty: many families cannot afford to pay for heating, hot water and electricity. Investing in RES could be one way of solving this problem.

According to the requirements for the energy classes of buildings, only Class A++ requires the inclusion of renewable energy sources. We have analysed cases where RES are also used in lower energy efficiency classes, and we will provide our calculations herein.

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% of apartment blocks have been renovated so far, which reflects the very low attractiveness and inefficiency of this approach.

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 a power supply for the heating of domestic hot water and towel dryers (coils) are very cost-ineffective. However, replacing these power supplies with heat pumps would not only reduce the amount consumer spending, but also eliminate the losses incurred by using boiler-houses and centralised network operations during the warm season.

Without sufficient funds for the full renovation of the building, it would be worth paying much more attention to partial renovations, in particular the modernisation of heating units. This would create opportunities for regulating the heat in each apartment individually, and thus an economic and energetic central heating system could be organised more efficiently.

A more efficient way of modernising buildings would be to employ a combined heat pump and photovoltaic (PV) system, integrated into a partial renovation of the building. This could save up to 60% of the annual costs of heating and hot water, as compared to a conventional renovation.

The renovation of an apartment building to Energy Class A++ is the best choice in the energy sense, but is not economically attractive and is only applicable in special cases.

A comprehensive analysis of the buildings and a simulation of the renovations has shown that upgrading the building to Energy Class C, together with the installation of the solar power plant, is the most cost-effective solution.

The creation of energy communities and a clearer legal framework for joint ownership is one of the most important tools available to the state policy to increase the number of prosumers.

Solar power plant prices are still high enough to discourage lower-income consumers, which is why state support is an indispensable tool for the further development of solar energy.

1. Lithuanian social conditions regarding PV

In the scope of this report, we concentrate on two aspects of energy issues. **First**, traditionally, photovoltaic is related, as the term implies, to production of electricity. Solar radiation is converted into electric current in 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 multifamily houses (MFHs). Solar electricity or **solar photovoltaic** is usually the term used in such a case – in short, solar PV.

Second, and less obvious, is use of solar energy for heating. In the course of development of solar energy utilisation technology, it was initially used to collect sunlight and transform it into heat, hence the name **solar thermal** technology. The panels on the roof are the collectors of sunlight, containing tubes with the liquid in it. Solar radiation heats up the liquid in the tubes which is then transported into the heating system ready for use, for example, to heat water.

As technologies advanced, solar PV technology experienced the steepest drop in prices, making it more competitive in comparison to solar thermal. Sunlight conversion into electricity factor increased hugely in the last few decades, while the cost of equipment dropped multiple times from what it cost back in 1990-2000. This made usage of solar PV widespread on global scale, which brought additional incentives as economies of scale made it noticeably affordable.

Certain economical 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 additional 30 percent across the board, with panels selling out at €0.20/Wp – the price by many considered close to the bottom for current production technology[2].

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

When it comes to electricity, the overall picture is modestly favourable to increase PV deployment. Electricity prices from the grid in Lithuania are one of the lowest in Europe – with 0.1097 Euros per kilowatt-hour, at 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 will pay out in 8 to 13 years, depending on current state support level and calculation assumptions. For countries with better parity-to-grid ratios, like Germany, Spain or Italy, the choice of solar electricity is obvious – self-generation and self-consumption brings easily visible benefits both for households and the industry.

In Lithuania, with average 0.1097 €/kWh, the choice is not obvious. Comparatively large upfront investment costs hinder ability to install solar PV for self-generation. Number of prosumers ('producing consumers') is still around 1000 – with absolute number of such installations are being in single-family housing sector.

For MFHs, huge own produced electricity legal hurdles exist. While exactly on MFH sector, the solar energy self-usage is the most desirable, for the reason of better social equality dynamics and as a tool of fighting energy poverty.

The latter is clearly a problem, poorly addressed by the State and non-state players. As shown by the European Energy Poverty Observatory[5], Lithuania is among the poorest countries, when it comes to citizens 'ability to keep home adequately warm'. See chart on the next page.

Poorest Lithuanian families spend as much as 50 percent on their monthly income for heat, electricity and warm water. The problem has its roots in legacy from Soviet times, as evident from pan-European statistics[6].

Caused by a combination of factors, including low household income, high energy costs and energy inefficient houses, it is estimated that energy poverty[7] presently affects around 50 million people across Europe, with profound consequences for citizens' health and wellbeing. For Central and Eastern

2 In total, price of installing 1 kWp of solar PV power station is around 1000 euros for small installations (in low kW figures range) and at 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 of human labour and administrative workload should also be added.

3 Time to press for this brochure, April 2019.

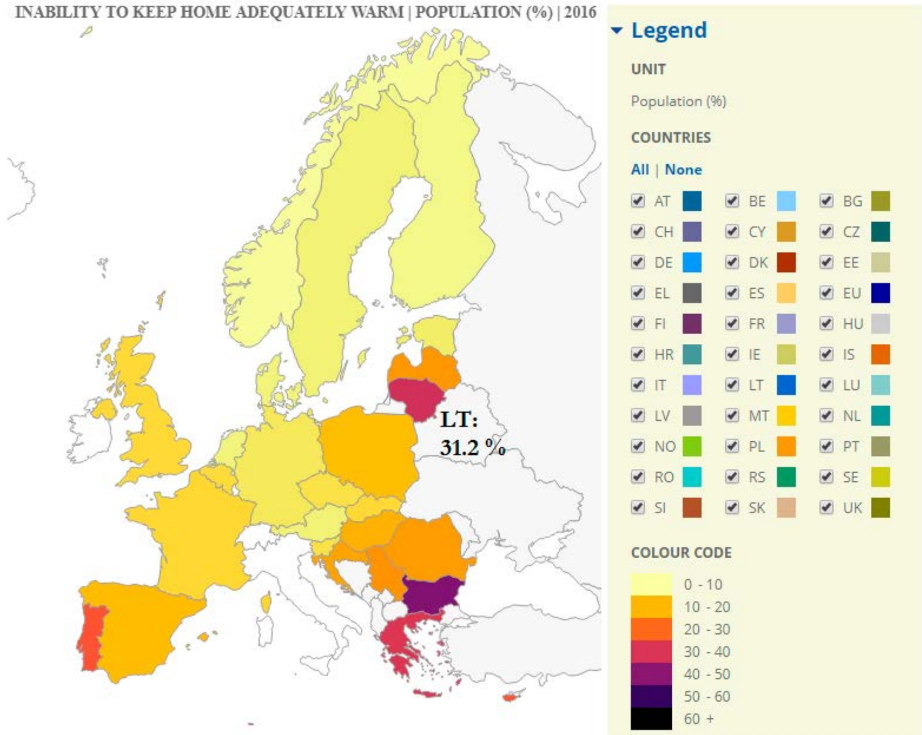
4 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Electricity_prices,_First_semester_of_2016-2018_(EUR_per_kWh).png

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).

Illustration 1: Inability to keep home adequately warm



Europe, the combination of the aforementioned factors creates a self-reinforcing vicious cycle: low income (and consequently low or non-existing[8] savings) hinders the ability to invest into energy efficiency of the house or flat they inhabit.

Massive flat privatisation campaign in 1990ies ended up with a ‚poisonous gift' – many families living in a housing they would normally not be able to afford to buy or rent – let alone to sustain it in a good shape and to improve. Families with low income and no savings are not able to bear the cost of house improvement – hence, State supported mechanisms 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 might have been expected. Without such action, the 2030 and 2050 climate and energy targets will be very difficult to meet. The potential exists for buildings to reduce energy consumption by 5 to 6 percent and lower CO2 emissions by about 5 percent. However, with only 0.4-1.2 percent of the building stock being renovated/improved annually it is clear that the processes need accelerating.

In 2015, around 15.2 percent 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 importance of energy efficiency measures is self-evident. The Energy Efficiency Directive (EED) has the potential to constitute a positive step in this direction by steering energy efficiency measures 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 in place to tackle this complex and multi-layered issue.

Illustration 2: Compensation for heat and hot water for state-support eligible consumers, 2010–2017

8 As of 2017, 12 percent of Lithuanian households admitted having no savings whatsoever, research conducted by Spinter tyrimai showed. Another 27 percent of population have savings equal to only 1 month (or less) worth of expenses.. Data from 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/m² and 1100 kWh/m² per year. Average radiation level in the major cities of Lithuania (kWh/m²/year): 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.

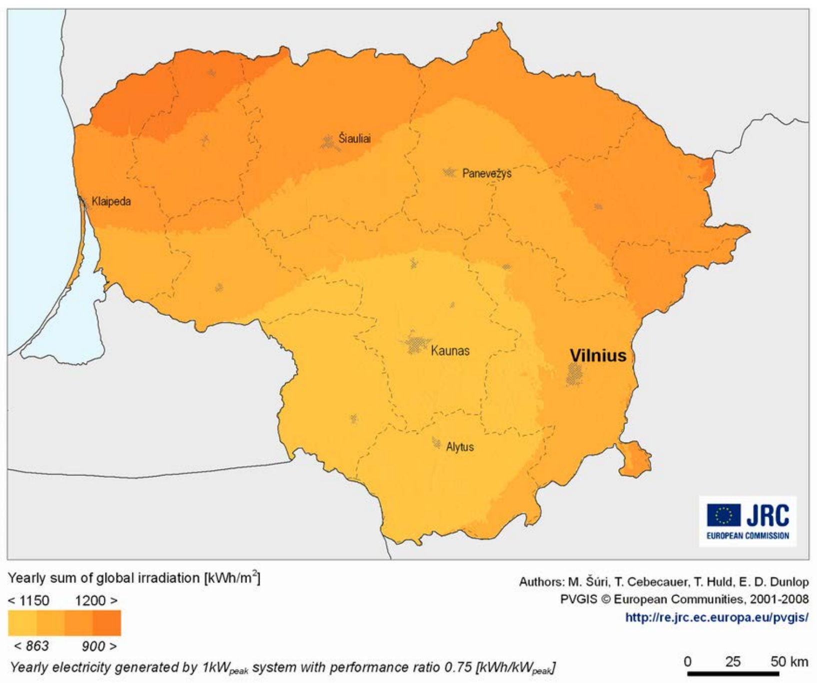
At such a level of radiation and by offering a small 30% support for the equipment, solar electricity production is cost effective. Therefore, it will definitely develop. The Lithuanian Energy Independence Strategy has foreseen that by 2020, 30% of the country's electricity will be generated from renewable energy sources, and the share of solar energy in these resources will be 6%. Meanwhile, in 2030, 45% of all energy will be produced from renewable sources, and the share of solar energy therein will be 25% to satisfy approximately 12% 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). In three years, the total volume of photovoltaic installations has reached 60 MW. In 2012, when the authorities did not respond in time to the dramatic fall in the price of 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, no new solar power plants were installed in Lithuania in the next 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 when there is a shortage, i.e. in the evening and in winter. At the same time, households started becoming not only electricity consumers but 'producing consumers' (prosumers), which has 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

Illustration 3: Solar irradiation in Lithuania



80 MW. Consumers were able to receive support of up to 30% of the equipment's price, and public bodies up to 100%.

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 in 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. 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 manufacturer. At the same time, excellent conditions for using solar electricity for domestic use, with the help of modern air-to-water heat pumps, will make this type of electricity a cheap choice for heat production. For this reason, we have prepared this feasibility study, in which we calculate the possibilities for incorporating solar energy into apartment renovations in Lithuania.

