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Lithuanian Case Study

Part I: Lithuanian Case Study approach and analysis of the building initial situation

1. Case Study Approach

Lithuanian case study consists of analysing the energy demand, energy consumption and CO2 emissions of the current situation of the building, as well as proposing alternatives that improve its energy efficiency, of an existing muti-storey dormitory building, located in Vilnius, Lithuania.

The economic cost of the proposed improvements will be studied, as well as the decrease in energy consumption and CO2 equivalent emissions produced by these improvements.

The proposed improvements will be of three types:

- Improving the thermal properties of the building's thermal envelope
- HVAC System Improvements
- Installation of local renewable energy generation systems

2. Description of the dormitory building

2.1. Introduction

Dormitory building is located in Stanevicіaus g. 108, Vilnius, Lithuania

The geographical coordinates of this building are:

Latitude: 54°43'52.7"N

Longitude: 25°15'14.8"E

It is a 5-storey building for residential use. Main entrance (front facade) of the dormitory is located on the East side of the building, facing Stanevičiaus Street. The building occupies a floor area of 600 m2 (40 m x 15 m).

Figure 1: Dormitory building in Vilnius

2.2. Building Plans

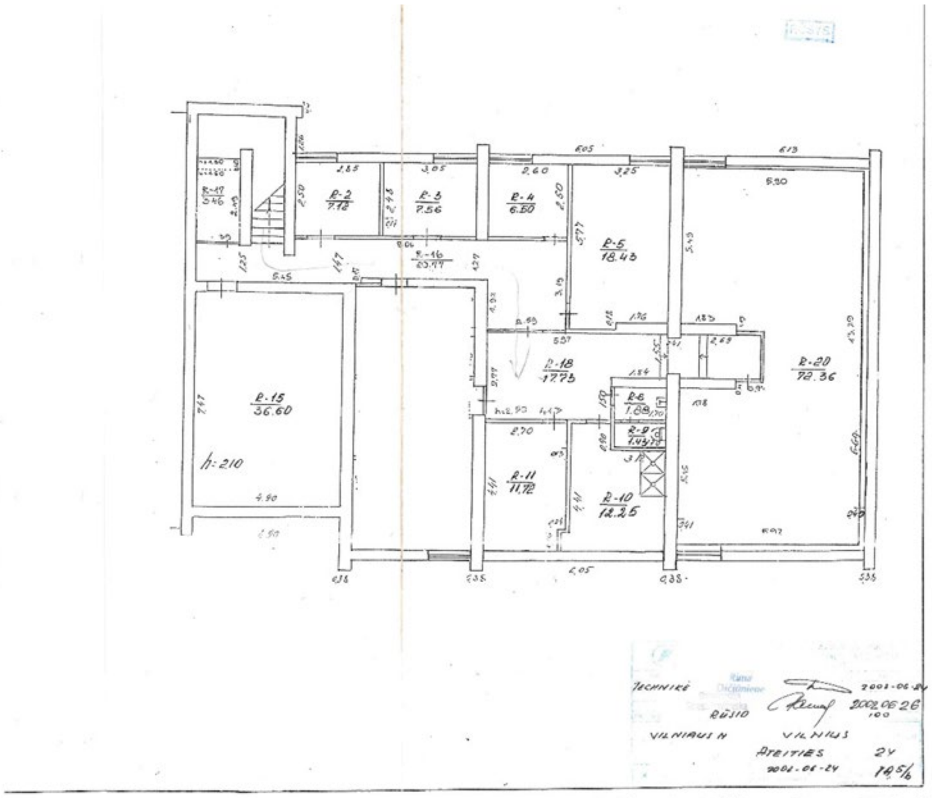


Figure 2 Basement plan**.**

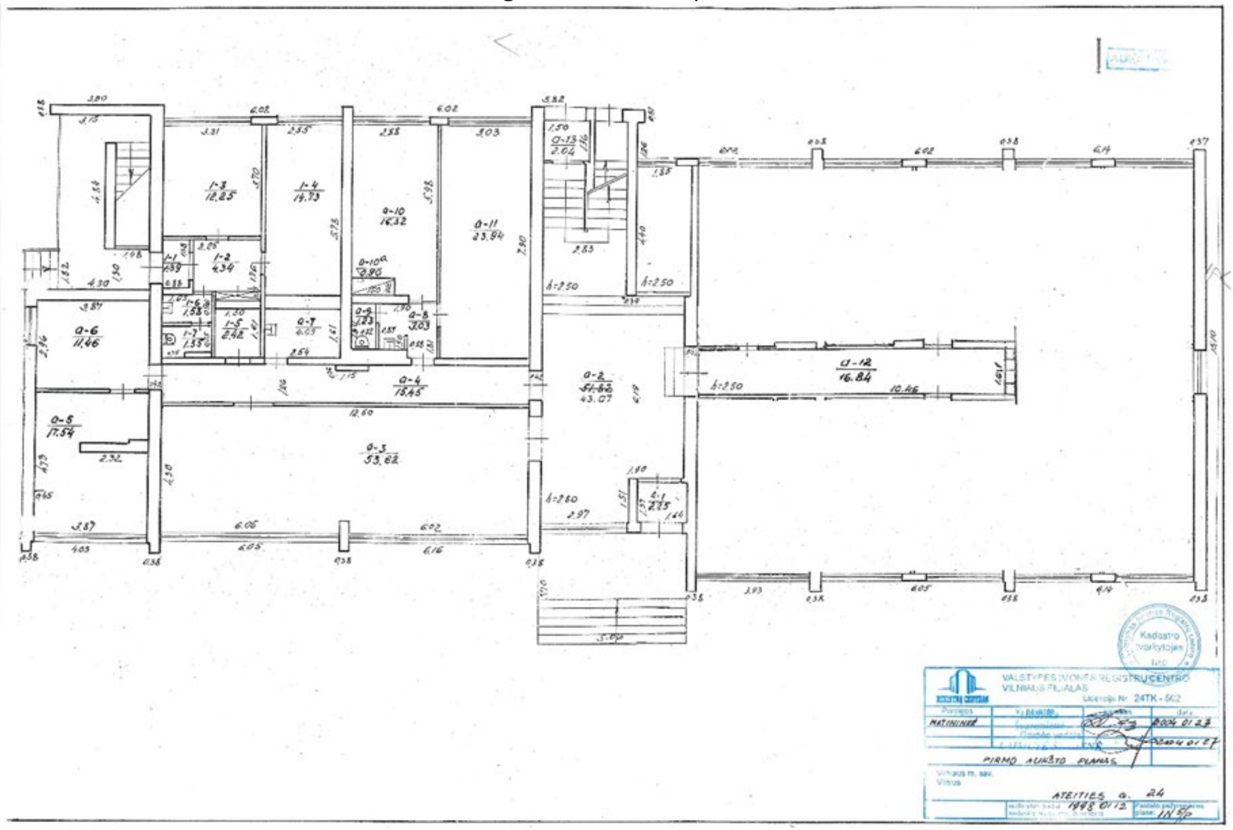


Figure 3 First floor plan (Ground floor).

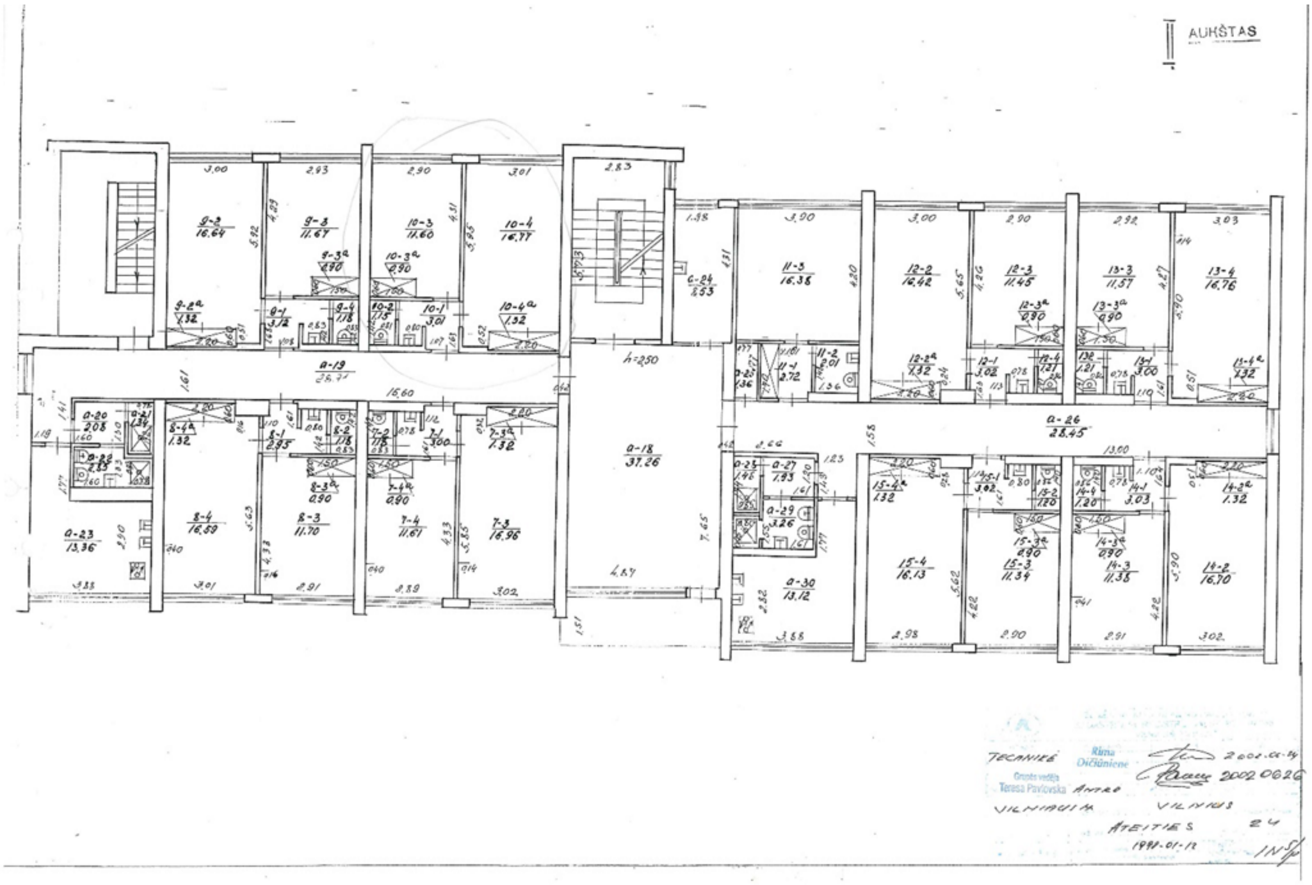


Figure 4 Second floor plan (First floor).

2.3. Thermal Envelope Materials

The thermal envelope of a building refers to the collective system of elements that separate the conditioned interior spaces from the unconditioned exterior environment. It includes exterior walls, roofs, floors (particularly those in contact with unconditioned areas or the ground), as well as windows and exterior doors.

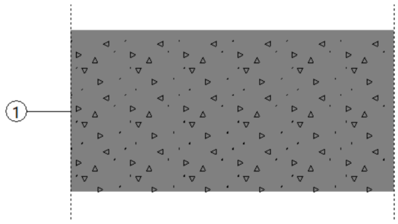
The primary function of the thermal envelope is to regulate the flow of heat, air, and moisture, thereby minimizing heat loss during cold seasons and heat gain during warm seasons. It also reduces air infiltration and exfiltration, contributing significantly to occupant thermal comfort and the overall energy efficiency of the building.

