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Spanish Case Study

Part III: Cost-benefit study of energy efficiency measures

3.11. Budget of the improvement alternatives

Improvement 1: Improved thermal envelope (6 cm mineral wool) + double glassed windows

- Description of the price of the **6 cm insulation system of the building facades for the exterior**:

Item	Cost (€ / m²)
Rock wool insulation (6 cm)	€20
Adhesive, anchors, mesh, profiles	€18
Plaster finish (multi-layer)	€12
Labor (installation)	€25
Scaffolding & safety (Single family house)	€9
Waste management and final cleaning	€2
Total Estimated Cost (Installed)	**86 €/ m²**

- Budget – **Interior Insulation on Party Walls, Roof or ground floor slab with Drywall System**

No.	Item	Description	Unit	Max. Price €/m²
1	Surface Preparation	Cleaning and preparing the existing wall or roof surface	m²	4,00
2	Rock Wool Insulation (6 cm)	Supply and installation of 60 mm rock wool panels between metal studs	m²	10,00
3	Metal Stud Framing	Installation of galvanized steel studs and tracks	m²	8,00
4	Drywall Cladding (Plasterboard)	Installation of 12.5 mm standard gypsum board over frame	m²	9,00
5	Joint Finishing and Surface Prep	Taping, joint compound, sanding	m²	5,00
6	Labor (if not included above)	General skilled labor for installation tasks	m²	12,00
7	Waste Disposal and Site Cleaning	Removal of debris and final worksite cleanup	m²	2,00
			Total (€/m²)	**50,00**

- Description of the **new windows** to be installed in the building.
  - Glazing: Double glazing (2 panes)
  - 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 (6 cm mineral wool) and new windows

Unit	Description	n.	measurement	price €	amount €
m2	6 cm mineral wool isolation layer in facades with plaster finish installed	1	93,88	86,00 €	8.073,68 €
m2	6 cm mineral wool isolation layer in party wall, roof and slabs (interior drywall system)	1	161,49	50,00 €	8.074,50 €
m2	Low emissive double-glazed PVC windows with argon gas (U= 1.7 W/m²·K)	1	11,32	270,00 €	3.056,40 €
ud	Replacing an exterior door in a duplex in Ceutí (Spain), with a thermal transmittance (U-value) of 1.7 W/m²·K, including removal of the old door and full installation.	1	1	1.200,00 €	1.200,00 €
				Total	**20.404,58 €**

Improvement 2: Replacement of Electric Water Heater with DHW Heat Pump (1.5 kW, 200 L)

No.	Item	Description	Unit	Price (€)
1	Supply of DHW Heat Pump Unit	Air-source heat pump for domestic hot water, 1.5 kW, 200 L tank (COP ~3.0)	unit	2.050,00 €
2	Removal of Existing Electric Heater	Safe disconnection and disposal of the old electric water heater	unit	80,00 €
3	Installation of Heat Pump	Plumbing, mounting, electrical connection, and integration	unit	500,00 €
4	Accessories and Installation Materials	Pipes, fittings, valves, insulation, brackets, fasteners	unit	150,00 €
5	Electrical Circuit Adaptation	Circuit breaker upgrade and safety adaptation (if needed)	unit	100,00 €
6	System Start-Up and Testing	Commissioning, functional testing, user instructions	unit	70,00 €
			Total	**2.950,00 €**

Improvement 3: 4-Panel PV Installation (1.94 kWp, Flat Roof, Ceutí)

Technical Specifications of the Photovoltaic panel system:

Location: Ceutí (Spain)
Building: Single family house
System Specifications:

- Number of Panels of glass silicon: 4 (3 m2 each panel)
- Panel Capacity: 480 W each
- Total Capacity: 1.94 kWp

No.	Item	Description	Unit	Unit Price (€)	Quantity	Subtotal (€)
1	Photovoltaic Panels (485 Wp)	High-efficiency monocrystalline panels with glass-silicon encapsulation	panel	280	4	1.120,00 €
2	Mounting Structure (Flat Roof)	Aluminum support structure (ballasted or fixed)	panel	75	4	300,00 €
3	Inverter (2–3 kW)	Grid-tied inverter sized for 2 kWp system, with basic monitoring	unit	700	1	700,00 €
4	Electrical Installation	Wiring (DC/AC), protections, combiner box, generation meter	system	500	1	500,00 €
5	Labor and Commissioning	Assembly, cabling, inverter setup, startup testing	system	600	1	600,00 €
6	Legalization and Admin (optional)	Documentation, grid connection, CIE, BOE, etc.	service	300	1	300,00 €
					Total	**3.520,00 €**

Improvement 4: Vaillant Aerothermal System (Heating + Cooling + DHW with Fan Coils)

Technical Summary:

- **System capacity:**
  - Heating: 7.37 kW (COP 4.42)
  - Cooling: 7.2 kW (EER ~2.7)
  - DHW: 200 L tank with integrated coil (uniSTOR)
- **Hot water** generated directly from aerothermal system
- **Savings** vs. traditional electric heater: up to 65%
- **Space requirement:** DHW tank + buffer in utility room or laundry area