3. Situation of renovations of apartment buildings in Lithuania

The process of the renovation of 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 controller of this process. The renovation mechanisms have been constantly improved.

The latest amendment to the resolution of the Government on the wider use of renewable energy for the renovation of housing was adopted in December 2018. Thanks to this, renewable energy is being fully integrated into the process of the modernisation of apartment buildings: the use of solar, wind, geothermal and aerothermal energy is being provided under favourable conditions. This allows for more diverse possibilities in the process of renovating multi-apartment buildings, and thus the more actively 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 31 December 2018, only 1650 buildings, or 6% of all apartment buildings, had been renovated. At the moment, 450 buildings are undergoing renovations. Therefore, approximately 35,000 buildings are still waiting for their turn. This means that we must look for simpler, cheaper and more efficient ways to modernise these buildings.

3.1. Energy modernisation options for multi-apartment buildings with their advantages and disadvantages

In Lithuania, the usual renovation practices involve insulation of the walls, roof and basement of the buildings, as well as replacement of the windows and exterior doors, insulation of the pipelines and replacement of the radiators. Active energy efficiency measures, such as the use of solar energy, aerothermal or geothermal energy, are very rare. However, using them could achieve the same energy saving result, only at significantly lower costs. Most importantly, it is possible to achieve greater results in reducing CO2 emissions and make 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, are found in a very advanced double net metering system that is being implemented in Lithuania. The essence of this system is that solar power can be produced at a time favourable for light energy generation, i.e. during the day or in summer; then, for a small fee, it can be passed to the grid for storage and used at the time when it is most needed, i.e. during the dark time 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 use sunlight for electricity.

3.1.1. Partial modernisation

The complete modernisation of an apartment building requires 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% of apartment buildings have been renovated, while also showing the effectiveness of such renovation.

Therefore, it is worth developing the renovations in another way – by taking small and very cost-effective steps. One of these steps is to use new means to modernise the heat distribution units of the apartment buildings. In this way, it is possible to reduce the heat consumption of an apartment by up to 15% and incur only a low cost. Another very cost-effective method 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 a power supply for the heating of 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 even 60%. 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 cheaper way by using aerothermal and solar energy.

3.1.3. Traditional renovations

Traditional renovations involve the thermal insulation of all exterior structural elements of a building in order to significantly increase their thermal resistance, i.e. 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. Therefore, it is not easy 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 'near 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 the building at Taikos Street 27, 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 (hereinafter referred to as the Utena Building) was chosen.

Its main general parameters are as follows:

- Number of apartments – 38.
- Useful area of apartments – 2,043 sq. m.
- Useful area of non-residential premises – 101 sq. m.
- Total area – 2,144 sq. m.

Key energy and economic parameters:

- Heat consumption per one sq. m. per year – 189 kWh
- Total heat consumption per year – 405,400 kWh
- Heat amount for hot water preparation per one sq. m. per year – 54 kWh
- Total heat amount for hot water preparation per year – 110,000 kWh
- Electricity consumption for domestic purposes per one sq. m per year – 30 kW
- Total electricity consumption for domestic purposes per year – 64,300 kW
- Energy Efficiency Class – F
- Cost of the construction work for the transfer of a building from Class F to Class C – EUR 378,000
- Cost of the 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 is Class F, and the energy efficiency of a typical multi-apartment building in Lithuania is Class E. This building was selected for the research because it is included in the German Government's innovative project programme and will be upgraded to the highest energy class. By having all the energy data of an apartment building before and after the renovation, as well as having information on the energy consumption after the renovation, it is possible to compare the various variants of the renovation in the simulation and in reality after the project has been implemented.

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

The purpose of such a renovation is to modernise the heating unit of the building so that it refuses to supply hot water during the warm (summer) period.

The heating units of these old buildings are very inefficiently managed, as it is difficult to control the temperature of the heated water by using them since it is managed centrally throughout the heating network. Therefore, it is not possible to regulate the heat consumption quickly in the building, depending on the changes in the air temperature during the day. Furthermore, all buildings are different, as well as the needs of their residents. After the modernisation of the heat substation, possibilities arise which allows for approximately 15% of the thermal energy to be saved in an economical way. The cost of such modernisation would be approximately EUR 20,000 for the building in question.

Another possibility to increase the energy efficiency is to give up the hot water supply from the central heating system. The economic indicators of such a refusal would be:

- Hot water consumption from May to October – 1,100 cubic metres
- Need for heat energy for the preparation of hot water of such an amount – 55,000 kWh
- Need for power of a heat pump for such a heat amount – 42 kW
- A heat pump will consume the following amount of electricity for producing such an amount of heat – 18,000 kWh
- Power of the solar power plant needed to produce such an amount of electricity – 19 kW
- Price of the solar plant – EUR 19,000

- Price of the heat pump including the installation – EUR 11,000
- Price of solar electricity using double net metering – 3 euro cents per kWh

Using these indicators, the following calculations were made:

- Price of heating of 1 cubic metre of water using solar electricity and a heat pump – 1.5 EUR/cubic metre
- Price of 1 cubic metre of hot water from a centralised network – 4.52 EUR/cubic metre
- Difference – 3 times.

In this case, the investment costs are not included. They consist of: EUR 20,000 for the modernisation of the heat substation and EUR 30,000 for the production of the hot water. However, this does not take into account the real costs of a centralised boiler room, which generates heat at a capacity 3 times lower than in the winter. In the case of a partial renovation with the usual 30% support, the following payback is achieved: for the renovation of the heating unit – 4.7 years; and for the hot water preparation – 6.5 years.

Thus, the partial or 'small renovation' is much more cost-effective than a traditional renovation when the insulation of the whole 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 already mentioned, the purpose of the renovation of old buildings, and more precisely, of their modernisation, 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, the aim is to reduce the CO2 emissions and to contribute to the protection of the environment from the greenhouse effect. For this purpose, the traditional way of heating the walls of a house 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, which comes from photovoltaic solar modules and air-to-water heat pumps. The legal, technical and administrative possibilities for this modernisation method in Lithuania are being finalised, 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 away from the electricity consumption site.

Below, the economic effect of using such a modernisation method on the example of Utena Building is described using the above building data.

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

This renovation, under the investment project, would cost EUR 378,000.

Let's calculate the cost of the same heat savings in another way – by using 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 effect.

The heat output of a heat pump, which would produce 253,000 kWh per year, should be 125 kW with a full installation cost of EUR 80,000.

The power of a solar power plant, which would produce 85,000 kWh of energy per year, should be 90 kW and has a full installation cost of EUR 90,000. Using this method, it would also be worth replacing the radiators, which would cost EUR 10,000.

Therefore, the total cost of modernising the building's energy system by using a solar power plant and heat pump is EUR 180,000. Meanwhile, the investment project for a traditional renovation foresees the cost of the construction work to be EUR 378,000.

As a result, it should be concluded that the modernisation of the energy system of the building, which allows for savings of 62% of the heat energy (as provided for in the renovation investment plan for transfers from Blass F to C) by replacing 'contaminated' heat energy to green energy, would be **2.1 times cheaper than the traditional house heating method**.

3.2.3. Traditional renovations

Traditional renovations include the work of 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 is planned to be reduced from 405,000 kWh/year to 152,000 kWh/year, i.e. 253,000 kWh/year. At the same time, the energy performance class of the building would be raised from Class F to Class C.

The cost of this works is EUR 378,000.

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

Of course, this does not include the social and aesthetic results of such a renovation: the house becomes more attractive externally, and it is more pleasurable to live there. Such factors are very important, but they are very difficult to estimate economically.

3.2.4. Traditional renovations combined with the use of renewable energy

In Europe, the movement to install passive zero-energy buildings with Energy Efficiency Class A++ is expanding. Such houses are undoubtedly the future of residential and non-residential buildings. Nonetheless, it is not possible to install an A++ house without using local energy production, i.e. renovated energy systems must be used for the building under renovation. Trying to install such experimental buildings is necessary, because both scientists and practitioners need to understand the specific requirements of these houses and learn how to equip them in economical and technically efficient ways.

This method was also calculated for the Utena Building. In this building, the plan is not only to insulate, but also to install a solar power plant in that building connected to a geothermal heat pump.

In case of Class A++ premises, the building's heat energy consumption is planned to be reduced from 405,000 kWh/year to 34,000 kWh/year, i.e. 371,000 kWh/year. In such cases, 1.62 kWh/year would be enough to heat 1 sq. m., while for the non-renovated house this figure is 188.86 kWh/year, so the heat consumption would decrease by as much as 99.1%. In order to achieve this result, a 18 kW solar power plant, as well as a 24 kW heat pump and a group of 8 kW solar thermal collectors for the hot water production needs be provided, in addition to the traditional insulation.