The performance of the thermal envelope is typically evaluated through its thermal resistance (R-value), thermal transmittance (U-value), and airtightness.

A well-designed and properly constructed thermal envelope is essential for achieving high energy performance standards, reducing operational energy costs, and maintaining indoor environmental quality.

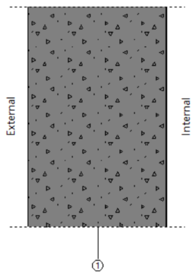
The characteristics of the elements that belong to the thermal envelope of the studied building are described below.

Floors in contact with the ground (screed)



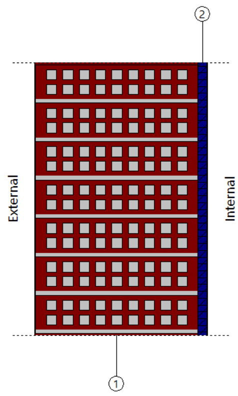
Layers
1 - Concrete. Medium density (density 2200): 30.00 cm Total thickness: 30.00 cm
Thermal description
Thermal resistance: 1.00 (m²·K)/W

Walls in contact with soil



Layers
1 - Concrete. Medium density (density 2200): 38.00 cm Total thickness: 38.00 cm
Thermal description
Thermal resistance: 0.23 (m²·K)/W

Façades



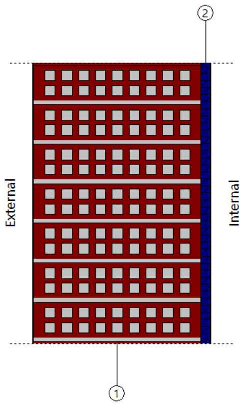
Layers
1 - M01 - 36 mm brick: 36.00 cm 2 - Plaster layer: 2.00 cm Total thickness: 38.00 cm
Thermal description
Heat transfer coefficient (U): 1.46 W/(m²·K) Thermal capacity: 48581.64 J/m²·K

Façade openings

Windows with PVC frame and double glass

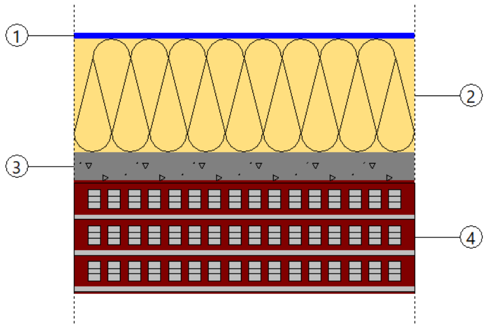
Heat transfer coefficient (U)	2.70	W/(m²·K)
Solar heat gain coefficient	0.70	

Party walls



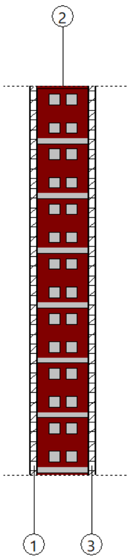
Layers
1 - M01 - 36 mm brick: 36.00 cm
2 - Plaster layer: 2.00 cm
Total thickness: 38.00 cm
Thermal description
Heat transfer coefficient (U): 1.46 W/(m²·K)
Thermal capacity: 48581.64 J/m²·K

roofs



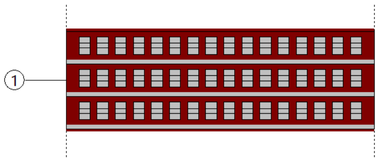
Layers
1 - Bitumen. Pure: 1.00 cm
2 - Mineral Wood Panel: 20.00 cm
3 - Concrete. Reinforced (with 2% of steel): 5.00 cm
4 - Hollow core concrete panels: 20.00 cm
Total thickness: 46.00 cm
Thermal description
Heat transfer coefficient (cooling): 0.15 W/(m²·K)
Heat transfer coefficient (heating): 0.15 W/(m²·K)
Thermal capacity: 11466.66 J/m²·K

Interior partitions



Layers
1 - Gypsum plastering (density 1000): 1.00 cm
2 - Brick wall 8 cm: 8.00 cm
3 - Gypsum plastering (density 1000): 1.00 cm
Total thickness: 10.00 cm
Thermal description
Heat transfer coefficient (U): 1.44 W/(m²·K)
Thermal capacity: 30703.87 J/m²·K

Intermediate slabs



Layers
1 - Hollow core concrete panels -Height 200 mm: 20.00 cm Total thickness: 20.00 cm
Thermal description
Ceiling slab Heat transfer coefficient (cooling): 2.08 W/(m²·K) Heat transfer coefficient (heating): 2.94 W/(m²·K) Floor slab Heat transfer coefficient (cooling): 2.94 W/(m²·K) Heat transfer coefficient (heating): 2.08 W/(m²·K) Floor slab exposed to open air Heat transfer coefficient (cooling): 3.57 W/(m²·K) Heat transfer coefficient (heating): 2.86 W/(m²·K) Thermal capacity: 143863.88 J/m²·K

2.4. Heating and air conditioning systems

The dormitory receives its heat through centralized district heating. Heat is supplied to the dormitory via an automated heat unit (heating control system), which automatically measures the outdoor (outdoor temperature sensor is located on the outside wall of the dormitory building) and indoor temperature. District heating is switched on throughout Lithuania when the average daily outdoor air temperature is at or below 10 °C for 3 continuous days. Analogously, it is switched off when the average daily outdoor temperature is above 10 °C for 3 continuous days.

In Lithuania, air conditioning is not relevant and is not compulsory under the regulatory framework.

The district heating generation/production equipment is located at a distance from the dormitory building (here is no power generation inside the dormitory building), and the heat supply is piped underground via a water Heat Transfer Fluid* (thermofix). Heat consumption regulation to every dormitory (block of apartments) is organized/executed by automatic regulation in substation (which is placed in dormitory basement level). Substation regulates heat consumption, according to weather temperature outside and debit of heat consumption pump.

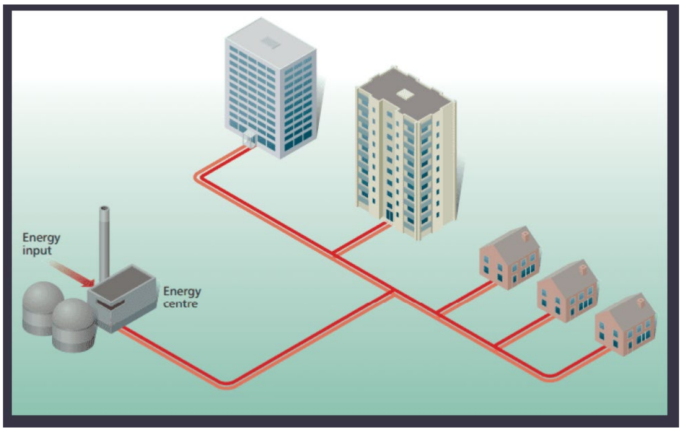
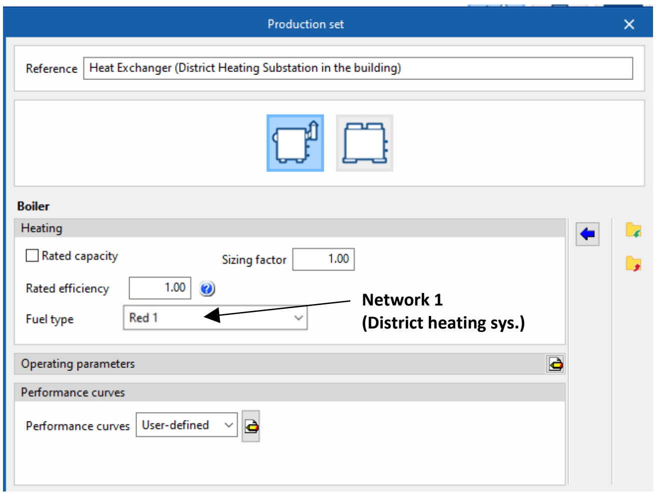
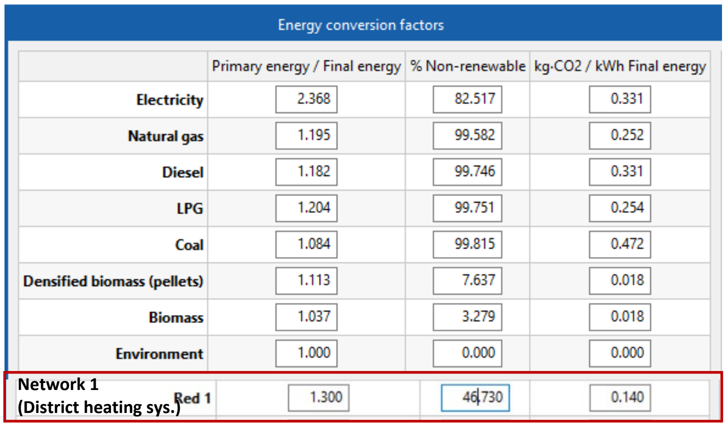


Figure 5: District heating system

Automatic module of heat substation regulates heat consumption by two options:
- by increasing or decreasing amount of Heat Transfer Fluid* to internal heating system of dormitory.
- by increasing or decreasing debit to the internal dormitory heating system.

Figure 6: Heat exchanger plate in substation (at building basement)





Energy conversion factors

	Primary energy / Final energy	% Non-renewable	kg-CO2 / kWh Final energy
Electricity	2.368	82.517	0.331
Natural gas	1.195	99.582	0.252
Diesel	1.182	99.746	0.331
LPG	1.204	99.751	0.254
Coal	1.084	99.815	0.472
Densified biomass (pellets)	1.113	7.637	0.018
Biomass	1.037	3.279	0.018
Environment	1.000	0.000	0.000
Network 1 (District heating sys.) Red 1	1.300	46.730	0.140

Figure 7: Performance parameters of the heat exchanger and the district heating system

2.5. Domestic hot water system

The domestic hot water system consists of a centralized community water heating system of the same type as the district heating system. In the building's energy model, it has been considered that the domestic hot water is supplied by the same network as the district heating system but with **a percentage of losses in distribution of 50%.**

In this study of the Lithuanian building, it has been assumed that the temperature of the water for domestic use in the network, before heating it, is 9 °C .

The occupancy considered in the building for the purposes of calculating the need for domestic hot water has been **180 people** in this case study. Domestic hot water needs: **28 litres per person and per day**.

3. Development of the Lithuanian dormitory building Case Study

3.1. Building BIM model

A **Building Information Model** (BIM) for energy analysis is a digital representation of a building that integrates both geometric and semantic data, enabling detailed simulations of the building's energy performance. Unlike a standard 3D model, a BIM includes information about materials, thermal properties, occupancy schedules, lighting systems, HVAC equipment, and more.

When used for energy analysis, the BIM serves as a data-rich foundation that can be exported to energy simulation software (EnergyPlus in this case study). This allows energy consultants to evaluate heating and cooling loads, daylighting, thermal comfort, and overall energy consumption.

Key benefits include:

- **Automated data transfer** from design to simulation
- **Improved accuracy** due to consistent and detailed inputs
- **Integrated design workflows** between architects, engineers, and energy analysts

The following figures show several views of the building's geometric BIM model.