Budget:

No.	Item	Description	Unit	Unit Price (€)	Quan,	Subtotal (€)
1	Vaillant aroTHERM Plus Outdoor Unit	Air-to-water heat pump, 7.37 kW heating / 7.2 kW cooling (COP 4.42), monobloc	unit	3.740,00 €	1	3.740,00 €
2	Vaillant uniSTOR DHW Tank (200 L)	Hot water storage tank with coil for aerothermal systems	unit	1.375,00 €	1	1.375,00 €
3	Fan Coil Units (Vaillant or compatible)	Hydronic fan coils, ultra-quiet, thermostat-controlled	unit	638,00 €	4	2.552,00 €
4	Hydraulic Circuit + DHW Integration	Piping, valves, circulation pump, for heating, cooling, and hot water	system	935,00 €	1	935,00 €
5	Electrical Panel Adaptation	Safety switches, control wiring, DHW-compatible configuration	unit	440,00 €	1	440,00 €
6	Removal of Old AC & Water Heater	Uninstalling multisplit AC + electric water heater, with legal disposal	service	220,00 €	1	220,00 €
7	Installation & Commissioning	Full system installation, hydraulic setup, tests, filling, configuration	system	1.320,00 €	1	1.320,00 €
8	Thermostats / Zoning Controls	Wired or wireless thermostats or digital interfaces	unit	110,00 €	4	440,00 €
					Total	**11.022,00 €**

- Improvement 5: Aerothermal heating and DHW system (for radiators)

Technical characteristics:

- Application: Heating + DHW only
- Radiators and distribution piping not included
- Ideal for homes upgrading from gas or electric systems
- Outdoor unit: Monobloc (no refrigerant handling on-site)
- High efficiency COP > 4 — up to 70% energy savings vs. gas

No.	Item	Description	Unit	Unit Price (€)	Qty	Subtotal (€)
1	Vaillant aroTHERM Plus	Outdoor monobloc unit, 7.37 kW heating (COP 4.42)	unit	3.400,00 €	1	3.400,00 €
2	Vaillant uniTOWER 200 L	Indoor hydraulic tower (hydraulic module + 200 L DHW tank + 3-way valve, pump, sensors)	unit	2.750,00 €	1	2.750,00 €
3	Electrical Panel & Protections	Electrical board adaptation and control wiring	unit	400,00 €	1	400,00 €
4	Removal of Gas Boiler	Safe disconnection and disposal	unit	180,00 €	1	180,00 €
5	Removal of Electric Water Heater	Safe disconnection and disposal	unit	120,00 €	1	120,00 €
6	Installation & Commissioning	Hydraulic and electrical connections, system start-up, testing	unit	950,00 €	1	950,00 €
					Total	**7.800,00 €**

Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Improvement 6: Thermal envelop isolation (10 cm mineral wool) and new windows

Unit	Description	n.	measurement	price €	amount €
m2	10 cm mineral wool isolation layer in facades with plaster finish installed	1	93,88	114,00 €	10.702,32 €
m2	10 cm mineral wool isolation layer in party wall, roof and slabs (interior drywall system)	1	161.49	66,400 €	10.722,94 €
m2	Low emissive double-glazed PVC windows with argon gas (U= 1.7 W/m²·K)	1	11,32	270,00 €	3.056,40 €
ud	Replacing an exterior door in a duplex in Ceutí (Spain), with a thermal transmittance (U-value) of 1.7 W/m²·K, including removal of the old door and full installation.	1	1	1.200,00 €	1.200,00 €
				Total	**25.681,66 €**

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:

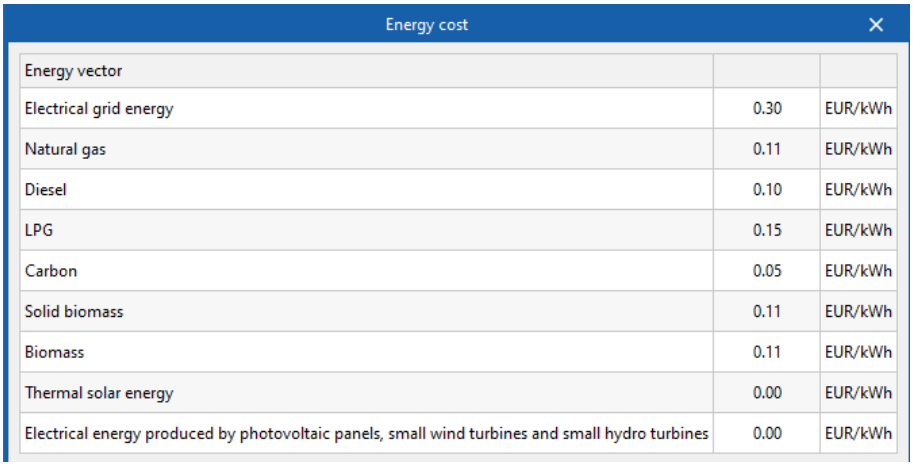
- B_t = Benefits (e.g., energy savings) in year *t*
- C_t = Operating or maintenance costs in year *t*
- r = Discount rate (interest rate or cost of capital)
- t = Year (1 to *n*)
- *I* = Initial investment cost
- n = Analysis period (in years)