Such a method of renovation would be very attractive for multi-apartment buildings, but its implementation price is as high as EUR 667,000 excluding the design and additional work. Such a project's net payback is **35 years**. Therefore, without additional state or other support, this method is not attractive to the residents. We hope that, with the support of having implemented the Utena Building's multi-apartment project, we will be able to calculate specifically whether the renovation of a building to the highest energy class is beneficial in terms of the financial and environmental aspects.

4. Technical Expertise

4.1 Method

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

There are about 20,000 buildings of these types in Lithuania (cf. Illustration 4).

At the first stage, thermal modelling of the selected buildings was carried out in the EnergyPlus program in order to determine the heat demand. The total demand for heat and hot water was determined on the basis of this value and the measured energy consumption for heating hot drinking water. At the same time, losses in hot water pipelines were assumed to be approximately 20 %, in heating pipelines – approximately 10 %. The demand for additional current was considered to be 2 % of the consumed heat. Indicators of electricity consumption are based on measured values.

Based on the combination of these values, it was possible to determine the total building energy demand. The procedure is shown in Illustration 5.

In addition to the model of the existing buildings, three models with different envelopes were made for each of them. The requirements for heat-transfer coefficients were considered in accordance with Lithuanian energy efficiency classes. In addition, airtightness requirements were also considered. The requirements for final and primary energy, indicated in

Illustration 4: 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 5: Energy Demand Calculation Process

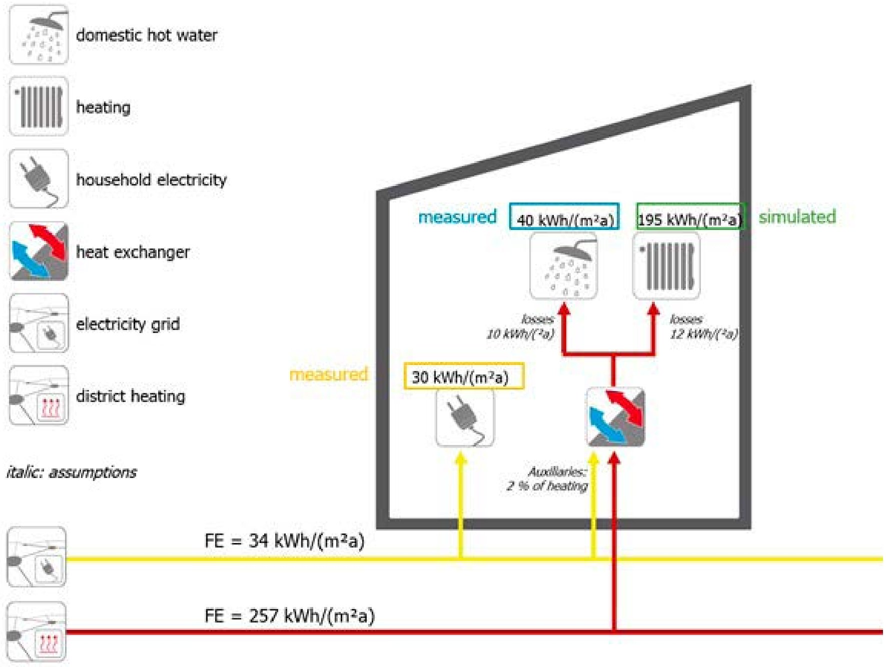


Illustration 6: Basic Data on a Brick House

	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 7: Basic Data on 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

the energy efficiency classes, including not only the building envelope but also energy generation parameters and energy sources were not considered.

These requirements were not considered, since this project compares building insulation and photovoltaic systems integration and analyses their impact on energy costs.

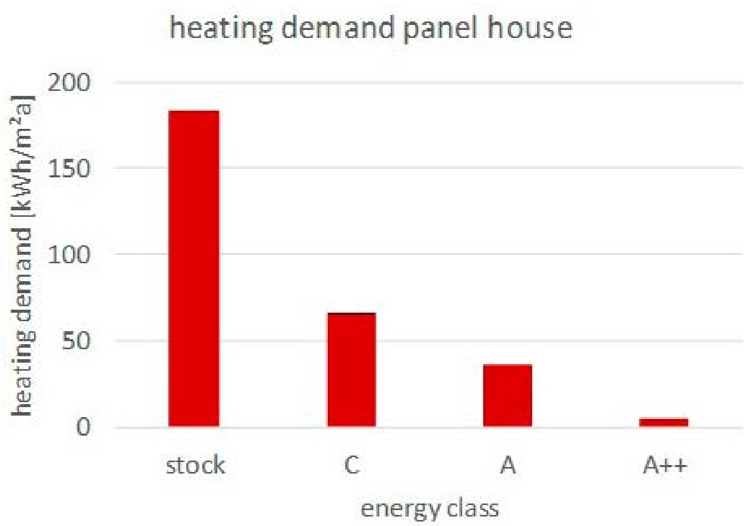
After determining the demands for electricity and heat, a model was compiled to calculate electricity generation and the share of individual use of electricity generated by a photovoltaic unit, depending on its direction and the location of the panels on the roof.

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

In contrast to the legal requirements, this project also considered household electricity.

Illustration 8: Heat Demand for a Brick House with Different Energy Efficiency Classes

Illustration 9: Heat Demand for a Panel House with Different Energy Efficiency Classes



4.2 Building and Modelling Conditions

Two unreconstructed buildings were selected for the project, corresponding to typical buildings in Lithuania. Both buildings are five-story. Photos and data on the areas and envelopes of the buildings are shown in Illustration 6 and 7.

The thermal model is compiled in the EnergyPlus program. As weather conditions, data of the Meteonorm system from Kaunas were 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 reconstructed buildings, the requirements for heat-transfer coefficient and air exchange n50 of the respective energy efficiency classes in Lithuania are 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 in the EnergyPlus program. 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 unreconstructed 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 was considered. In this class, ventilation system is absent to save costs. Illustration 8 shows a heat demand model for a brick house.

Illustration 9 shows the heat demand for a panel house. In this case, energy efficiency class A++ also considered a ventilation system with heat recovery. The average heat demand: 184 kWh/(m²a) for an unreconstructed state, 67 kWh/(m²a)

Illustration 10: Final Energy Demands Including Electricity Consumption in a Brick House

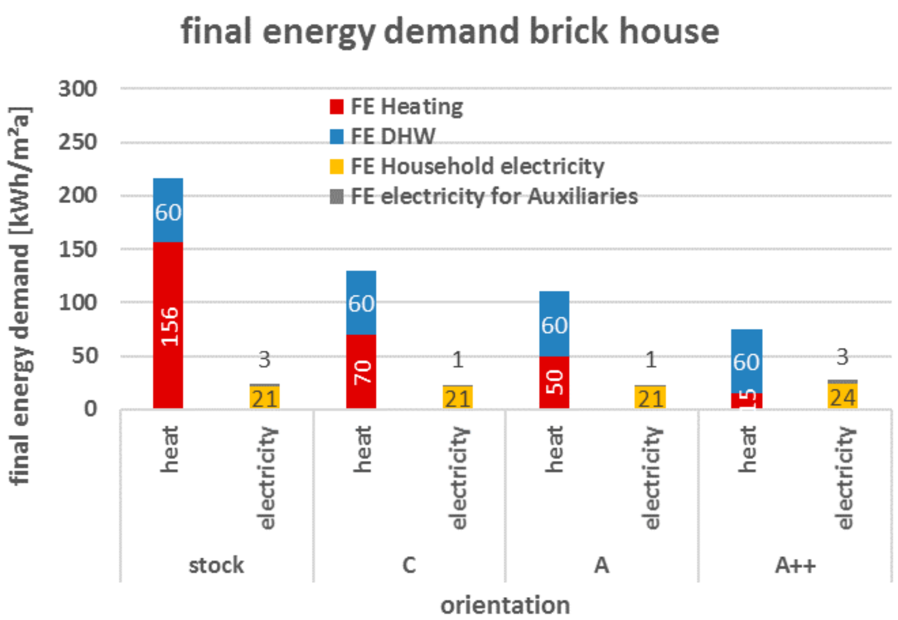


Illustration 11: Final Energy Demands Including Electricity Consumption in a Panel House