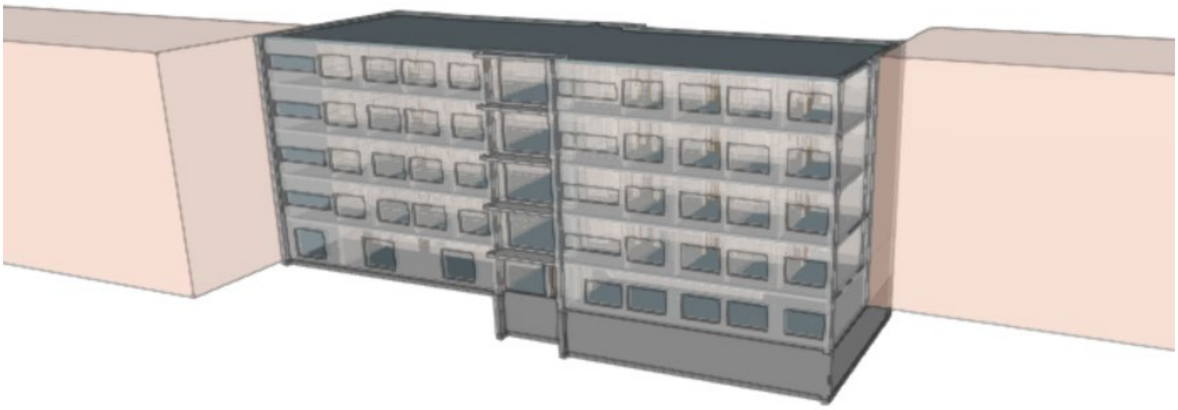


Figure 8 BIM model

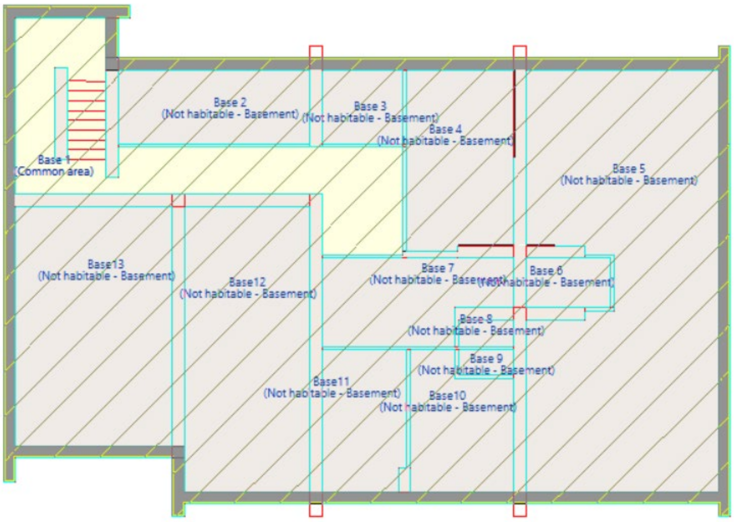


Figure 9 Basement plan in BIM model

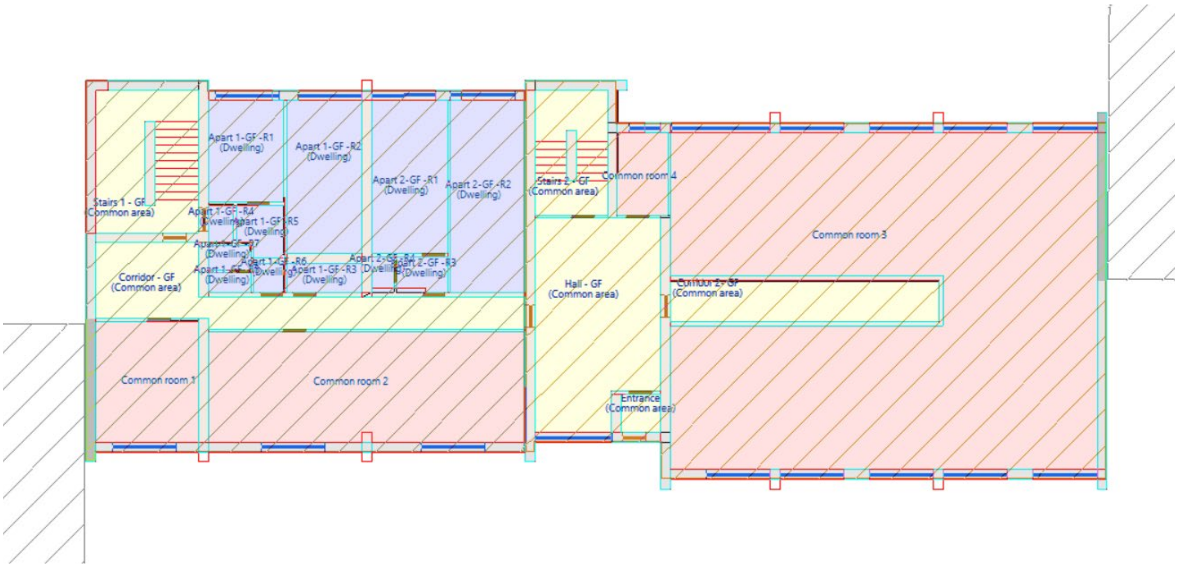


Figure 10 Ground floor in BIM model

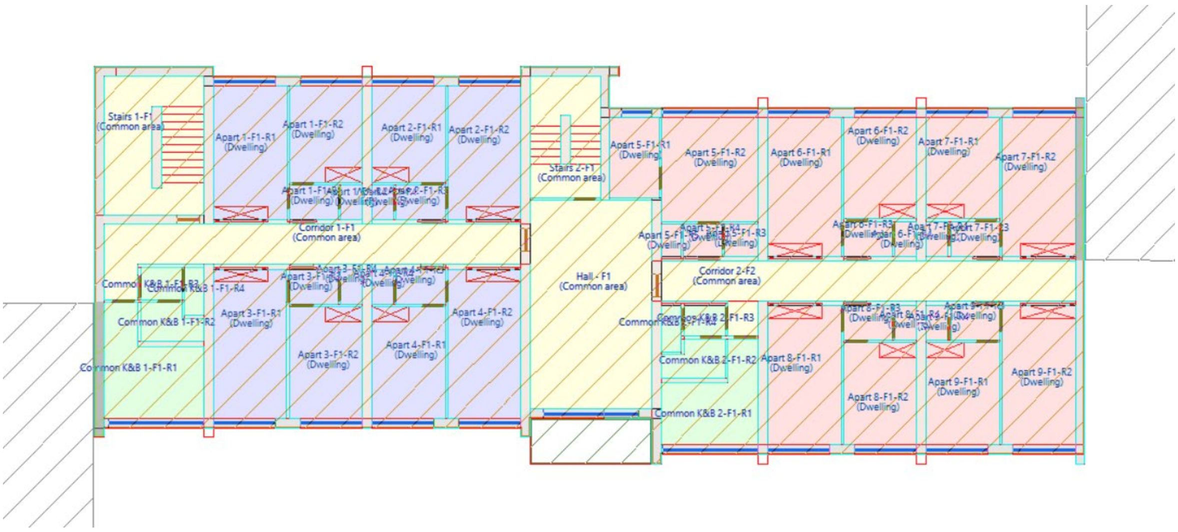


Figure 11 Floor type in BIM model

3.2. Analytical model of the building.

The **analytical model of the building** is made up of the interior spaces of the building into which the interior volume of the building is divided with its characteristics (volume of space, surfaces that eliminate the space...).

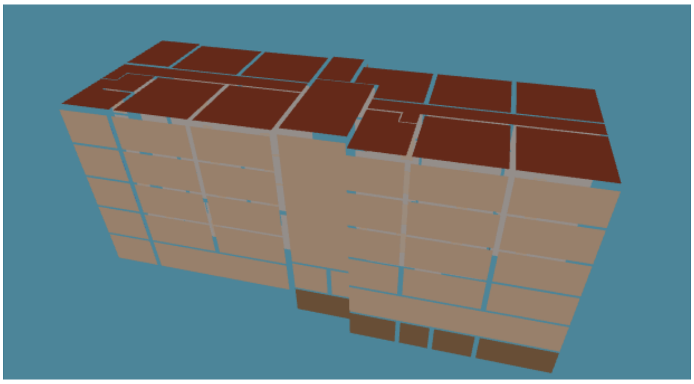


Figure 12 Analytical model of the building

In this work, the interior spaces of the building have been grouped into 16 different zones.

These zones are:

- Z01 - Not habitable
- Z02 - Common areas
- Z03 - Common rooms - GF
- Z04 - Common Kitchen and Bath - F1
- Z05 - Common Kitchen and Bath - F2
- Z06 - Common Kitchen and Bath - F3
- Z07 - Common Kitchen and Bath - F4
- Z08 - Apartments GF
- Z09 - Apartments F1-Left
- Z10 - Apartmente F1 Right
- Z11 - Apartments F2 Left
- Z12 - Apartments F2 Right
- Z13 - Apartments F3 Left
- Z14 - Apartments F3 Right
- Z15 - Apartments F4 Left
- Z16 - Apartments F4 Right

Zone 1 (not habitable) is the basement floor

Zone 2 (common areas) correspond to the spaces of the stairs, the corridors and the halls of every building floor.

Zone 3 (common rooms – GF) is a group of common rooms in the ground floor of the building.

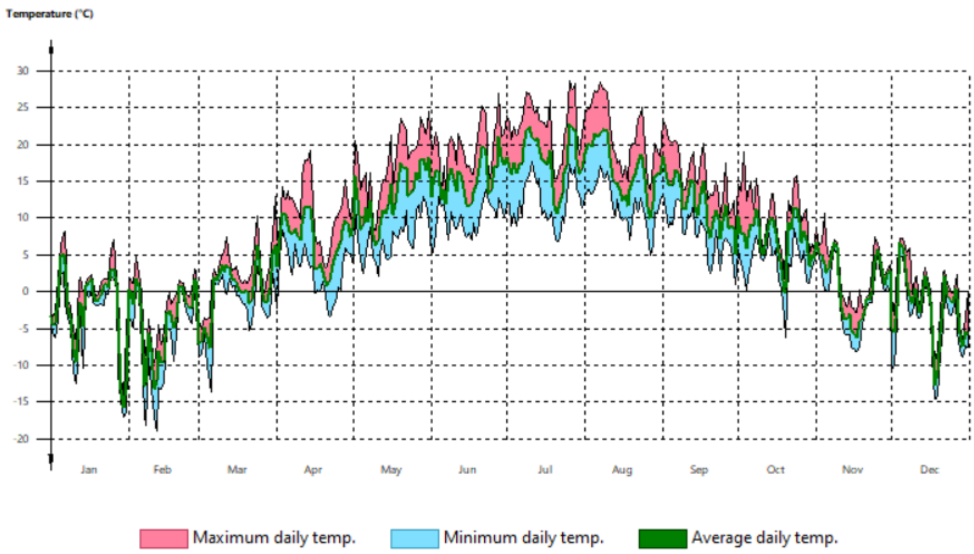
The rest of the areas correspond to groups of apartments on the different floors of the building.

The ventilation of the existing building consists of natural ventilation.

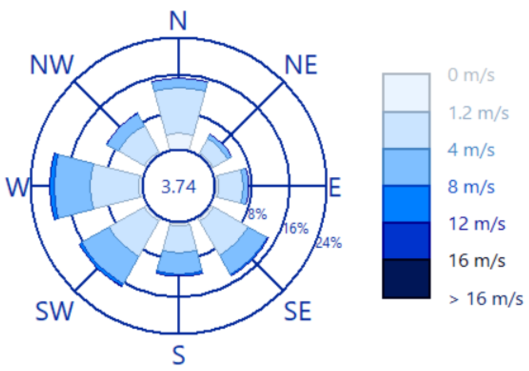
The ventilation needs introduced in the model have been **0.63 interior air renovations per hour** for dwellings, common areas, and kitchens and bathrooms, and 1 renovation per hour for the basement.

