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Romanian Case Study

Part III: Cost-benefit study of energy efficiency measures

1. Budget of the improvement alternatives

Improvement 1: Improved envelope (insulating the exterior walls with 15 cm mineral wool, the upper floor with 30 cm mineral wool and insulating the slab floors with 10 cm extruded polystyrene, triple glazed windows (U=0.8 W/m²K), air-water heat pump, mechanical ventilation, underfloor heating

- Description of the price

Item	Cost (€ / m²)
10 cm extruded polystyrene insulation	€12.4
30 cm mineral wool insulation	€7.5
15 cm mineral wool wall insulation	€20.4
Triple glazed Windows	€290
Total Estimated Cost (Installed)	**330 €/ m²**

Improvement 1 budget:

Unit	Description	n.	measurement	price €	amount €
m2	10 cm extruded polystyrene insulation for the slab floors	1	407	12.4	5050
m2	30 cm mineral wool for the upper floor	1	460	7.5	3450
m2	15 cm mineral wool for insulating the exterior walls	1	260	20.4	5300
m2	Triple-glazed PVC windows (U= 0.8 W/m²·K)	1	63	290	18400
m2	Aluminium doors	1	12	350	4200
	Heat pump air-water 23 kW	1	1	11000	11000
	Boiler 100l	1	1	300	300

	Complete heating system (underfloor system)	1	1	28000	28000
	Ventilation system (3 ventilation units)	1	3	3200	9600
				Total	**85300 €**

Improvement 2: Improved envelope (insulating the exterior walls with 10 cm mineral wool, the upper floor with 20 cm mineral wool and insulating the slab floors with 8 cm extruded polystyrene, triple glazed windows), air-water heat pump, mechanical ventilation, underfloor heating

- Description of the price

Item	**Cost (€ / m²)**
8 cm extruded polystyrene insulation	€9,92
20 cm mineral wool insulation	€5
10 cm mineral wool wall insulation	€13.5
Triple glazed Windows	€290
Total Estimated Cost (Installed)	**319 €/ m²**

Improvement 1 budget:

Unit	**Description**	**n.**	**measurement**	**price €**	**amount €**
m2	8 cm extruded polystyrene insulation for the slab floors	1	407	9,92	4040
m2	20 cm mineral wool for the upper floor	1	460	5	2300
m2	10 cm mineral wool for insulating the exterior walls	1	260	13.5	3550
m2	Triple-glazed PVC windows (U= 0.8 W/m²·K)	1	63	290	18400
m2	Aluminium doors	1	12	350	4200
	Heat pump air-water 23 kW	1	1	11000	11000
	Boiler 100l	1	1	300	300
	Complete heating system (underfloor system)	1	1	28000	28000
	Ventilation system (3 ventilation units)	1	3	3200	9600
				Total	**81390 €**

Improvement 3: Improved envelope (insulating the exterior walls with 15 cm mineral wool, the upper floor with 30 cm mineral wool and insulating the slab floors with 10 cm extruded polystyrene, triple glazed windows (U=0.8 W/m²K), water-water heat pump, mechanical ventilation, underfloor heating

- Description of the price

Item	Cost (€ / m²)
10 cm extruded polystyrene insulation	€12.4
30 cm mineral wool insulation	€7.5
15 cm mineral wool wall insulation	€20.4
Triple glazed Windows	€290
Total Estimated Cost (Installed)	**330 €/ m²**

Improvement 1 budget:

Unit	Description	n.	measurement	price €	amount €
m2	10 cm extruded polystyrene insulation for the slab floors	1	407	12.4 €	5050 €
m2	30 cm mineral wool for the upper floor	1	460	7.5	3450
m2	15 cm mineral wool for insulating the exterior walls	1	260	20.4	5300
m2	Triple-glazed PVC windows (U= 0.8 W/m²·K)	1	63	290	18400
m2	Aluminium doors	1	12	350	4200
	Heat pump water-water 24 kW	1	1	13900	13900
	Boiler 100l	1	1	300	300
	Complete heating system (underfloor system)	1	1	28000	28000
	Ventilation system (3 ventilation units)	1	3	3200	9600
				Total	**88200 €**

Improvement 4: **Improved envelope (insulating the exterior walls with 10 cm mineral wool, the upper floor with 20 cm mineral wool and insulating the slab floors with 8 cm extruded polystyrene, triple glazed windows), water-water heat pump, mechanical ventilation, underfloor heating**

- Description of the price

Item	Cost (€ / m²)
8 cm extruded polystyrene insulation	€9,92
20 cm mineral wool insulation	€5
10 cm mineral wool wall insulation	€13.5
Triple glazed Windows	€290
Total Estimated Cost (Installed)	**319 €/ m²**

Improvement 1 budget:

Unit	Description	n.	measurement	price €	amount €
m2	8 cm extruded polystyrene insulation for the slab floors	1	407	9,92	4040
m2	20 cm mineral wool for the upper floor	1	460	5	2300
m2	10 cm mineral wool for insulating the exterior walls	1	260	13.5	3550
m2	Triple-glazed PVC windows (U= 0.8 W/m²·K)	1	63	290	18400
m2	Aluminium doors	1	12	350	4200
	Heat pump water-water 24 kW	1	1	13900	13900
	Boiler 100l	1	1	300	300
	Complete heating system (underfloor system)	1	1	28000	28000
	Ventilation system (3 ventilation units)	1	3	3200	9600
				Total	**84290 €**

2. 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.