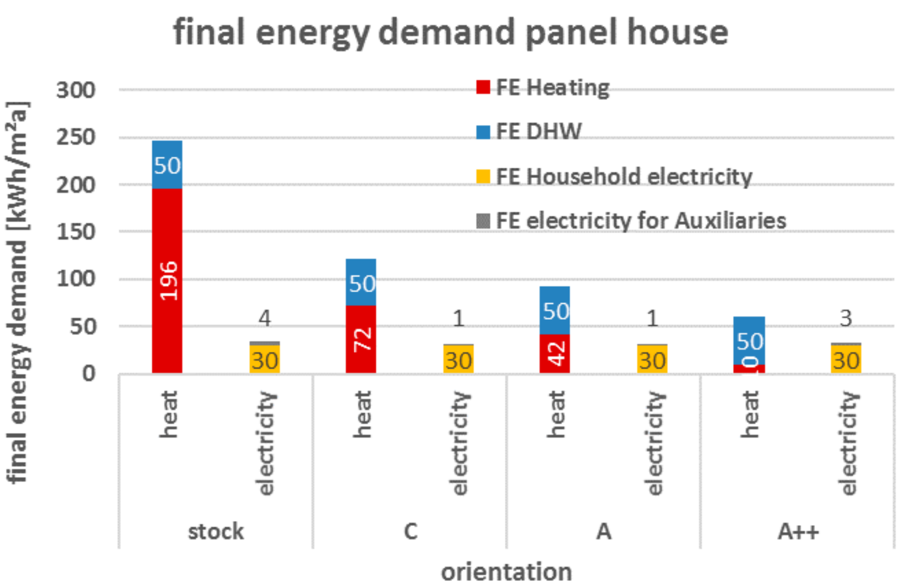


Illustration 12: Energy Costs (without Base Rates) in a Brick House

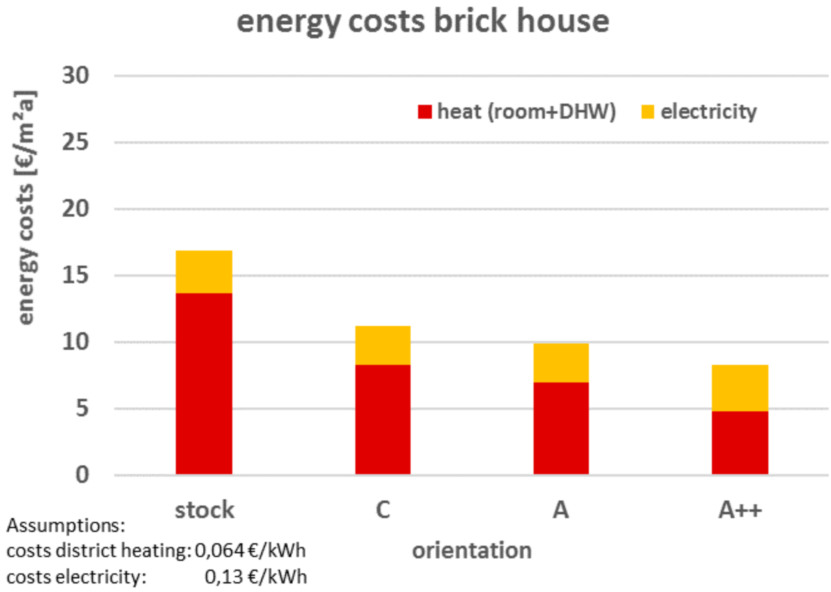
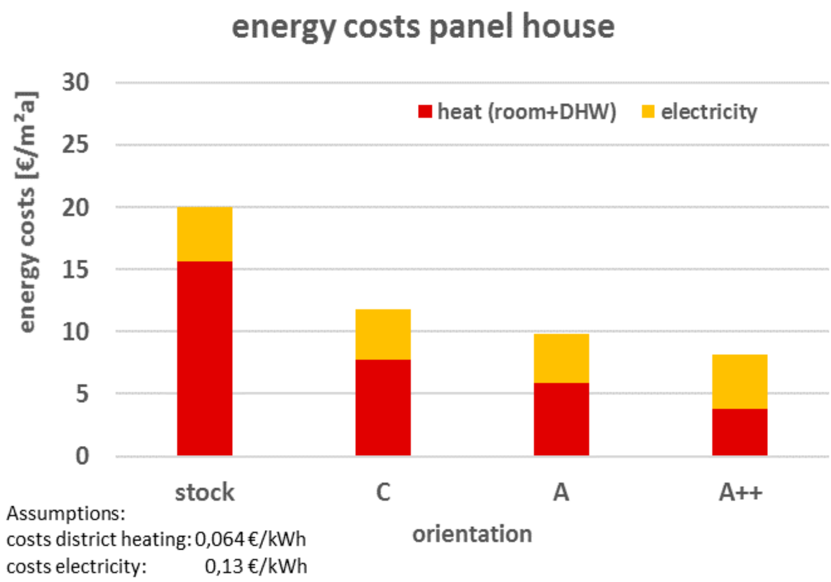


Illustration 13: Energy Costs (without Base Rates) in a Panel House



in energy efficiency class C, 37 kWh/(m²a) in energy efficiency class A and 8 kWh/(m²a) in energy efficiency class A++.

4.4 Building energy demands and energy costs

Illustrations 10 and 11 show the energy demand of the entire building. This also takes into account electricity consumption for household needs in apartments, as it also affects the cost of electricity in apartments. Losses in the heating network of an unreconstructed building are 12 kWh/(m²a), of a reconstructed one – 5 kWh/(m²a), losses in water pipelines are 10 kWh/(m²a). It is considered that after energetic reconstruction, the consumption of drinking water will not change. Only heat distribution losses that occur in the thermal envelope and reduce the heat demand for heating will be minimized. For this reason, it is believed that the energy requirements for hot water will not change.

It is clearly seen that the higher the energy efficiency class, the greater the share of the need for electricity in the total energy demand. In addition, it is clear that the cost of hot water decisively affects the total heat consumption.

Taking into account the rates for central heating and electricity, as of January 2019, the share of electricity increases even more (cf. Illustrations 12 and 13).

On the basis of these indicators, an analysis is made of how feasible a photovoltaic unit is, comparing with insulation reinforcement, from the economic and environmental point of view.

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.

The panels are considered to be installed at an angle of 10 °, since in this case more panels can be installed on the same

Illustration 14: Comparing Different Angles of Panels Placed on the Roof on an Example of Berlin

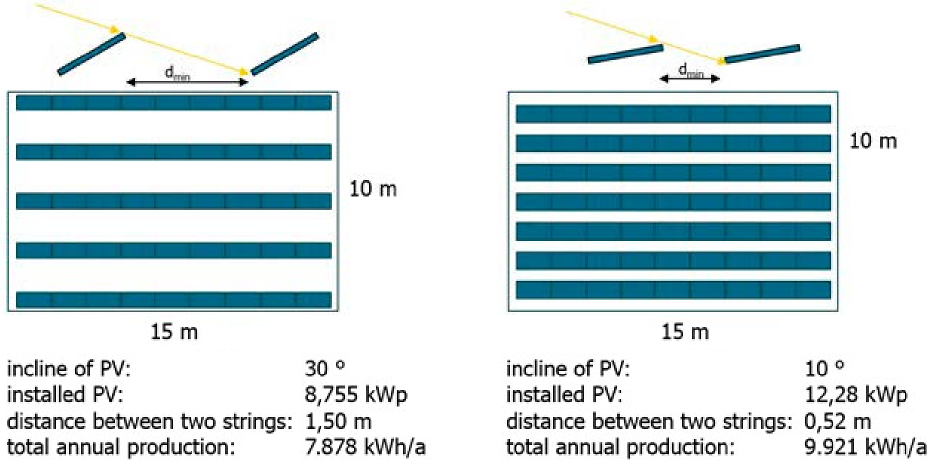


Illustration 15: Photovoltaic Modules Electricity Production, Use for Individual Needs and Supply to the Network with a Different Number and Orientation of the Modules on the Roof, Brick House

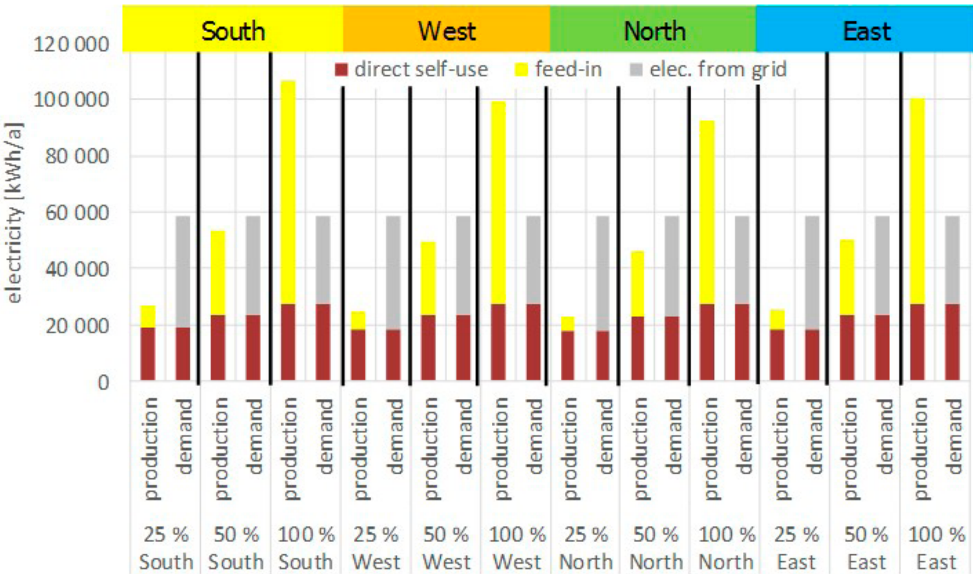
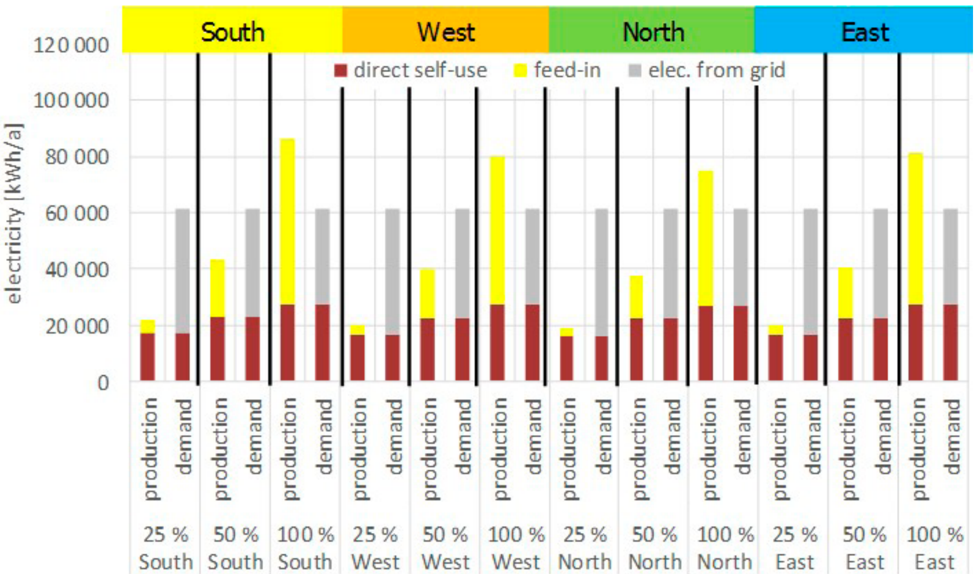


Illustration 16: Photovoltaic Modules Electricity Production, Use for Individual Needs and Supply to the Network with a Different Number and Orientation of the Modules on the Roof, Panel House



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 14).

The model was made for both buildings, 4 directions (north, east, south, west) and three options for panels number on the roof (25 %, 50 % and 100 % of the available roof area). The available roof area is considered to be 80 % 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 a brick house) and 91 kW-peak (for a panel house).

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

In any case, since it is more profitable to use generated energy individually, supplying excess energy to the network and measuring net consumption, than to supply all the energy, it is important to calculate the share of individual 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 demands on a 15-minute base. Illustrations 15 and 16 show energy balances with a different number of modules on the roof and their different orientation, with the modules tilted at an angle of 10 °.