3.3. Climatic data

The data of the **outside temperature** considered in this case study in this climatic zone are as follows:
Data from: *LTU_Kaunas.266290_IWEC.epw*

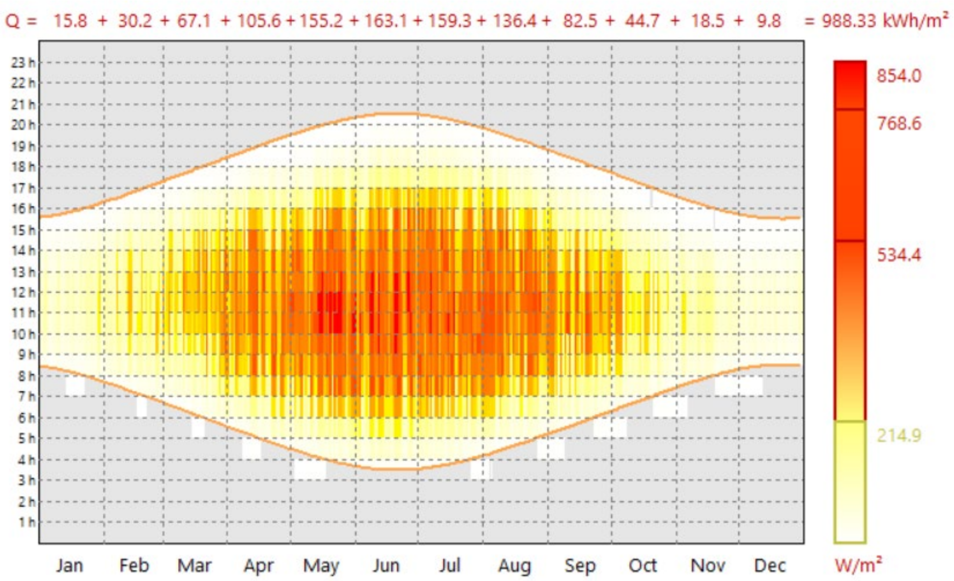


Wind distribution:



Solar irradiation on the site of the house:

The graph below shows the global irradiance on a horizontal surface



3.4. Operational conditions of conditioned spaces for private residential use

For the energy analysis of the building, the operational conditions of the conditioned spaces of the building have been used, which are indicated in the following table.

Table 1: Operational conditions of the conditioned spaces of the building for private residential use

		Schedule (typical week)			
		0:00-6:59	7:00-14:59	15:00-22:59	23:00-23:59
High setpoint temperature (ºC)	January to May	--	--	--	--
	June to September	25	--	25	27
	October to December	--	--	--	--
Low setpoint temperature (ºC)	January to May	17	20	20	17
	June to September	--	--	--	--
	October to December	17	20	20	17

3.5. Building Energy Model

A building energy model is a detailed digital simulation of a building's energy use, created to analyse and predict its energy performance. It includes inputs such as the building's geometry, orientation, construction materials, insulation levels, HVAC systems, lighting, occupancy patterns, and local climate data. The model uses this information to calculate energy consumption for heating, cooling, lighting, ventilation, and plug loads over time.

This model is essential for:

- Evaluating design alternatives
- Estimating energy savings
- Complying with building codes
- Supporting green building certifications (e.g., LEED, BREEAM)
- Performing cost-benefit analysis of energy efficiency measures

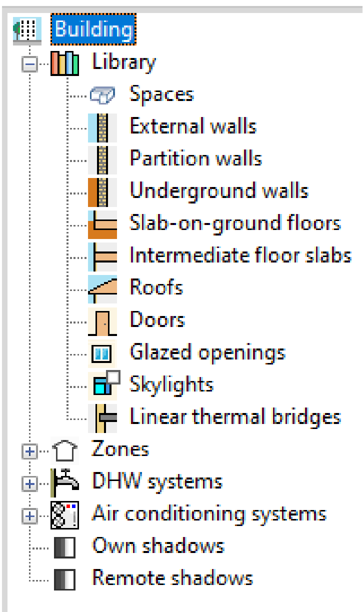


Figure 12: Some components of the Building Energy Model

3.6. Lithuanian dormitory building project in BIMServer.center

The BIM model of the building, the analytical model and the energy model of the current situation of the building are shared on the **BIM platform**. BIMServer.center.

This project can be visited using the following link:

https://bimserver.center/es/project/1007275?tab=0

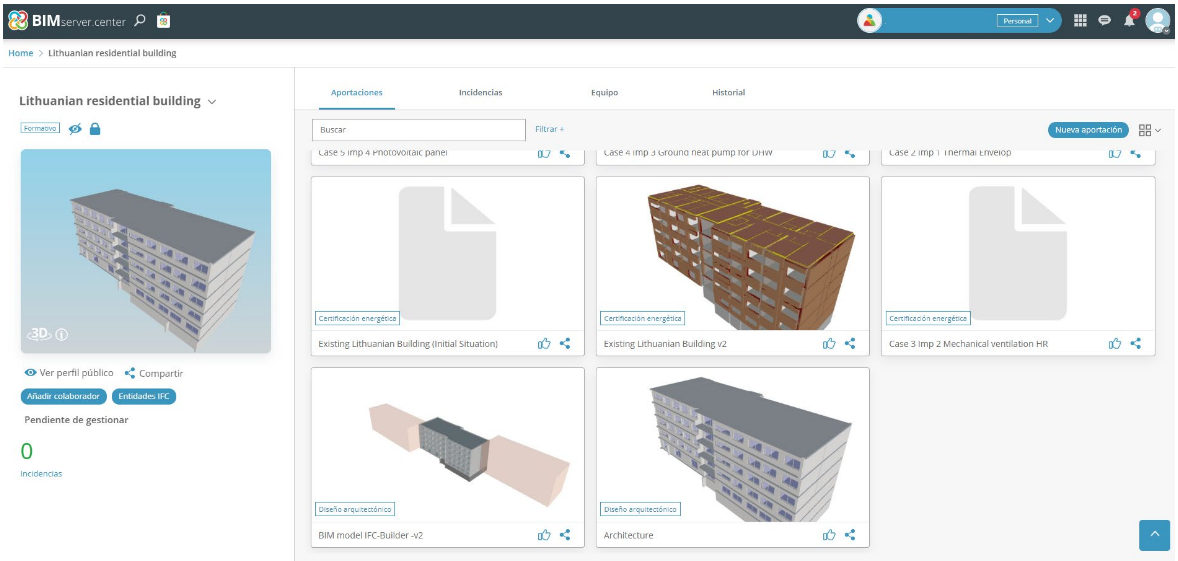
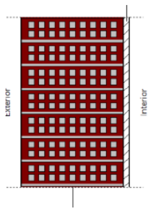


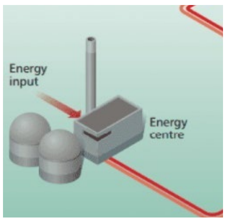
Figure 13: Dormitory building project in BIMServer.center

3.7. Cases analysed. Description

- **Case 1: Initial situation: Façade without isolation + doble glazed windows + Centralized District heating and Centralized District DHW + natural ventilation.**

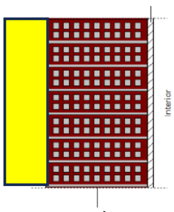


+ Heating & DHW



+ doble-glazed windows (U=2.7 W/m²·K)

- **Case 2: Improvement 1: 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas (U= 0.8 W/m²·K)**



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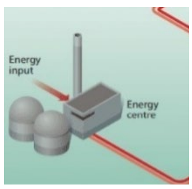
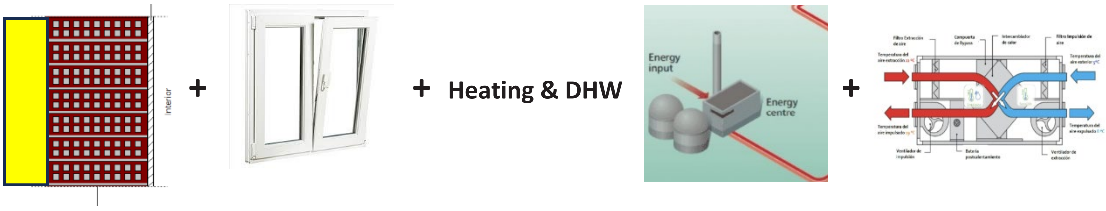
+ Heating & DHW



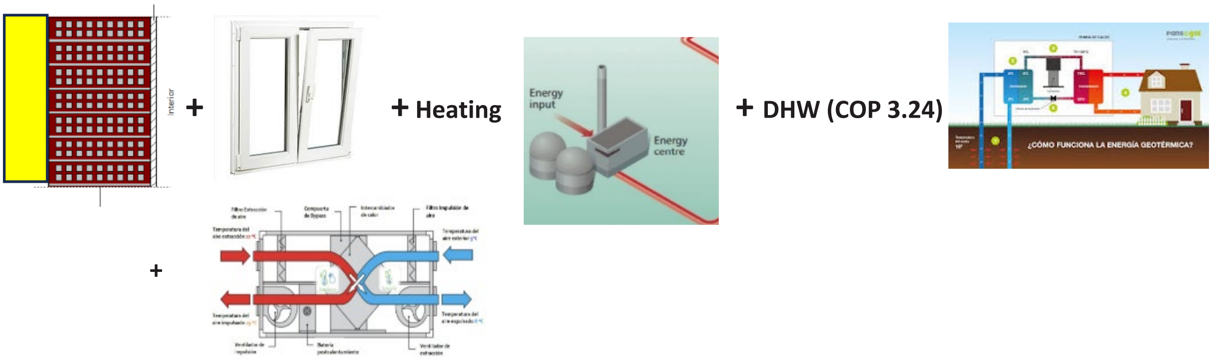
Façade: 20 cm Mineral Wood layer.
Windows: low emissive triple-glazed windows with argon gas and PVC frames (U= 0.8 W/m2·K)

- **case 3: Improvement 2:** 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + **Mechanical ventilation system with heat recovery**

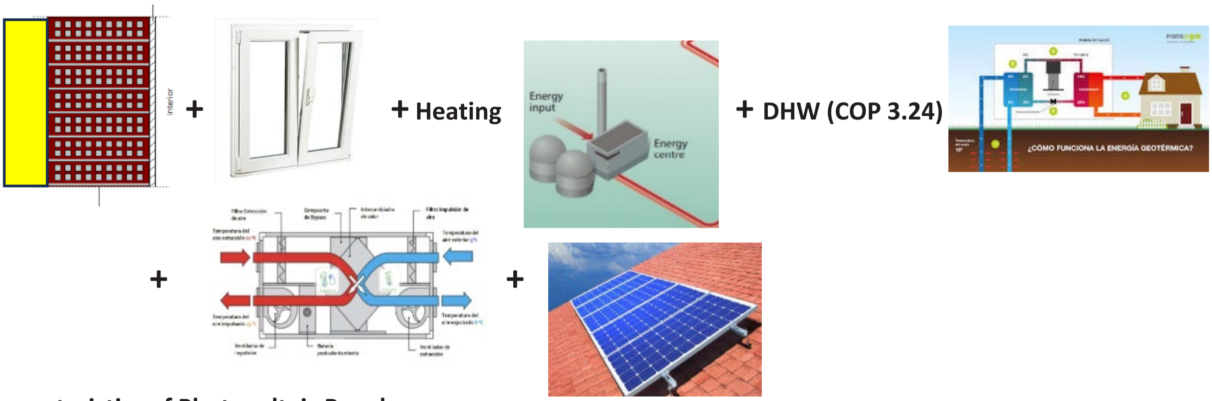


Mechanical ventilation system: 2 Fans (750 W/(m^3/s), each). Sensitive heat exchanger efficiency: 70%

- **Case 4: Improvement 3: DHW with ground heat pump (COP 3.24)** + 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + Mechanical ventilation system with heat recovery.