If NPV > 0 → The investment is profitable

If NPV = 0 → The investment breaks even

If NPV < 0 → The investment is not financially viable

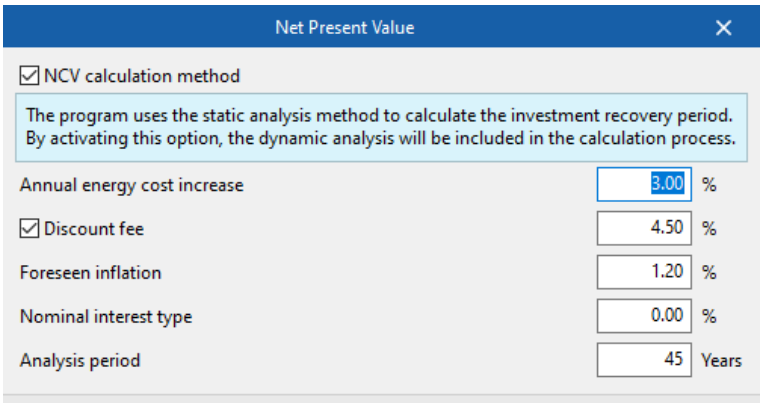
Energy cost considered:



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:



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 1 (Case 1)	0.00	1642.32	0.00	0.00	0.00	162.20	27.48
Case 3: 6 cm Isolation and DHW Heat pump	23354.58	225.15	1417.17	16.48	18.09	22.23	3.77
Case 4: 6 cm isolation +DHW heat pump + PV Panels	26874.58	0.00	1642.32	16.36	17.96	0.00	0.00
Case 5: 10 cm isolation + DHW heat pump + PV panels	32151.66	0.00	1642.32	19.58	21.62	0.00	0.00
Case 6: 6 cm Insolation + H & AC and DHW Aerothermal with fan coil + PV panels	34946.58	0.00	1642.32	21.28	23.55	0.00	0.00

	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 2 (Case 2)	0.00	1067.51	0.00	0.00	0.00	119.73	24.93
Case 7: 6 cm Isolation + Aerothermal with radiators for HS and DHW	28204.58	183.40	884.10	31.90	42.35	18.12	3.08
Case 8: 6 cm insolation Aerothermal for HS and DHW and PV panels	31724.58	0.00	1067.51	29.72	38.47	0.00	0.00

In the tables 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 1 (Case 1)	0.00	0.00	0.00	0.00	1642.32	0.00	0.00	0.00	0.00
Case 3: 6 cm Isolation and DHW Heat pump	23354.58	0.00	23354.58	23354.58	225.15	1417.17	0.00	1417.17	16.48
Case 4: 6 cm isolation +DHW heat pump + PV Panels	26874.58	0.00	26874.58	26874.58	0.00	1642.32	0.00	1642.32	16.36
Case 5: 10 cm isolation + DHW heat pump + PV panels	32151.66	0.00	32151.66	32151.66	0.00	1642.32	0.00	1642.32	19.58
Case 6: 6 cm Insolation + H & AC and DHW Aerothermal with fan coil + PV panels	34946.58	0.00	34946.58	34946.58	0.00	1642.32	0.00	1642.32	21.28

	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 2. (Case 2)	0.00	0.00	0.00	0.00	1067.51	0.00	0.00	0.00	0.00
Case 7: 6 cm Isolation + Aerothermal with radiators for HS and DHW	28204.58	0.00	28204.58	28204.58	183.40	884.10	0.00	884.10	31.90
Case 8: 6 cm insolation Aerothermal for HS and DHW and PV panels	31724.58	0.00	31724.58	31724.58	0.00	1067.51	0.00	1067.51	29.72

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 single family detached house in Ceutí (Spain), using BIM technologies, identifying major inefficiencies in envelope insulation, window performance, DHW systems, and heating system. 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 and roof insulation.
  - Replacement of windows.

- Domestic hot water system modernization (by mean of heat pump system)
- Heating and cooling system modernization (by means of aerothermal systems)
- 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 100% and CO_2 emissions also by 100%.
- **Cost-Benefit Results Vary by Measure.** The financial assessment revealed that:
  - Deep renovation strategies (isolation, window replacement) require higher investment but offer long-term returns.
  - Heating, cooling and DHW system modernization greatly reduce energy consumption and gas emissions.
  - PV panels contribute significantly to decarbonization goals.
  - If all the measures considered in the study are implemented, the payback period is considerably reduced (18 years) since 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 heat pump system and 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 single family house. 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.