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

From an economic point of view, it is unreasonable 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 previous chapters, energy demands were determined and the potential of a photovoltaic system installation was analysed. On this basis, an economic analysis is carried out. The analysis is based on full costs, by analogy with VDI 2067, i.e. capital investments, current costs (for maintenance and repair), and costs (for energy) associated with needs over a 20-year period are determined.

To analyse the effect of photovoltaic systems, ten versions were investigated:

1) without reconstruction, without a photovoltaic unit
2) without reconstruction, 25 % of the roof area is occupied by a photovoltaic unit
3) without reconstruction, 50 % of the roof area is occupied by a photovoltaic unit
4) without reconstruction, 100 % of the roof area is occupied by a photovoltaic unit
5) reconstruction of the building envelope according to the requirements of class C, without a photovoltaic unit
6) reconstruction of the building envelope according to the requirements of class C, 25 % of the roof area is occupied by a photovoltaic unit
7) reconstruction of the building envelope according to the requirements of class C, 50 % of the roof area is occupied by a photovoltaic unit
8) reconstruction of the building envelope according to the requirements of class C, 100 % of the roof area is occupied by a photovoltaic unit
9) reconstruction of the building envelope according to the requirements of class A, without a photovoltaic unit
10) reconstruction of the building envelope according to the requirements of class A++, without a photovoltaic unit

Illustration 17: Investments in a Brick House

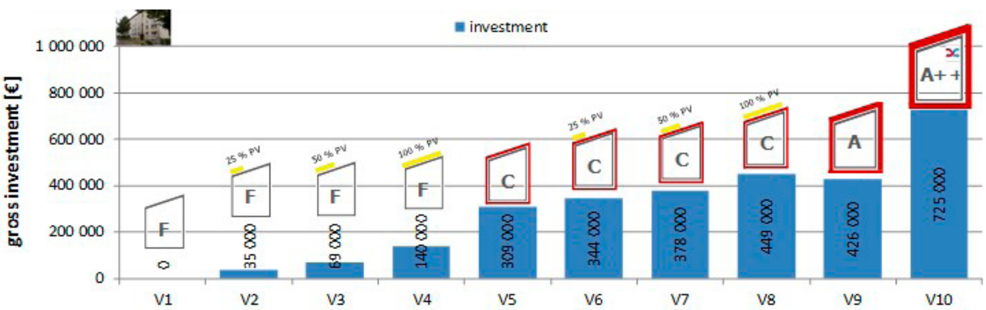


Illustration 18: Investment in a Panel House

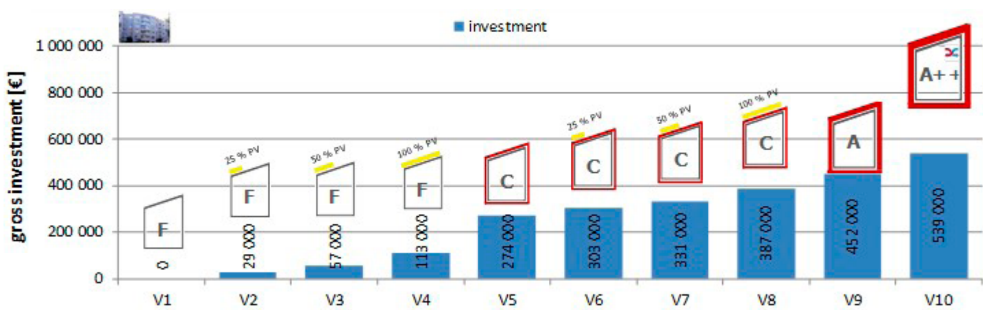


Illustration 19: Total Costs for a Brick House for the First Year

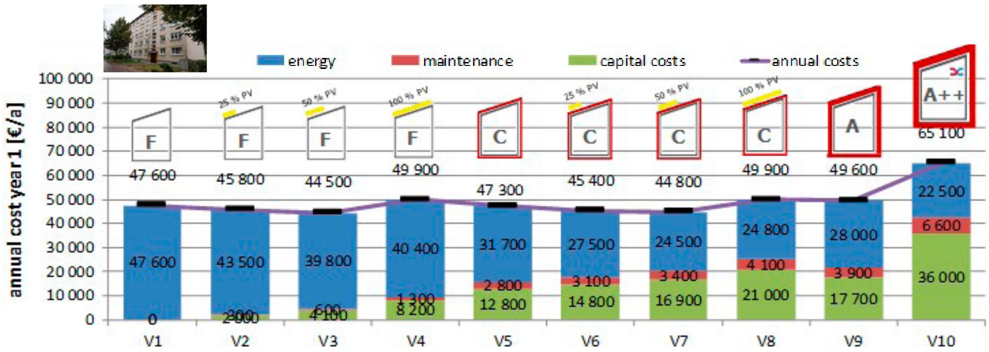


Illustration 20: otal Costs for a Panel House for the First Year

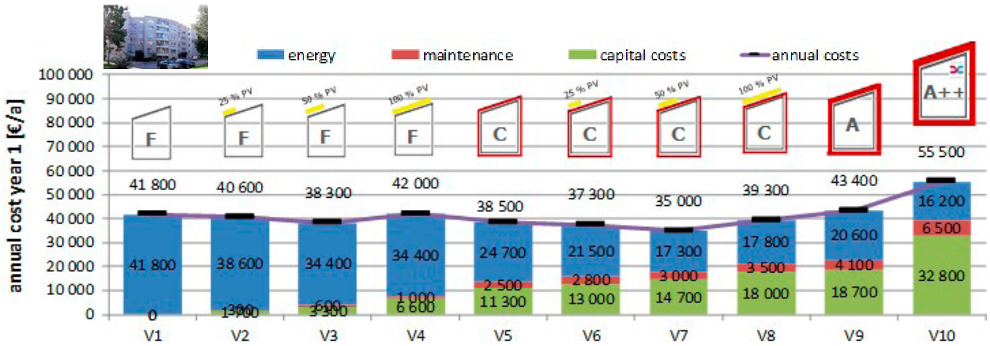


Illustration 21: Total Costs for 20 Years in a Brick House

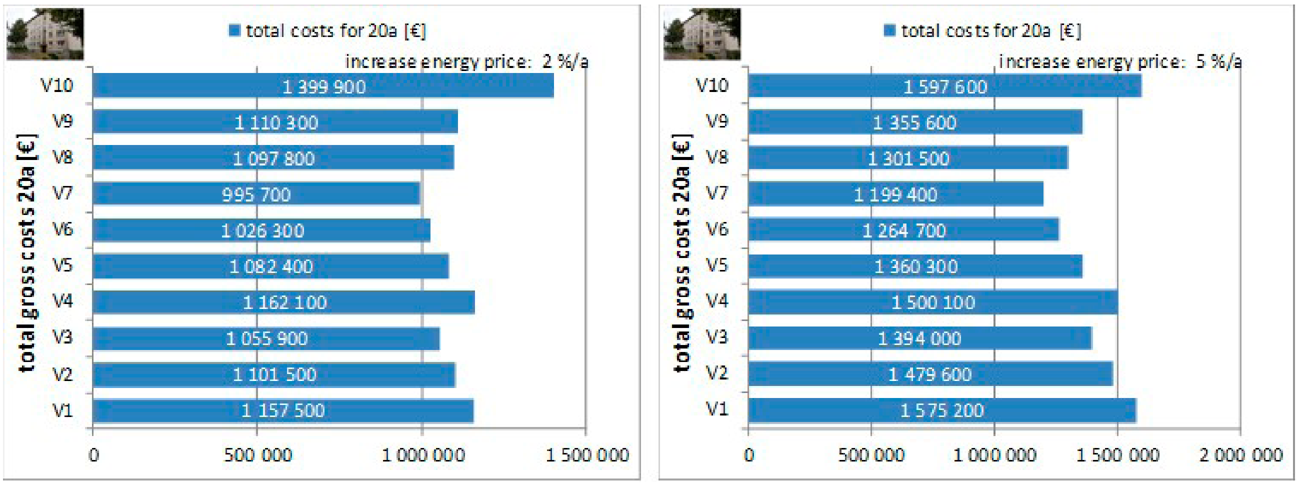
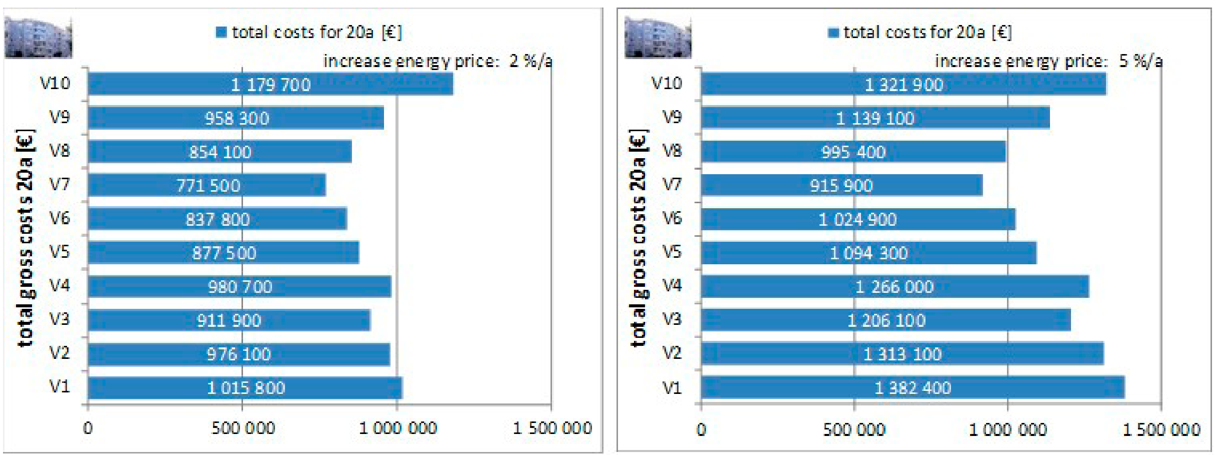


Illustration 22: Total Costs for 20 Years in a Panel House



As a base for calculations, specific indicators of investments per cm and m² of insulation are used, as well as per photovoltaic unit (1100 euro/kW-peak net). For building envelopes only extra energy costs are taken.