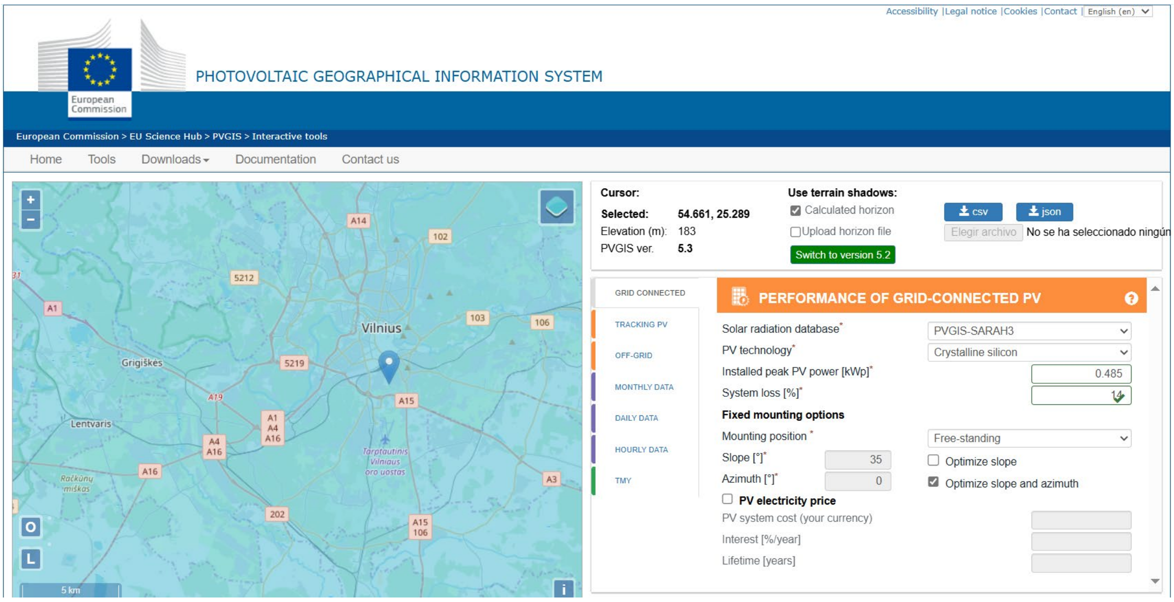


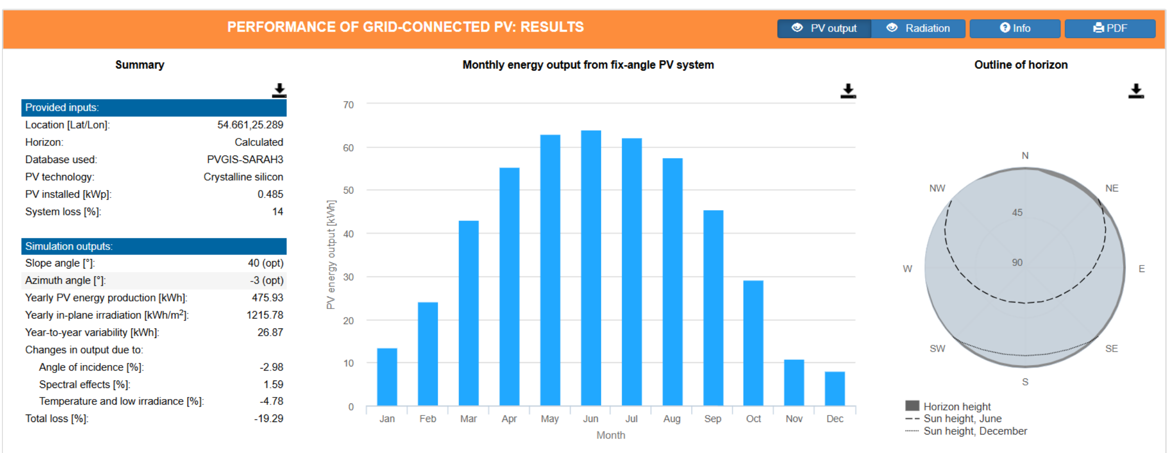
- **Case 5: Improvement 4: Photovoltaic panels (150 panels of 480 W- 3 m2 unit) ➔ (71250 kWh year)** + DHW with geothermal heat pump+ 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + Mechanical ventilation system with heat recovery.



Characteristics of Photovoltaic Panels:

The power of the module is 485W, efficiency – 22.4%.
Size of the panel (module): 3 m^2.
Orientation (azimuth angle) : -3°
Slope angle: 40°





Energy production of the photovoltaic system by month in Vilnius:

	Energy production per panel kwh	Number of panels	Energy production kwh
January	13,57	150	2035,50
February	24,05	150	3607,50
march	42,96	150	6444,00
April	55,27	150	8290,50
may	62,92	150	9438,00
June	64,01	150	9601,50
July	62,07	150	9310,50
August	57,54	150	8631,00
September	45,52	150	6828,00
October	29,07	150	4360,50
November	10,86	150	1629,00
December	8,08	150	1212,00
Total	**475,92**		**71388,00**

3.8. Case Results. Energy Consumption and Energy rating of the existing building.

In this section and in the following one, the annual consumption of final energy, primary energy and non-renewable primary energy corresponding to the different technical services of the building are shown for the initial situation of the building and for the 4 alternatives to improve its energy performance. The consumption of heating and cooling services includes the electricity consumption of the auxiliary equipment of the air conditioning systems.

In addition, the energy rating of the cases studied (initial situation and the 4 improvement alternatives) is also shown. This rating has been calculated following Spanish standards considering its equivalent climate zone: E1

In order to clarify concepts, some definitions are introduced here:

Total primary energy consumption.

Total Primary Energy Consumption in the context of a building energy efficiency analysis refers to the total amount of energy from all sources (like electricity, gas, oil, or renewables) that is required to operate the building, including the energy used to produce and deliver that energy.

More specifically:

- **"Primary energy"** means the energy in its original, raw form—before it is converted into electricity or heat. For example, coal, natural gas, crude oil, or sunlight.
- This includes energy **used on-site** (like gas for heating) and **converted energy** (like electricity), but it also accounts for the **losses that occur during generation, transmission, and distribution**.

So, Total Primary Energy Consumption tells you how much raw energy is ultimately needed to run the building, giving a full picture of its environmental impact.

Primary energy consumption of non-renewable origin.

Primary energy consumption of non-renewable origin refers to the **total amount of non-renewable primary energy** used to operate a building, including:

- **Fossil fuels**: coal, natural gas, and oil
- **Nuclear energy**
- **Any other non-renewable energy sources**

This measurement includes:

- Energy **directly used on-site**, like natural gas for heating
- Energy **used indirectly**, such as electricity generated from coal or gas (including losses from generation and transmission)

Energy consumption at the point of consumption (final energy).

Energy consumption at the point of consumption, also known as **final energy consumption**, refers to the **amount of energy actually used by the building** for its various functions, such as:

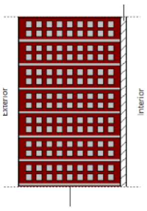
- **Heating**
- **Cooling**
- **Lighting**
- **Hot water**
- **Appliances and equipment**

This is the **energy delivered to the building** and **measured at the meter**, such as electricity bills or gas usage. It **does not include energy losses** that occurred during production, conversion, or transmission (which are included in *primary energy*).

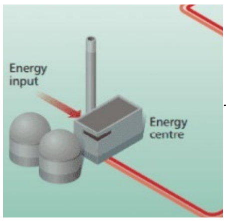
In summary:

- **Final energy** = Energy used **inside the building**, as seen by the user.
- **Primary energy** = Final energy **plus upstream losses** (e.g. power plant efficiency, grid transmission losses).

- **Case 1: Initial situation: Façade without isolation + doble glazed windows + Centralized District heating and Centralized District DHW + natural ventilation.**



+ Heating & DHW



+ doble-glazed windows (U=2.7 W/m²·K)

Energy Consumption of the building: Initial situation.

Energy consumption of the building's technical services

BUILDING (S_u = 2363.76 m²)

Technical Services	EF (kWh/year)	EF (kWh/m²·year)	EP_{tot} (kWh/year)	EP_{tot} (kWh/m²·year)	EP_{nren} (kWh/year)	EP_{nren} (kWh/m²·year)
Heating	292781.52	123.86	418789.87	177.17	225989.72	95.61
Cooling	28.09	0.01	66.19	0.03	54.37	0.02
DHW	163407.07	69.13	212428.82	89.87	99268.50	42.00
	456216.68	193.00	631284.88	267.07	325312.59	137.63

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
BUILDING (S_u = 2363.76 m²)															
Energy demand	**Heating**	**52165.8**	**51779.7**	**42518.5**	**19344.9**	**5454.6**	**--**	**--**	**--**	**--**	**26047.1**	**41740.0**	**52017.3**	**291067.8**	**123.1**
	Cooling	**--**	**--**	**--**	**--**	**--**	**--**	**0.2**	**75.4**	**--**	**--**	**--**	**--**	**75.6**	**0.0**
	DHW	**13878.4**	**12535.3**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**163407.2**	**69.1**
	TOTAL	**66044.2**	**64315.0**	**56396.9**	**32775.6**	**19333.0**	**13430.7**	**13878.6**	**13953.8**	**13430.7**	**39925.5**	**55170.7**	**65895.7**	**454550.6**	**192.3**
Network 1 (Red 1)	**Heating**	46351.1	46018.6	37546.5	16676.3	4530.8	--	--	--	--	22725.0	36966.8	46224.4	257039.5	108.7
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	13878.4	12535.3	13878.4	13430.7	13878.4	13430.7	13878.4	13878.4	13430.7	13878.4	13430.7	13878.4	163407.2	69.1
Electricity	**Heating**	6125.3	6072.3	5212.7	2780.7	976.5	--	--	--	--	3473.7	5007.3	6093.5	35741.9	15.1
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity (Substitution System)	**Heating**	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Cooling	--	--	--	--	--	--	--	28.1	--	--	--	--	28.1	0.0
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**66354.8**	**64626.2**	**56637.5**	**32887.7**	**19385.7**	**13430.7**	**13878.4**	**13906.5**	**13430.7**	**40077.2**	**55404.8**	**66196.3**	**456216.7**	**193.0**

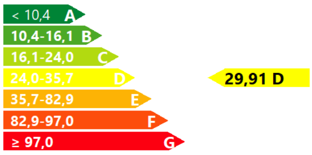
where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Initial situation.

Climatic zone (eq.)	E1	Use	Private residential

1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Heating emissions [kgCO₂/m²·year]	A	DHW emissions [kgCO₂/m²·year]	C
	20.23		9.68	
	COOLING		LIGHTING	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	A	Lighting emissions [kgCO₂/m²·year]	-
	0.00		-	

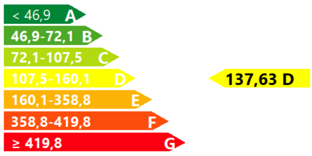
2\. The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2 \cdot year$	$kgCO_2 \cdot year$
CO2 emissions from electricity consumption	5.01	11839.88
CO2 emissions from other fuels	24.90	58862.51

3. ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

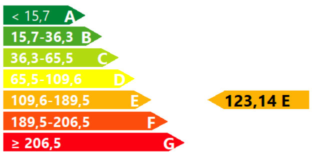
4\.