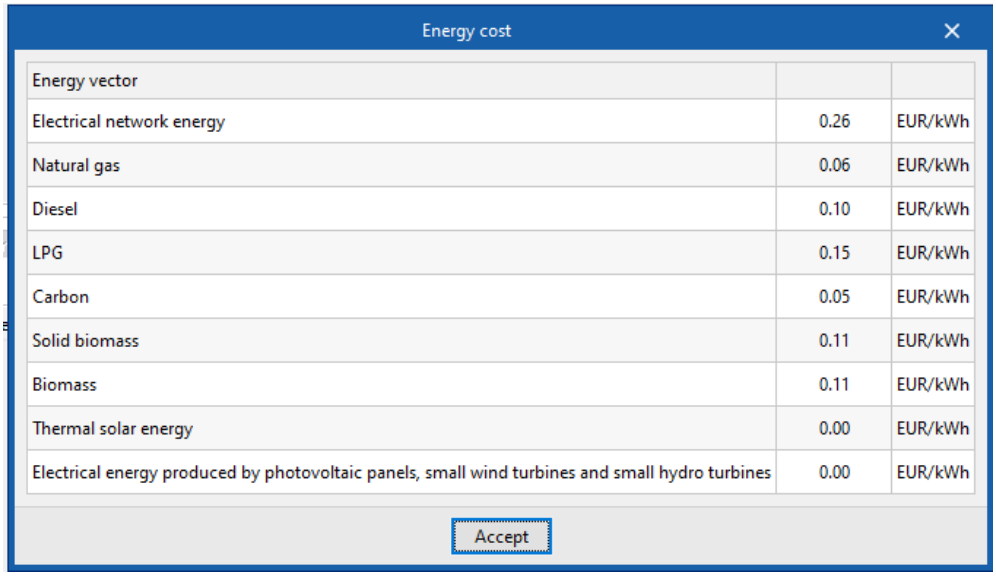
$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} - I$$

Where:

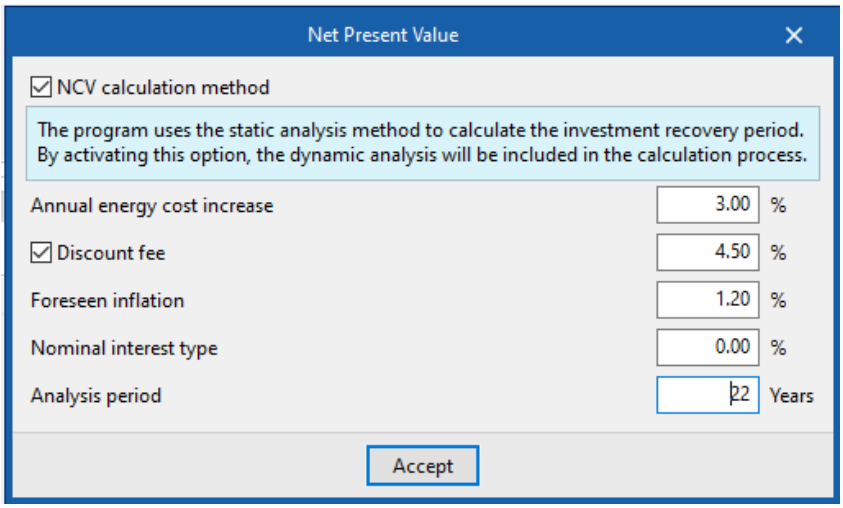
- Bt = Benefits (e.g., energy savings) in year t
- Ct = Operating or maintenance costs in year t
- r = Discount rate (interest rate or cost of capital)
- t = Year (1 to n)
- I = Initial investment cost
- n = Analysis period (in years)

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:



Parameters for the Net present value method:



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)
Case 0 (initial situation)	0.00	16504.43	0.00	0.00	0.00	187.96	34.70
Case 1	85300.00	9757.83	6746.60	12.64	13.72	264.23	55.38
Case 2	81390.00	9694.97	6809.46	11.95	12.93	261.92	54.76
Case 3	88200.00	9392.78	7111.64	12.40	13.44	250.75	51.82
Case 4	84290.00	9694.97	6809.46	12.38	13.42	261.92	54.76

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)	
Case 0 (Initial situation)	0.00	0.00	0.00	0.00	16504.43	0.00	0.00	0.00	0.00
Case 1	85300.00	0.00	85300.00	85300.00	9757.83	6746.60	0.00	6746.60	12.64
Case 2	81390.00	0.00	81390.00	81390.00	9694.97	6809.46	0.00	6809.46	11.95
Case 3	88200.00	0.00	88200.00	88200.00	9392.78	7111.64	0.00	7111.64	12.40
Case 4	84290.00	0.00	84290.00	84290.00	9694.97	6809.46	0.00	6809.46	12.38

3. Conclusions

The following conclusions can be drawn from this study:

- **Comprehensive Building Assessment Completed**. The case study thoroughly evaluated the current energy performance of an educational building in Romania, using BIM technologies, identifying major inefficiencies in envelope insulation, window performance, heating 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 Modelled.** A wide range of energy renovation measures were proposed and simulated, including:
  - External wall/roof/floor slab insulation.
  - Replacement of windows with triple glazed.
  - Heating system modernization (by mean of air or water heat pump system and underfloor heating system)
  - Mechanical ventilation with heat recovery
- **Substantial Energy Savings Potential.** The analysis showed that implementing a combination of passive and active measures could reduce the primary energy consumption for heating by 70%. These savings are particularly significant given Romania'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.
  - Heating system modernization and the new mechanical ventilation reduce energy consumption.
  - If all the measures considered in the study are implemented, the payback period is considerably reduced (12 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 heating system and ventilation system). 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 building. 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.