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

The principle of net counting is considered, that is, supplying excess electricity to the network and purchasing provided electricity on more favourable terms (~ 4 c/kWh), when the production of a photovoltaic plant is not enough. The maximum amount of energy that can be bought from the network on preferential terms corresponds to the amount of energy supplied or, in case of excess power of a photovoltaic unit, (production is greater than demand) the electricity demand. Illustrations 17 and 18 show the required investment for the respective options.

The required investment is from 12.70 euro/m² or 636 euro/RU to 262.68 euro/m² or 13,181 euro/RU for a brick house and from 14.19 euro/m² or 763 euro/RU to 263.83 euro/m² or 14,184 euro/RU for a panel house. The difference is significant. Capital expenditures are increasing especially due to subsequent installation of a ventilation system with heat recovery (V10).

Illustrations 19 and 20 show the total expenses for the first year (without an increase in energy prices). It can be noted that despite reconstruction to class A+, the total expenses differ by 10 % for brick and by approximately 15 % for panel houses. It is also seen that with reconstruction to class A++ energy costs are minimal, however, the total costs for the year are maximal due to large investments. Minimal total annual costs arise in version V7 with reconstruction to class C and covering 50 % of the roof with the panels. Somewhat higher total costs with 100 % roof area use compared to using only 50 % can be justified with a net counting system. If more energy is produced than a building requires during the year, the difference 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 also clear that energy reconstruction is more economical than a photovoltaic unit (see comparison of V5 and V2-V4). Increasing the insulation standard reduces efficiency for purely physical reasons (see comparison of V5 and V9-V10). This means that installing a photovoltaic unit in combination with a reconstruction to energy efficiency class C is more economical than a reconstruction to class A or A++ (see comparison of V7 and V9-10).

If we take the growth of prices for electricity and heating in

Illustration 23: Electricity Costs in a Brick House

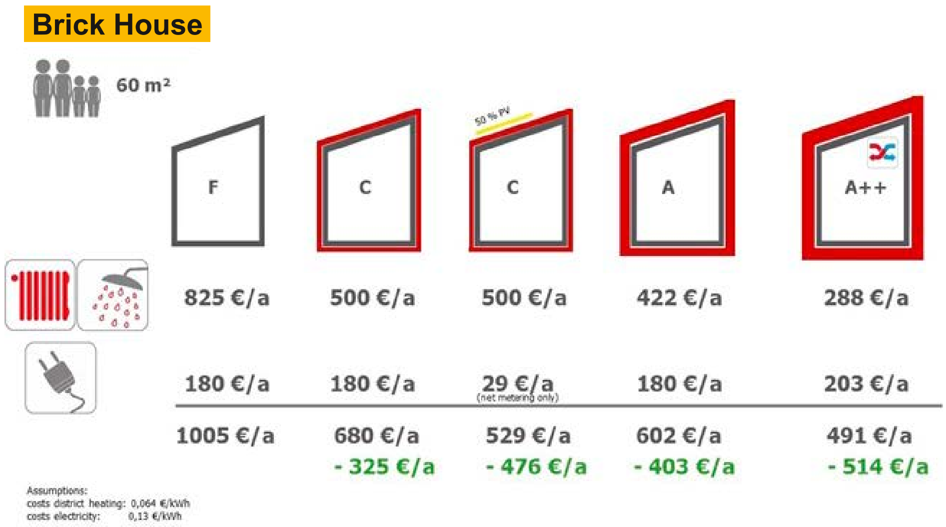


Illustration 24: Static Depreciation Period of a Brick House

Illustration 25: Electricity Costs in a Panel House

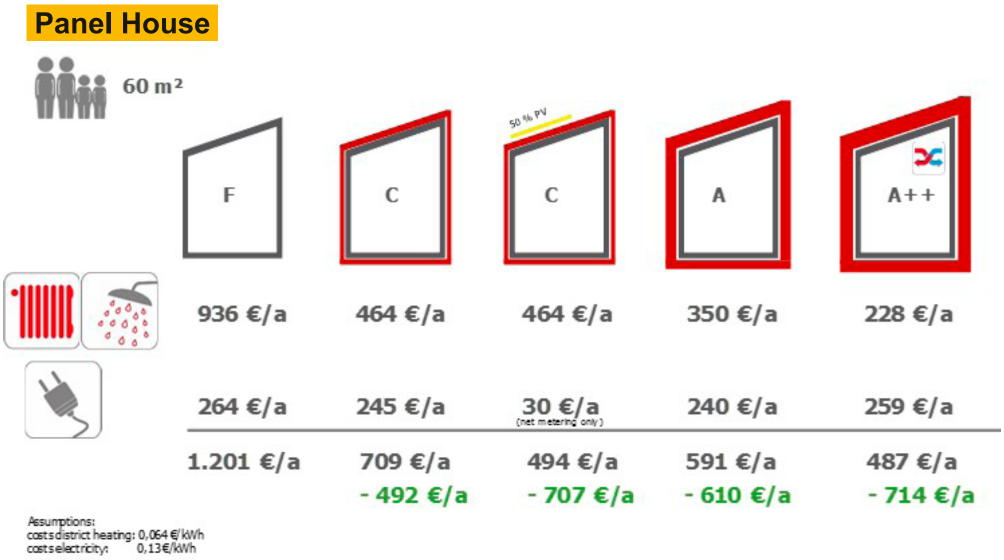
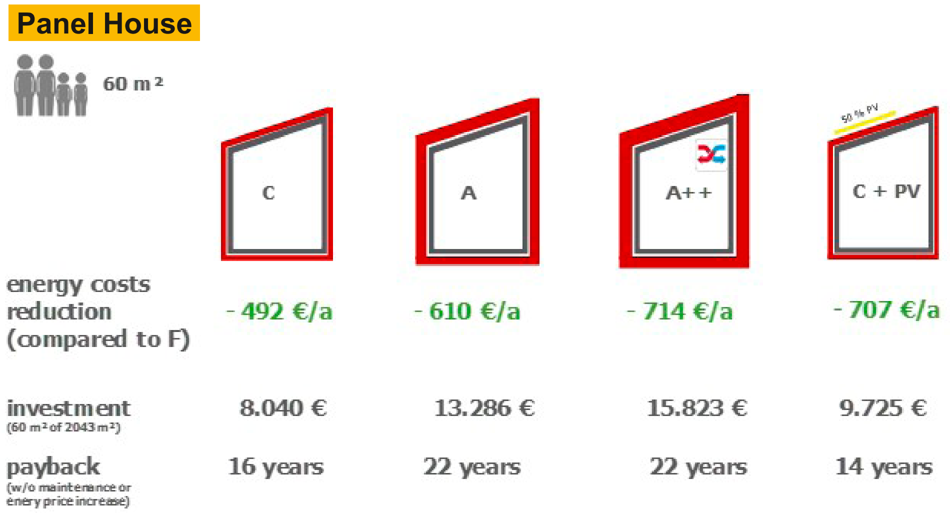


Illustration 26: Static Depreciation Period of a Panel House



an amount of 2 % or 5 % per year with constant electricity prices in the net metering system, the total costs for 20 years will be from 1.0 (V7, 2 % per year) to 1.6 million euro (V10, 5 % per year) for a brick house (cf. Illustration 21) or from 0.8 (V7, 2 % per year) to 1.4 million euro (V10, 5 % per year) for a panel house (cf. Illustration 22).

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

With regard to energy shortages, the impact of energy costs on reconstruction and use of photovoltaic units is further analysed. As an example, a family of 4 people was taken in an apartment of 60 m².

Illustrations 23 to 26 show energy costs for the first year after reconstruction in accordance with individual energy efficiency classes, as well as investments for this family and static depreciation excluding maintenance and repair.

It is clear that the combination of reconstruction to class C and the use of a photovoltaic system is characterized by a minimal depreciation period and the second, from the beginning, size of annual energy costs. Lower energy costs are provided only by reconstruction up to class A++, in any case, it is associated with higher capital investments.

4.7 Conclusions and Recommendations

The economic analysis results show that unreconstructed buildings should be primarily reconstructed in terms of energy consumption. On the one hand, it will increase the comfort inside the building, on the other hand, it will reduce physical problems, for example, heat bridges. In addition, energy costs will be significantly reduced.

When reconstructing, however, it should be noted 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 %, the next 20 cm (creating an insulation layer of 40 cm) reduce this need only by another 20 %. Thus, the effectiveness of insulation is reduced.

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

In addition, it turned out that in a reconstructed building (class C) 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. About 40 % of the needs can be covered directly by a photovoltaic unit.

It is preferable to reconstruct a building to class C and install solar panels with an annual output approximately equal to the annual energy demands of a building.

When designing a photovoltaic unit, the static requirements and the required area shall be considered; as a result, it may 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. In addition, it is obvious that photovoltaic systems with a capacity higher than the consumption of a building, are economically unprofitable due to the net metering principle. If we assume that the excess energy can be sold at current exchange prices, in this case it will be possible to obtain an additional source of income.

We tried to figure out how large such income can be. In a brick house, when using the entire roof area, 106 MWh per year can be produced. 78 MWh per year are supplied to the network, 31 MWh per year is returned via the net metering system. In this case, 47 MWh per year does not generate income. Based on changes in stock prices for a year, we can assume that the average price during periods of supplying energy to the network is 4.82 cents per kWh. The average price per year is 4.03 cents per kWh. If we assume that the surplus of 47 MWh per year will be sold at a price of 4.82 cents per kWh, the additional income will amount to 2,256 euros per year. To generate 47 MWh per year, a power of about 47 kW-peak is required. Including subsidies, the investment will be around 37,000 euro. Due to the income from sales at the stock price, the additional photovoltaic plant will pay for itself within 16.5 years.

This means that in this case legal conditions will also be required. Additional income will help to cope with the lack of energy.

It is also necessary to create clear legal rules on the basis of which homeowners' associations would be able to install and operate photovoltaic units.