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Primary energy heating [kWh/m²·year]	A	DHW Primary energy [kWh/m²·year]	E
	95.61		42	
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	A	Primary energy lighting [kWh/m²·year]	-
	0.02		-	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5\.

HEATING DEMAND	COOLING DEMAND
	**Non-Qualifying**
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6\.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

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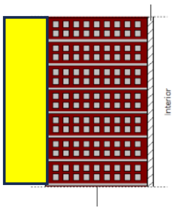
Lithuanian Case Study

Part II: Analysis of improvement measures

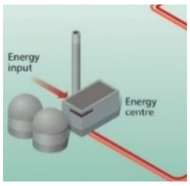
3.9. Case Results II. Energy Consumption and Energy rating of the alternatives to improve the building.

- **Case 2: Improvement 1: 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas (U= 0.8** W/m²·K)



\+

\+ Heating & DHW



Energy consumption of the building's technical services

BUILDING (S_u = 2363.76 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	200814.53	84.96	287076.39	121.45	154795.61	65.49
Cooling	255.00	0.11	605.12	0.26	498.75	0.21
DHW	163407.07	69.13	212428.82	89.87	99268.50	42.00
	364476.60	154.19	500110.34	211.57	254562.86	107.69

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
BUILDING (S_u = 2363.76 m²)															
Energy demand	**Heating**	**30802.2**	**30389.4**	**23188.1**	**7188.8**	**892.3**	**--**	**--**	**--**	**--**	**14109.0**	**23932.2**	**30858.1**	**161360.1**	**68.3**
	Cooling	**--**	**--**	**--**	**--**	**--**	**67.0**	**224.7**	**387.9**	**--**	**--**	**--**	**--**	**679.6**	**0.3**
	DHW	**13878.4**	**12535.3**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**163407.2**	**69.1**
	TOTAL	**44680.6**	**42924.7**	**37066.5**	**20619.5**	**14770.7**	**13497.8**	**14103.1**	**14266.3**	**13430.7**	**27987.4**	**37362.9**	**44736.5**	**325446.8**	**137.7**
Network 1 (Red 1)	**Heating**	33534.1	33179.9	25740.5	8572.9	1367.9	--	--	--	--	14721.0	25809.1	33527.9	176453.3	74.6
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	13878.4	12535.3	13878.4	13430.7	13878.4	13430.7	13878.4	13878.4	13430.7	13878.4	13430.7	13878.4	163407.2	69.1
Electricity	**Heating**	4364.2	4313.9	3605.2	1567.7	385.7	--	--	--	--	2302.3	3473.6	4348.5	24361.2	10.3
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity	**Heating**	--	--	--	--	--	--	--	--	--	--	--	--	--	

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
(Substitution System)	**Cooling**	--	--	--	--	--	18.5	85.5	151.0	--	--	--	--	255.0	0.1
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**51776.7**	**50029.2**	**43224.1**	**23571.3**	**15632.0**	**13449.2**	**13963.9**	**14029.4**	**13430.7**	**30901.7**	**42713.4**	**51754.8**	**364476.6**	**154.2**

where:

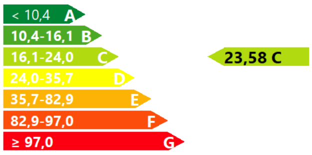
S_u: Living area included in the thermal envelope, m².

$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Improvement 1.

Climatic zone (eq.)	E1	**Use**	Private residential

1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	**PARTIAL INDICATORS**			
	**HEATING**		**DHW**	
	Heating emissions [kgCO₂/m²·year]	**A**	DHW emissions [kgCO₂/m²·year]	**C**
	13.86		**9.68**	
	COOLING		**LIGHTING**	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	**A**	Lighting emissions [kgCO₂/m²·year]	**-**
	0.00		**-**	

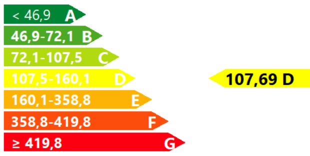
2\. The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2 \cdot year$	**$kgCO_2 \cdot year$**
CO2 emissions from electricity consumption	3.45	8147.96
CO2 emissions from other fuels	20.13	47580.45

3. ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

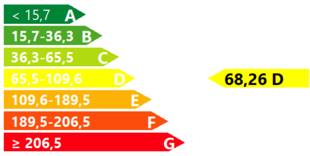
4\.

GLOBAL INDICATOR	**PARTIAL INDICATORS**			
	**HEATING**		**DHW**	
	Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
	65.49		**42**	
	COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
	0.21		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

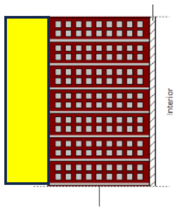
5\.

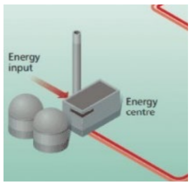
HEATING DEMAND	**COOLING DEMAND**
	**Non-Qualifying**
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

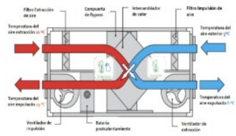
6\.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **case 3: Improvement 2: 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + Mechanical ventilation system with heat recovery**


+

+ Heating & DHW


+


Energy Consumption of the building: Improvement 2.

Energy consumption of the building's technical services

BUILDING (S_u = 2363.76 m²)

Technical Services	EF (kWh/year)	EF (kWh/m²·year)	EP_{tot} (kWh/year)	EP_{tot} (kWh/m²·year)	EP_{nren} (kWh/year)	EP_{nren} (kWh/m²·year)
Heating	119584.90	50.59	170980.28	72.33	92224.49	39.02
Cooling	433.93	0.18	1028.24	0.44	848.59	0.36
DHW	163407.09	69.13	212428.82	89.87	99268.50	42.00
Ventilation	10956.42	4.64	25944.64	10.98	21408.58	9.06
	294382.35	124.54	410381.98	173.61	213750.17	90.43

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
BUILDING (S_u = 2363.76 m²)															
Energy demand	**Heating**	**24288.4**	**24134.4**	**17534.5**	**3449.2**	**125.8**	**--**	**--**	**--**	**--**	**9397.8**	**18295.8**	**24482.1**	**121707.9**	**51.5**
	Cooling	**--**	**--**	**--**	**--**	**--**	**55.3**	**444.8**	**631.7**	**--**	**--**	**--**	**--**	**1131.8**	**0.5**
	DHW	**13878.4**	**12535.3**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**13878.4**	**13430.7**	**13878.4**	**13430.7**	**13878.4**	**163407.2**	**69.1**
	TOTAL	**38166.8**	**36669.7**	**31412.9**	**16879.9**	**14004.2**	**13486.0**	**14323.2**	**14510.1**	**13430.7**	**23276.2**	**31726.5**	**38360.5**	**286246.8**	**121.1**
Network 1 (Red 1)	**Heating**	21224.8	21106.8	15060.6	2564.8	41.7	--	--	--	--	7743.8	15879.6	21412.8	105034.9	44.4
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	13878.4	12535.3	13878.4	13430.7	13878.4	13430.7	13878.4	13878.4	13430.7	13878.4	13430.7	13878.4	163407.2	69.1
Electricity	**Heating**	2780.9	2777.0	2186.8	572.3	37.8	--	--	--	--	1250.5	2137.8	2790.4	14533.5	6.1
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Ventilation	1036.0	935.8	1036.0	1002.6	1036.0	697.2	720.4	720.4	697.2	1036.0	1002.6	1036.0	10956.4 4.6	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity (Substitution System)	**Heating**	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Cooling	--	--	--	--	--	21.3	170.0	242.7	--	--	--	--	433.9	0.2
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**38920.2**	**37362.5**	**32161.8**	**17570.4**	**14994.0**	**14149.2**	**14768.8**	**14841.6**	**14127.9**	**23917.6**	**32450.7**	**39117.7**	**294382.3**	**124.5**

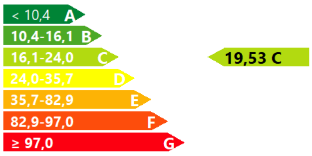
where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Building with improvement 2.

Climatic zone (eq.)	E1	Use	Private residential

1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Heating emissions [kgCO2/m²·year]	A	DHW emissions [kgCO2/m²·year]	C
	8.26		9.68	
	COOLING		LIGHTING	
Global emissions[kgCO2/m²·year][1]	Cooling emissions [kgCO2/m²·year]	A	Lighting emissions [kgCO2/m²·year]	-
	0.00		-	

2.

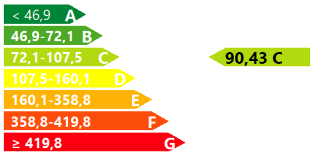
The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2\cdot year$	$kgCO_2\cdot year$
CO2 emissions from electricity consumption	3.63	8580.79
CO2 emissions from other fuels	15.90	37586.01

3. ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Primary energy heating [kWh/m²·year]	A	DHW Primary energy [kWh/m²·year]	E
	39.02		42	
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	A	Primary energy lighting [kWh/m²·year]	-
	0.36		-	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

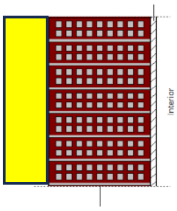
The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

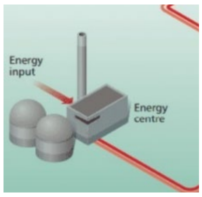
HEATING DEMAND	COOLING DEMAND
	**Non-Qualifying**
6. Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

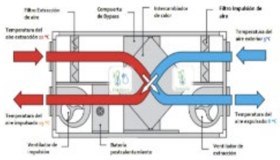
- **Case 4: Improvement 3: DHW with ground heat pump (COP 3.24) + 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + Mechanical ventilation system with heat recovery.**



+

+ Heating


+ DHW (COP 3.24)


+


Energy Consumption of the building: Improvement 3.

Energy consumption of the building's technical services

BUILDING (S_u = 2363.76 m²)

Technical Services	EF		EP$_{tot}$		EP$_{nren}$	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	119614.32	50.60	171037.01	72.36	92267.04	39.03
Cooling	434.13	0.18	1028.24	0.44	848.59	0.36
DHW	114707.05	48.53	170904.64	72.30	80270.95	33.96
Ventilation	10956.42	4.64	25944.64	10.98	21408.58	9.06
	245711.93	103.95	368914.52	156.07	194795.17	82.41

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP$_{tot}$: Total primary energy consumption.
EP$_{nren}$: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
BUILDING (S_u = 2363.76 m²)															
Energy demand	**Heating**	**24283.8**	**24129.9**	**17530.4**	**3447.0**	**125.6**	**--**	**--**	**--**	**--**	**9395.1**	**18292.1**	**24477.7**	**121681.5**	**51.5**
	Cooling	**--**	**--**	**--**	**--**	**--**	**55.4**	**445.0**	**631.9**	**--**	**--**	**--**	**--**	**1132.3**	**0.5**
	DHW	**9742.2**	**8799.4**	**9742.2**	**9428.0**	**9742.2**	**9428.0**	**9742.2**	**9742.2**	**9428.0**	**9742.2**	**9428.0**	**9742.2**	**114707.0**	**48.5**
	TOTAL	**34026.0**	**32929.3**	**27272.7**	**12874.9**	**9867.8**	**9483.4**	**10187.3**	**10374.2**	**9428.0**	**19137.3**	**27720.0**	**34220.0**	**237520.8**	**100.5**
Network 1 (Red 1)	**Heating**	21267.3	21100.7	15054.9	2561.9	41.6	--	--	--	--	7740.1	15874.4	21406.9	105047.8	44.4
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity	**Heating**	2788.8	2778.9	2188.5	573.2	37.8	--	--	--	--	1251.5	2139.3	2792.1	14550.1	6.2
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	3489.0	3151.4	3489.0	3376.5	3489.0	3376.5	3489.0	3489.0	3376.5	3489.0	3376.5	3489.0	41080.5 17.4	
	Ventilation	1036.0	935.8	1036.0	1002.6	1036.0	697.2	720.4	720.4	697.2	1036.0	1002.6	1036.0	10956.4 4.6	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity (Substitution System)	**Heating**	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Cooling	--	--	--	--	--	21.3	170.1	242.8	--	--	--	--	434.1	0.2
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment		--	--	--	--	--	--	--	--	--	--	--	--	--	
		--	--	--	--	--	--	--	--	--	--	--	--	--	
		6253.2	5648.1	6253.2	6051.5	6253.2	6051.5	6253.2	6253.2	6051.5	6253.2	6051.5	6253.2	73626.5	31.1
	$C_{ef,total}$	**34834.4**	**33622.4**	**28021.7**	**13565.6**	**10857.6**	**10146.5**	**10632.8**	**10705.5**	**10125.2**	**19778.8**	**28444.3**	**34977.2**	**245711.8**	**103.9**

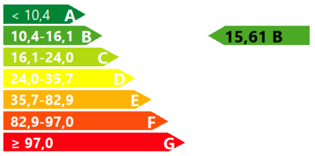
where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Building with improvement 3.

Climatic zone (eq.)	E1	Use	Private residential

1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Heating emissions [$kgCO_2/m^2 \cdot year$] 8.26	A	DHW emissions [$kgCO_2/m^2 \cdot year$] 5.75	C
	COOLING		LIGHTING	
Global emissions[$kgCO_2/m^2 \cdot year$][1]	Cooling emissions [$kgCO_2/m^2 \cdot year$] 0.00	A	Lighting emissions [$kgCO_2/m^2 \cdot year$] -	-

2.

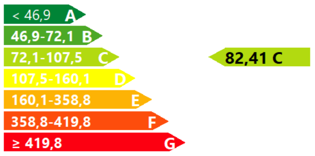
The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2 \cdot year$	$kgCO_2 \cdot year$
CO2 emissions from electricity consumption	9.39	22184.00
CO2 emissions from other fuels	6.22	14710.82

3. ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

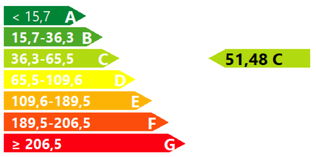
4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
	HEATING		DHW	
	Primary energy heating [$kWh/m^2 \cdot year$] 39.03	A	DHW Primary energy [$kWh/m^2 \cdot year$] 33.96	E
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[$kWh/m^2 \cdot year$][1]	Primary energy cooling [$kWh/m^2 \cdot year$] 0.36	A	Primary energy lighting [$kWh/m^2 \cdot year$] -	-

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

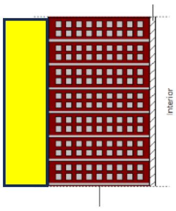
HEATING DEMAND	COOLING DEMAND
	**Non-Qualifying**
Heating demand[$kWh/m^2 \cdot year$]	Cooling demand[$kWh/m^2 \cdot year$]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

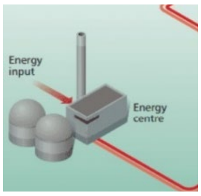
- **Case 5: Improvement 4: Photovoltaic panels (150 panels of 480 W- 3 m2 unit) ➔ (71250 kWh year) + DHW with geothermal heat pump+ 25 cm isolation layer in facades + low emissive triple-glazed windows with argon gas U= 0.8 + Mechanical ventilation system with heat recovery.**

L



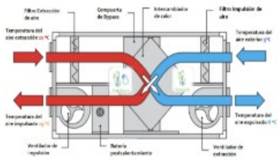
+

+ Heating



+ DHW (COP 3.24)

+



+

Energy Consumption of the building: Improvement 4.

Energy consumption of the building's technical services

BUILDING (S_u = 2363.76 m²)

Technical Services	EF (kWh/year)	EF (kWh/m²·year)	EP_{tot} (kWh/year)	EP_{tot} (kWh/m²·year)	EP_{nren} (kWh/year)	EP_{nren} (kWh/m²·year)
Heating	119958.96	50.75	157892.13	66.80	73054.39	30.91
Cooling	431.18	0.18	619.31	0.26	267.10	0.11
DHW	114707.05	48.53	132517.16	56.06	25438.79	10.76
Ventilation	10956.42	4.64	15704.83	6.64	6783.99	2.87
	246053.61	104.09	306733.43	129.77	105544.29	44.65

where:

S_u: Living area included in the thermal envelope, m².

EF: Final energy consumed by the technical service at the point of consumption.

EP_{tot}: Total primary energy consumption.

EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·year)
BUILDING (S_u = 2363.76 m²)															
Energy demand	**Heating**	**24351.2**	**24196.6**	**17591.8**	**3481.9**	**129.0**	**--**	**--**	**--**	**--**	**9437.9**	**18348.5**	**24543.5**	**122080.3**	**51.6**
	Cooling	**--**	**--**	**--**	**--**	**--**	**54.3**	**441.6**	**628.4**	**--**	**--**	**--**	**--**	**1124.3**	**0.5**
	DHW	**9742.2**	**8799.4**	**9742.2**	**9428.0**	**9742.2**	**9428.0**	**9742.2**	**9742.2**	**9428.0**	**9742.2**	**9428.0**	**9742.2**	**114707.0**	**48.5**
	TOTAL	**34093.4**	**32996.1**	**27334.0**	**12909.9**	**9871.2**	**9482.2**	**10183.9**	**10370.6**	**9428.0**	**19180.1**	**27776.4**	**34285.7**	**237911.5**	**100.6**
Network 1 (Red 1)	**Heating**	21279.0	21160.5	15109.8	2591.7	43.4	--	--	--	--	7777.7	15924.7	21466.0	105352.8	44.6
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity	**Heating**	2790.0	2786.0	2195.1	577.9	39.6	--	--	--	--	1256.3	2145.5	2799.4	14589.8	6.2
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	3489.0	3151.4	3489.0	3376.5	3489.0	3376.5	3489.0	3489.0	3376.5	3489.0	3376.5	3489.0	41080.5	17.4
	Ventilation	1036.0	935.8	1036.0	1002.6	1036.0	697.2	720.4	720.4	697.2	1036.0	1002.6	1036.0	10956.4	4.6
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Electricity (Substitution System)	**Heating**	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Cooling	--	--	--	--	--	20.9	168.8	241.5	--	--	--	--	431.2	0.2
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment		--	--	--	--	--	--	--	--	--	--	--	--	--	
		--	--	--	--	--	--	--	--	--	--	--	--	--	
		6253.2	5648.1	6253.2	6051.5	6253.2	6051.5	6253.2	6253.2	6051.5	6253.2	6051.5	6253.2	73626.5	31.1
	$C_{ef,total}$	**34847.3**	**33689.2**	**28083.2**	**13600.1**	**10861.3**	**10146.0**	**10631.5**	**10704.2**	**10125.2**	**19821.1**	**28500.7**	**35043.7**	**246053.5**	**104.1**

where:

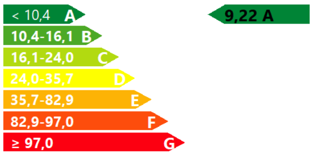
S_u: Living area included in the thermal envelope, m².

$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Building with improvement 4.

Climatic zone (eq.)	E1	**Use**	Private residential

1. **ENERGY RATING OF THE BUILDING IN EMISSIONS**

GLOBAL INDICATOR	PARTIAL INDICATORS			
	**HEATING**		**DHW**	
	Heating emissions [$kgCO_2/m^2 \cdot year$]	**A**	DHW emissions [$kgCO_2/m^2 \cdot year$]	**C**
	6.89		**1.82**	
	COOLING		**LIGHTING**	
Global emissions[$kgCO_2/m^2 \cdot year$][1]	Cooling emissions [$kgCO_2/m^2 \cdot year$]	**A**	Lighting emissions [$kgCO_2/m^2 \cdot year$]	**-**
	0.00		**-**	

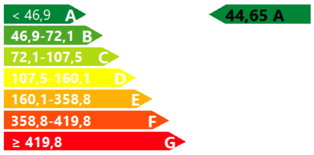
2. The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2 \cdot year$	**$kgCO_2 \cdot year$**
CO2 emissions from electricity consumption	2.98	7034.16
CO2 emissions from other fuels	6.24	14753.51

3. **ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION**

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

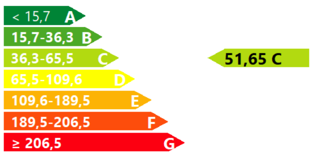
4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
	**HEATING**		**DHW**	
	Primary energy heating [$kWh/m^2 \cdot year$]	**A**	DHW Primary energy [$kWh/m^2 \cdot year$]	**E**
	30.91		**10.76**	
	COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[$kWh/m^2 \cdot year$][1]	Primary energy cooling [$kWh/m^2 \cdot year$]	**A**	Primary energy lighting [$kWh/m^2 \cdot year$]	**-**
	0.11		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

HEATING DEMAND	COOLING DEMAND
	**Non-Qualifying**
6. Heating demand[$kWh/m^2 \cdot year$]	Cooling demand[$kWh/m^2 \cdot year$]

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

3.10. Analysis of Results. Emissions, Energy Consumption and Energy rating of the cases

Comparison of results

Final energy consumption (kWh/m2·year)

Technical Services	Case 1 Initial situation	Case 2 Imp 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+ Imp 3	Case 5 Imp 1+Imp 2+ Imp 3+ Imp 4
Heating	123.86	84.96	50.59	50.60	50.75
Cooling	0.01	0.11	0.18	0.18	0.18
DHW	69.13	69.13	69.13	48.53	48.53
Ventilation	--	--	4.64	4.64	4.64
	193.00	154.19	124.54	103.95	104.09

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope + triple glassed windows

Imp 2- Improvement 2: Mechanical ventilation with heat recovery

Imp 3- Improvement 3: Ground heat pump for DHW

Imp 4 - Improvement 4: Photovoltaic panels

Total primary energy consumption (kWh/m2·year)

Technical Services	Case 1 Initial situation	Case 2 Imp 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+ Imp 3	Case 5 Imp 1+Imp 2+ Imp 3+ Imp 4
Heating	177.17	121.45	72.33	72.36	66.80
Cooling	0.03	0.26	0.44	0.44	0.26
DHW	89.87	89.87	89.87	72.30	56.06
Ventilation			10.98	10.98	6.64
	267.07	211.57	173.61	156.07	129.77

Primary energy consumption of non-renewable origin (kWh/m2·year)

Technical Services	Case 1 Initial situation	Case 2 Imp 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+ Imp 3	Case 5 Imp 1+Imp 2+ Imp 3+ Imp 4
Heating	95.61	65.49	39.02	39.03	30.91
Cooling	0.02	0.21	0.36	0.36	0.11
DHW	42.00	42.00	42.00	33.96	10.76
Ventilation			9.06	9.06	2.87
	137.63	107.69	90.43	82.41	44.65
Energy rating	**D**	**D**	**C**	**C**	**A**

Building Emissions (kgCO2/m2·year)

Technical Services	Case 1 Initial situation	Case 2 Imp 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+ Imp 3	Case 5 Imp 1+Imp 2+ Imp 3+ Imp 4
CO2 from electricity	5.01	3.45	3.63	9.39	2.98
CO2 from other fuels	24.90	20.13	15.90	6.22	6.24
	29.91	23.58	19.53	15.61	9,22
Energy rating	**D**	**C**	**C**	**B**	**A**

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope + triple glassed windows

Imp 2- Improvement 2: Mechanical ventilation with heat recovery

Imp 3- Improvement 3: Ground heat pump for DHW

Imp 4 - Improvement 4: Photovoltaic panels

Erasmus+ Project ID: 2023-1-ES01-KA220-HED-000156652

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Lithuanian Case Study

Part III: Cost-benefit study of energy efficiency measures

3.11. Budget of the improvement alternatives

Improvement 1: Improved thermal envelope + triple glassed windows

Description of the price of the insulation system of the building facades for the exterior:

Item	Cost (€ / m²)
Rock wool insulation (25 cm)	€25
Adhesive, anchors, mesh, profiles	€8
Plaster finish (multi-layer)	€6
Labor (installation)	€15
Scaffolding & safety (5-story building)	€4
Total Estimated Cost (Installed)	**€58 per m²**

Description of the new windows to be installed in the building.