Appendix

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

Illustration 27: Heat Demand in a Brick House, North-South Direction, Before Reconstruction

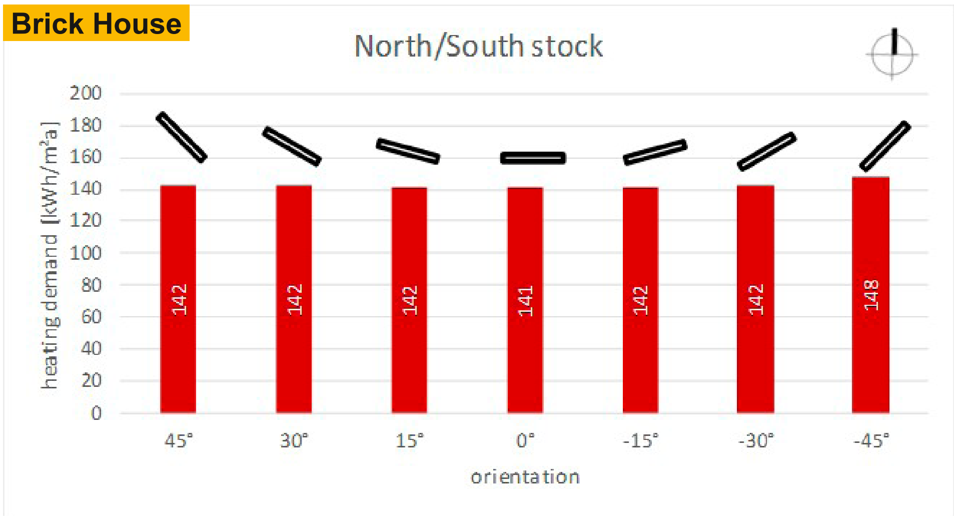


Illustration 28: Heat Demand in a Brick House, East-West Direction, Before Reconstruction

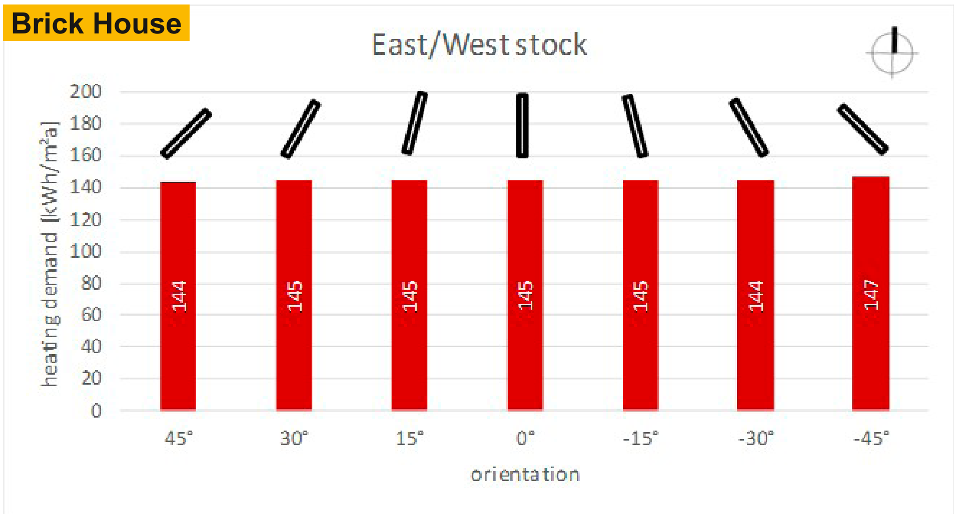


Illustration 29: Heat Demand in a Brick House, North-South Direction, After Reconstruction to Class C

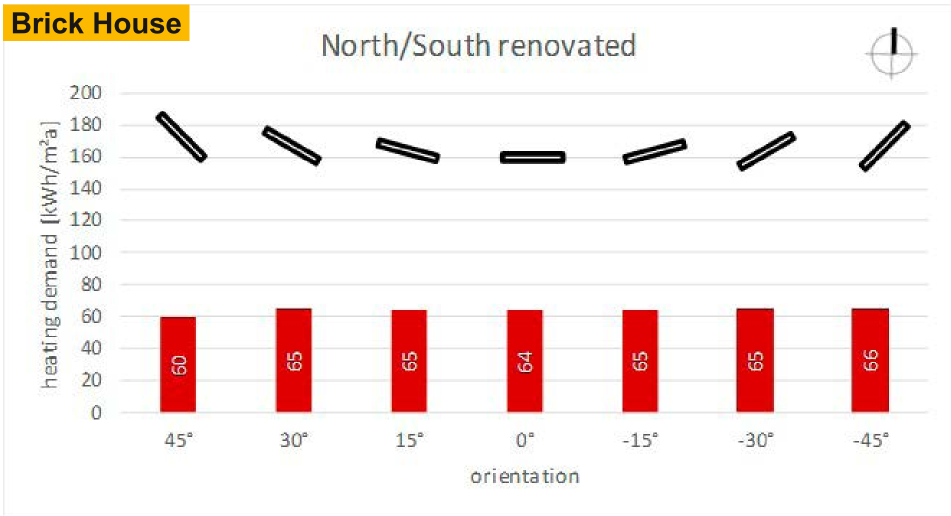


Illustration 30: Heat Demand in a Brick House, East-West Direction, After Reconstruction to Class C

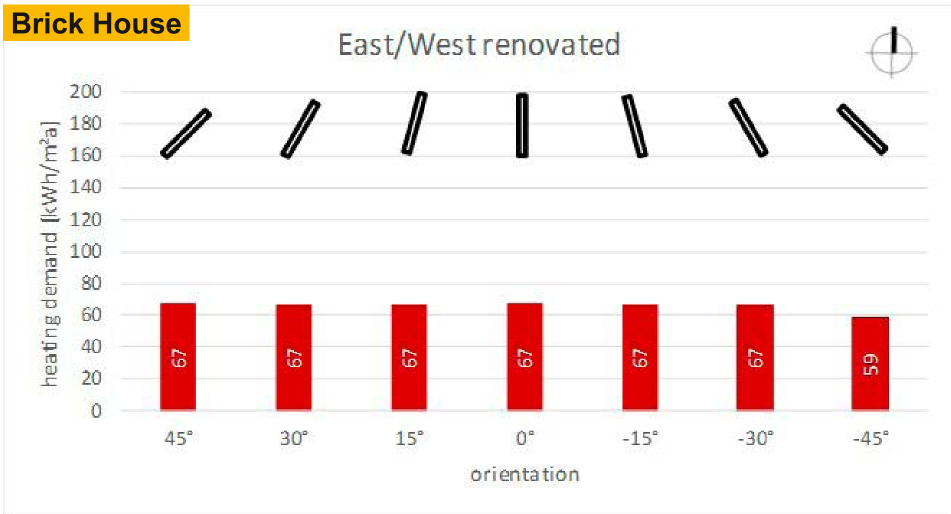


Illustration 31: Heat Demand in a Panel House, North-South Direction, Before Reconstruction

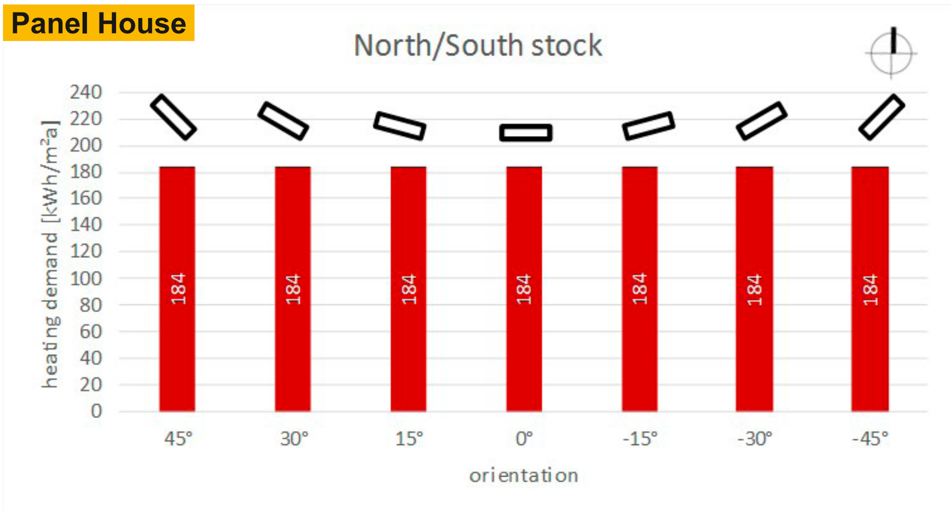


Illustration 32: Heat Demand in a Panel House, East-West Direction, Before Reconstruction

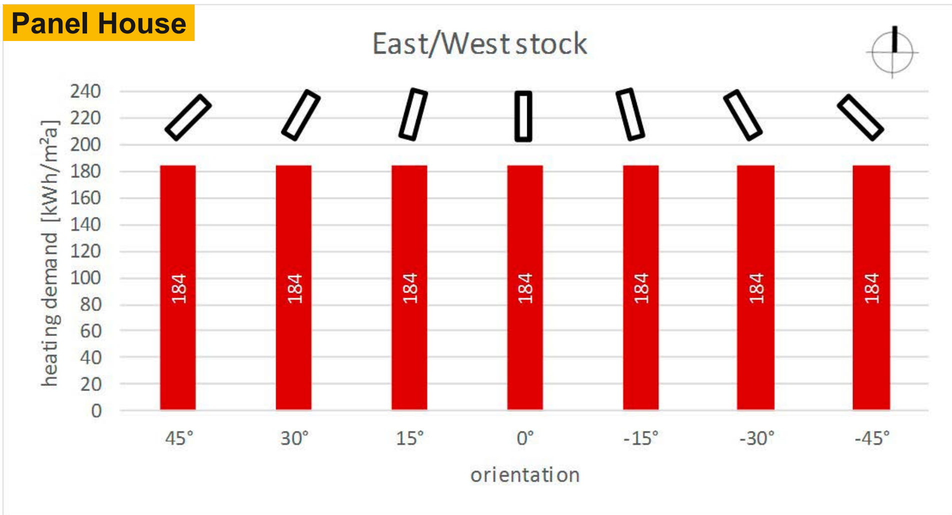


Illustration 33: Heat Demand in a Panel House, North-South Direction, After Reconstruction to Class C