- Glazing: Triple glazing (3 panels)
- Coating: Low-emissivity (Low-E) on at least one pane
- Gas fill: Argon gas between panes (for thermal insulation)
- Frame: uPVC with thermal break
- Installation: Retrofit in existing wall opening (including sealing, trim, disposal of old window)

Improvement 1 budget:

Improvement 1: Thermal envelop isolation and new windows

Unit	Description	n.	measurement	price €	amount €
m2	25 cm mineral wool isolation layer in facades with plaster finish installed	1	900,8	58,00 €	52.246,40 €
m2	Low emissive triple-glazed PVC windows with argon gas (U= 0.8 W/m²·K)	1	407,57	420,00 €	171.179,40 €
				Total	**223.425,80 €**

- Improvement 2: Mechanical ventilation with heat recovery

Technical Specifications of the ventilation system:

Item	Description
Total ventilation capacity required	1.47 m³/s (5,292 m³/h)
System includes	2 fans, 70% heat recovery unit, full ductwork, insulation, controls
Building type	Existing 5-story residential building, 600 m²/floor
Estimated total cost (Lithuania)	€ 42.500,00
Energy savings	~50–60% savings in heating energy vs. simple exhaust system

Improvement 2: Mechanical Ventilation system with heat recovery

Component	Description	Estimated Cost (€)
2 Fans (1.47 m^3/s total, 750 W/(m^3/s))	High-efficiency EC fans, variable speed	4.000,00 €
Heat Recovery Unit (≥70% efficiency)	Sensitive plate or rotary exchanger	6.000,00 €
Ductwork and Air Diffusers (approx. 300 m)	Galvanized steel ducts, dampers, grilles	14.000,00 €
Insulation for ducts	Thermal + acoustic (mandatory for HRV systems)	3.000,00 €
Control system + sensors (CO_2, temp, etc.)	Smart automation, demand control	3.000,00 €
Installation (retrofit complexity)	Cutting, ceiling routing, labor intensive	10.000,00 €
Engineering project & permits	Design, balancing, legal compliance	2.500,00 €
TOTAL ESTIMATED COST	Turnkey mechanical ventilation system	**42.500,00 €**

Improvement 3: Ground heat pump for DHW

Improvement 3: Geothermal heat pump + hot water tanks + boreholes + internal distribution

Component	Description	Estimated Cost (€)
Geothermal Heat Pump (20 kW)	High-efficiency unit for DHW	14.000,00 €
Hot Water Storage Tanks (3000 liters)	Storage for peak demand	6.000,00 €
Vertical Boreholes (4 × 100 m)	Drilling, piping, antifreeze, connection	20.000,00 €
Hydraulic System (pumps, valves, controllers)	Includes expansion tanks, valves, sensors	5.000,00 €
DHW Internal Piping (5-story building)	Insulated pipes, distribution network	10.000,00 €
Installation and Commissioning	Labor, insulation, testing	10.000,00 €
Engineering Project and Permits	Design, documentation, local approvals	3.000,00 €
TOTAL ESTIMATED COST	Complete turnkey system	**68.000,00 €**

Improvement 4: Photovoltaic panels

Technical Specifications of the Photovoltaic panel system:

Location: Lithuania
Building: 5-story existing structure
System Specifications:
- Number of Panels: 150
- Panel Capacity: 480 W each
- Total Capacity: 72 kWp
- Estimated Annual Production: 71,250 kWh

Improvement 4: Photovoltaic panels

Component	Estimated Cost
Total System Capacity	72 kWp
Cost per kWp	€850
Total Installation Cost	**€61,200**

3.12. Cost-benefit study of energy efficiency measures

A cost-benefit analysis (CBA) in the context of building energy renovation is a structured evaluation used to determine whether the investment in upgrading a building's energy performance is economically justified.

It compares all expected costs of the renovation against the financial and non-financial benefits it will generate over the building's lifecycle.

In this case study, the *CypeTherm Impromevent plus* software has been used to perform this analysis.
In this study, two methods have been used to carry out this analysis:

- Simple Payback Period (SPP)
- Net Present Value (NPV)

Method 1: The **Simple Payback Period** is one of the most straightforward methods for evaluating the financial return of an investment in energy efficiency, such as the energy renovation of a building.

The Simple Payback Period (SPP) is the amount of time (typically expressed in years) it takes for the cumulative energy cost savings generated by an investment to equal the initial cost of that investment.

$$\text{SPP} = \frac{\text{Initial Investment Cost}}{\text{Annual Energy Savings}}$$

Method 2: The **Net Present Value** method is one of the most widely used and robust financial tools for evaluating the profitability of an investment over time. In the context of building energy renovation, NPV helps determine whether the long-term energy savings and other benefits outweigh the initial costs of the retrofit.

NPV is the sum of all future cash flows (such as energy savings, maintenance savings, or subsidies), discounted back to their present value, minus the initial investment cost.

It accounts for the time value of money, recognizing that money received (or saved) in the future is worth less than money today.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} - I$$

Where:

- B_t = Benefits (e.g., energy savings) in year *t*
- C_t = Operating or maintenance costs in year *t*
- r = Discount rate (interest rate or cost of capital)
- t = Year (1 to *n*)
- *I* = Initial investment cost
- n = Analysis period (in years)

If NPV > 0 → The investment is profitable

If NPV = 0 → The investment breaks even

If NPV < 0 → The investment is not financially viable

Energy cost considered:

Energy cost

Energy vector		
Electrical grid energy	0.30	EUR/kWh
Natural gas	0.11	EUR/kWh
Diesel	0.10	EUR/kWh
LPG	0.15	EUR/kWh
Carbon	0.05	EUR/kWh
Solid biomass	0.11	EUR/kWh
Biomass	0.11	EUR/kWh
Thermal solar energy	0.00	EUR/kWh
Electrical energy produced by photovoltaic panels, small wind turbines and small hydro turbines	0.00	EUR/kWh

Parameters for the Net present value method:

Net Present Value

☑ NCV calculation method

The program uses the static analysis method to calculate the investment recovery period. By activating this option, the dynamic analysis will be included in the calculation process.

Annual energy cost increase	3.00	%
☑ Discount fee	4.50	%
Foreseen inflation	1.20	%
Nominal interest type	0.00	%
Analysis period	22	Years

Summary of the results of the Cost-Benefit study of energy efficiency measures:

	Net cost of the investment (EUR)	Annual energy cost (EUR)	Annual net savings (EUR)	Payback (year)	NCV (year)	Annual consumption of non-renewable primary energy (kWh/m²)	Emissions (kg CO2/m²)
Initial situation	0.00	56977.73	0.00	0.00	0.00	137.63	29.90
Case 2: Imp 1 Thermal envelope	223425.80	44773.87	12203.86	18.31	20.17	107.70	23.58
Case 3: Imp 2 Mechanical ventilation HR + case 2	265925.80	37311.48	19666.25	13.52	14.72	90.43	19.53
Case 4: Imp 3 Ground heat pump for DHW + case 3	360385.80	31668.47	25309.25	14.24	15.54	82.42	15.60
Case 5: Imp 4 Photovoltaic panel + case 4	395125.80	17973.56	39004.17	10.13	10.86	44.65	9.22

In the table above, the NCV column answers the following question: How many years will it take to recover the investment, considering the time value of money?

	Net investment cost				Annual net savings				Investment recovery period (year)
	Cost (EUR)	Grants (EUR)	Resultant net cost (EUR)	Difference (EUR)	Energy cost (EUR/year)	Energy savings (EUR/year)	Maintenance (EUR/year)	Net savings (EUR/year)	
Initial situation	0.00	0.00	0.00	0.00	56977.73	0.00	0.00	0.00	0.00
Case 2: Imp 1 Thermal envelope	223425.80	0.00	223425.80	223425.80	44773.87	12203.86	0.00	12203.86	18.31
Case 3: Imp 2 Mechanical ventilation HR + case 2	265925.80	0.00	265925.80	265925.80	37311.48	19666.25	0.00	19666.25	13.52
Case 4: Imp 3 Ground heat pump for DHW + case 3	360385.80	0.00	360385.80	360385.80	31668.47	25309.25	0.00	25309.25	14.24
Case 5: Imp 4 Photovoltaic panel + case 4	395125.80	0.00	395125.80	395125.80	17973.56	39004.17	0.00	39004.17	10.13

4. Conclusions

The following conclusions can be drawn from this study:

- **Comprehensive Building Assessment Completed**. The case study thoroughly evaluated the current energy performance of a multi-story dormitory building in Lithuania, using BIM technologies, identifying major inefficiencies in envelope insulation, window performance, DHW systems, and ventilation. The building was characterized by high energy consumption and poor thermal comfort, especially during the heating season.
- **Energy Efficiency Measures Identified and Modeled.** A wide range of energy renovation measures were proposed and simulated, including:
  - External wall insulation. (The roof was already isolated in 2014)
  - Replacement of windows.
  - Domestic hot water system modernization (by mean of ground heat pump system)
  - Mechanical ventilation with heat recovery
  - Integration of rooftop photovoltaic (PV) panels
- **Substantial Energy and CO_2 Savings Potential.** The analysis showed that implementing a combination of passive and active measures could reduce non-renewable primary energy consumption by more than 67% and CO_2 emissions by over 70%. These savings are particularly significant given Lithuania's cold climate and long heating season.
- **Cost-Benefit Results Vary by Measure.** The financial assessment revealed that:
  - Deep renovation strategies (insolation, window replacement) require higher investment but offer long-term returns.
  - DHW system modernization and the new mechanical ventilation reduce energy losses due to the old existing systems.
  - PV panels contribute significantly to decarbonization goals.
  - If all the measures considered in the study are implemented, the payback period is considerably reduced (10 years) since greater energy savings are achieved.
- **Combination of Measures Yields Best Results.** The most balanced and sustainable outcome is achieved by combining passive improvements (insulation, airtightness) with active systems (modern

DHW system and ventilation system, PV panels). This synergy maximizes energy savings keeping indoor comfort, and enhances the building's overall value.

- **Technical and Economic Feasibility Confirmed.** Despite initial investment barriers, the study confirms that energy renovation is technically viable and economically beneficial for the dormitory. Using metrics such as NPV and SPP, all measures show acceptable economic performance, especially if they are implemented at the same time.
- **Supports National and EU Renovation Goals.** The case aligns with the EU's Green Deal and Renovation Wave strategy, contributing to targets for carbon neutrality, energy efficiency, and healthier indoor environments in public and residential buildings.