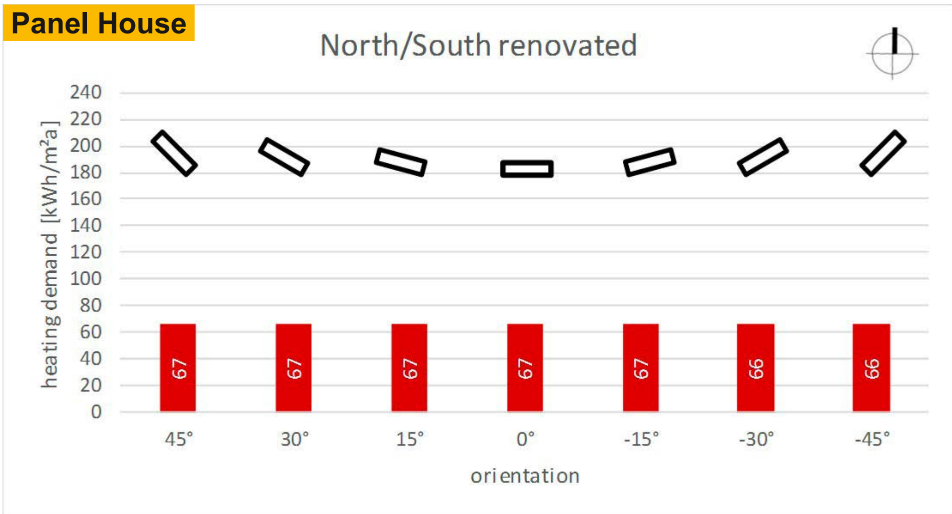
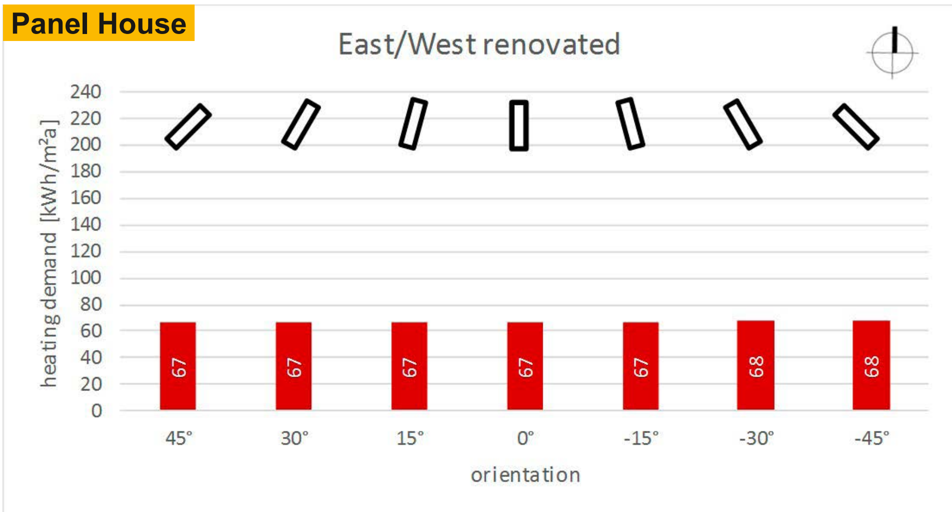


Illustration 34: Heat Demand in a Panel House, East-West Direction, After Reconstruction to Class C



Profitability Analysis Conditions:

building envelope (additional energy costs, net):

Table 2: Building Envelope Costs

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 €

Source: BMVBS

Maintenance and repair approach: 1 % of investment per year

Utility systems:

- Photovoltaic systems with peripheral devices (inverters, cables, wiring): 1,100 euro/kW-peak (net)
- Subsidy: 332 euro/kW-peak (gross)
- Heating, ventilation and air conditioning with heat recovery: 75 euro/m^2 (gross)

Maintenance and repair approach: 1 % of investment per year

Energy Costs:

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

VAT for heating: 9%

Other VAT: 21 %

5. Assessment of the legal and financial environment

5.1. Legal regulations

When faced with the use of solar installations in communities of residential 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 communities of residential 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 the more active 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 the 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 these 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 the community required for issuing a consent for the installation of a solar power plant on the roof or walls of the building that would be used for the electricity purposes of the community members.

From 1 November 2017, such communities can take advantage of the benefits in the laws of the Republic of Lithuania not only for installing a solar power plant, but also the benefits for producing consumers, i.e. the possibility of transferring the unused energy immediately for storage to 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 to the electricity supplier, and then when no or not enough solar energy is produced (at night or during the autumn-winter period), the produced can to recover it. It is true, however, that this service incurs a network maintenance fee set by the National Commission for Energy Control and Prices, which amounts to approximately 4 euro cents including VAT.

The new law on energy partnerships 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 the 'victims' of the binary tariff for heat, while the poorest apartment owners and those affected by energy poverty (those receiving state support) lost out on compensation. This situation requires a more detailed study, but this issue is probably one of the problems that needs 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 shared 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 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 a supply of solar power to the general inlet of the building, and 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 for it 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 the free electricity suppliers. In this case, each member of the building community is free to choose an electricity supplier, and the installation of a total electricity accounting device becomes very problematic, as each supplier of the electricity 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 free 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 by 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, in order to take advantage of a solar plant held in joint ownership, the right to choose a supplier should be restricted even more. Such questions will trigger sharp discussions between lawyers, energy professionals and members of the community, but they should undoubtedly be legally regulated.

The distribution of solar power to individual customers, as well as who must perform that distribution when each consumer has an individual contract with the electricity supplier, would also require legal regulations. The easiest way would be to distribute the generated solar electricity by the 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 would likely to be unacceptable for less energy-consuming families. 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 very 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, which is present 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. But when a total accounting method is applied, dividing the cost of the 'storage' in proportion to electricity consumption has the following effects: for those who use electricity during the daytime, these costs are relatively higher than for those who use electricity in the evening. Thus, while the use of electricity during the daytime should be encouraged more, 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. In this way, if the community does not consume the electricity produced by itself during the 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 possible currently to install a small power plant at a price below 1,000 EUR/kW. If electricity costs more than a dozen cents per kWh, then the payback time for a solar power plant will not be less than 10-15 years. Such a payback time will certainly not be acceptable for many consumers. In order to make this term more attractive, it should not exceed 8 years. Given this scenario, the installation of solar power plants requires investment support of at least 30%. These investments should be included under the most favourable conditions in the renovation programme for apartment buildings. (However, even in this case, the distribution of electricity has problematic nuances, 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 the activities of the 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 $CO2$ emissions by 30 tons per year. In this way, communities of residential homes would make a significant contribution to meeting the country's climate change commitments.

It should also be borne in mind that, even if the community receives 30% support for a typical 60 kW plant, the members of the community would still need to contribute EUR 42,000 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 the right promotional tools, and by such an expansion, the state would save tens of millions of euros while increasing its energy security and independence.

Furthermore, since almost all the required solar energy equipment is produced in Lithuania, the significant development of solar power plants would create hundreds of jobs in the manufacturing companies, as well as in the design, installation and operation companies, and this would make a significant contribution to the development of the Lithuanian economy.

The activities of Lithuanian residential (or energy) communities using solar energy would then be a very significant factor in 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 EUR 17 million are foreseen for the promotion of solar energy for apartment buildings in 2019-2020.

The programme 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 announced 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 from receiving support for a part of the buildings. On the contrary, there are cases where, according to the Government's priorities (after discussing them with the non-governmental sector and business associations), there is a tendency to promote a particular segment of apartment buildings – for example, houses whose renovation possibilities are typically limited (say, in old town areas).
- **Minimised bureaucratic procedures.** Minimised requirements for the applications must be provided by the ministry and the institutions responsible for imple-

menting the possible support programme – otherwise, an over-bureaucratic process will cause many apartment buildings to be reluctant to take up the applications.

- **Complex approach.** Synergistic effects are possible by combining solar energy promotion programmes with the 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-induced pollution problems. Therefore, the Ministry of Energy, together with the Ministry of Environment and the Ministry of Transport and Communications, should provide special measures to promote not only photovoltaic installations, but also the use of the generated electricity for electric car charging. Suppose, for example, that if the installation of a solar power plant is carried out as a separate project without additional elements, the compensation rate is X percent; if additional heat pumps are installed, the compensation rate then 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 (and in the absence of it, from the network) – the amount of the compensation is increased by another 10 percentage points, etc. Such state measures would significantly increase the susceptibility of the producing consumers' ecosystem to future demand-response schemes, as well as promoting the use of electric vehicles to store the reserve energy, and would stabilise the system.

Conclusions

With this study, we wanted to analyse the different factors that will determine solar energy developments in the residential housing market. The residents of apartment buildings in Lithuania are a statistically part of the society in receipt of a lower income, which is heavily influenced by the volatility of the heating, hot water and electricity costs. Lithuania is a country where the majority of people suffer from energy poverty, i.e. they are 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 term 'prosumers' (producing consumers) is gaining popularity worldwide. In Lithuania, the government has been working for years to improve the conditions for producing consumers. The problem of global warming, which is becoming more and more relevant in Lithuania, is also very important.

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% of the investments in power plants.

Based on technical calculations for partial and complete renovations without 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 wishes 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 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 more actively. Stakeholders should therefore be concerned about informing the public and changing the perceived attitudes. Demonstration projects could also contribute to this goal.

The low purchasing power of many residents of apartment buildings leads to increased fear of investing in instruments whose performance and effectiveness are not entirely clear to them. People with lower incomes are not inclined to risk their property, and prefer to use time-tested tools such as window replacements and wall insulation. In addition, the relatively low price of electricity (received from the grid) in Lithuania does not encourage the consumer to become a producer, because the benefits would be insignificant.

We recommend continuing to encourage people to choose renewable energy sources. 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 consumers to become producers.

Acronyms

EED	Energy Efficiency Directive
kWh	Kilowatt-hour
kWp	Peak kilowatt
MFH	Multi-family house. According to Lithuanian laws, a residential building with more than 2 flats is considered to be MFH.
PV	Photovoltaic
RU	Residental Unit
TFA	Total floor area

List of Illustrations