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Roadmap for the renovation of “Nicolae Bălcescu” High School

Scarlat Varnav st., no. 2, Medgidia, Constanța county

OUR-CEE

Overcoming Underperforming Renovations in Central and Eastern Europe

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BUILDING DESCRIPTION AND CURRENT ENERGY PERFORMANCE

"Nicolae Bălcescu" high school



Education building



Medgidia, Scarlat Varnav St., No. 2
Constanța county



Constructed in 1968



The construction system is reinforced concrete frames with load-bearing brick masonry



Building importance category "C" - normal according to HGR no. 766/1997

Building importance class II, according to P100/1-2013

Fire resistance rating II, according to P118-99



Built area - 1.023m²
Gross floor area - 3.494 m²
Height - UL +GF+2F



Energy performance class B
Final energy consumption
61,9 kWh/m²*an
Primary energy consumption
121,9 kWh/m²*an
CO₂ emission index - 15 CO₂/m²*year



The site's usual opening hours are between 8:00 - 16:00, from Monday to Friday, in accordance with the academic year calendar.



Approximately 21,19 kWh/m²*year represents renewable share, including energy generated by solar panels and the national electricity grid mix (SEN).



The building does not comply with the nZEB standard. Both the primary energy consumption and the associated carbon emissions exceed the maximum threshold established by the national calculation methodology MC-001-2022.



The RERp indicator (percentage of energy consumed from renewable sources relative to the total primary energy consumption) is 17.39%

Breakdown of areas and average standard indoor temperatures

Floor	Area [m ²]	Volume [m ³]	Avg. standardised indoor temp. [°C]
UNDERGROUND LEVEL			
Total	347,82	737,38	
Heated area E	347,82	737,38	17,85
Cooled area E	347,82	737,38	
GROUND FLOOR			
Total	819,19	2711,52	
Heated area E	819,19	2711,52	18,21
Cooled area E	819,19	2711,52	

Floor	Area [m ²]	Volume [m ³]	Avg. standardised indoor temp. [°C]
1ST FLOOR			
Total	834,41	2761,90	
Heated area E	834,41	2761,90	18,17
Cooled area E	834,41	2761,90	
ETAJ 2			
Total	837,98	2773,71	
Heated area E	837,98	2773,71	17,87
Cooled area E	837,98	2773,71	

TOTAL

Total heated area	2839,40	8984,51	18,02
Total cooled area	2839,40	8984,51	

Previous renovations

According to the available information, the last major renovation of the building was carried out in 2023.

The works included:

- Modernisation of the façade
- Replacement of exterior joinery with high-performance, thermally insulated windows.

Regarding earlier interventions, data is limited, and the specifics of any works undertaken prior to this renovation are not known.

Energy sources used

Currently, the building uses two main energy sources to meet its functional requirements: natural gas (indirectly) and electricity.

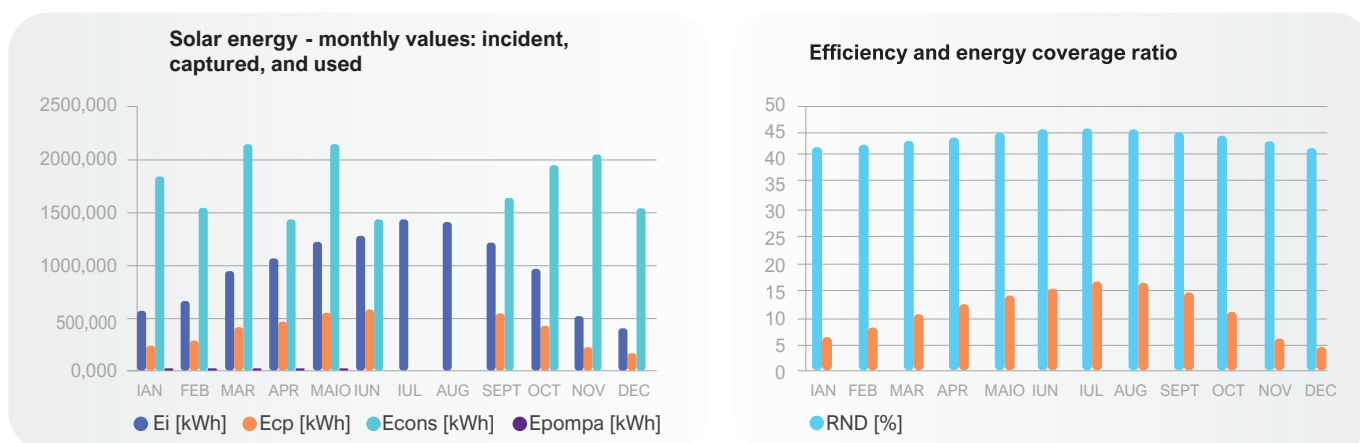
- **Natural gas** is used to power remote cogeneration turbines, which provide heating via the municipal district heating network, as well as to supply domestic hot water. The wall-mounted boilers operate on combustion, and their energy efficiency varies. While the use of natural gas is cost-effective in the short term, it contributes significantly to CO₂ emissions, directly impacting the building's carbon footprint.
- **Electricity** is primarily used for interior and exterior lighting, powering electronic equipments, and various auxiliary systems. Currently, lighting is provided by LED fixtures, which reduce energy consumption compared to traditional sources. However, electricity supplied through the national grid is generated from an energy mix which includes both conventional and renewable sources, resulting in varying levels of CO₂ emissions.

The integration of alternative energy sources, such as photovoltaic panels or energy recovery systems, could significantly reduce conventional energy consumption and help optimise long-term operational costs. Additionally, increasing the share of energy from renewable sources would reduce greenhouse gas emissions and support sustainability objectives.

On-site renewable energy

The building uses solar thermal panels for domestic hot water, as well as photovoltaic panels to generate renewable electricity on-site. In addition, a portion of the electricity consumed is sourced from renewables through the national energy grid, which includes hydro, wind, and solar power.

The contribution of the solar thermal panels



Primary and final energy demand

Primary energy consumption calculated in accordance with the national energy performance calculation methodology, MC001-2022 and current applicable regulations

System	Current			Reference building	
	Final/primary energy consumption	Annual CO ₂ emissions	Energy Performance Class	Primary energy consumption	CO ₂ emissions
1. Heating	27,5 / 47,0	6,5	B		
2. Hot water	7,7 / 8,1	1,3	A		
3. Cooling					
4. Mechanical ventilation	15,6 / 39,0	4,2	E		
5. Lighting	11,1 / 27,9	3,0	C		
TOTAL / CLASS	61,9 / 122,0	15,0	B	72,5	10,9

Energy bill

Natural gas consumption and costs over a two-year analysis period, 2019 - 2022, representing the timeframe before and after the renovation works.

Natural gas consumption:

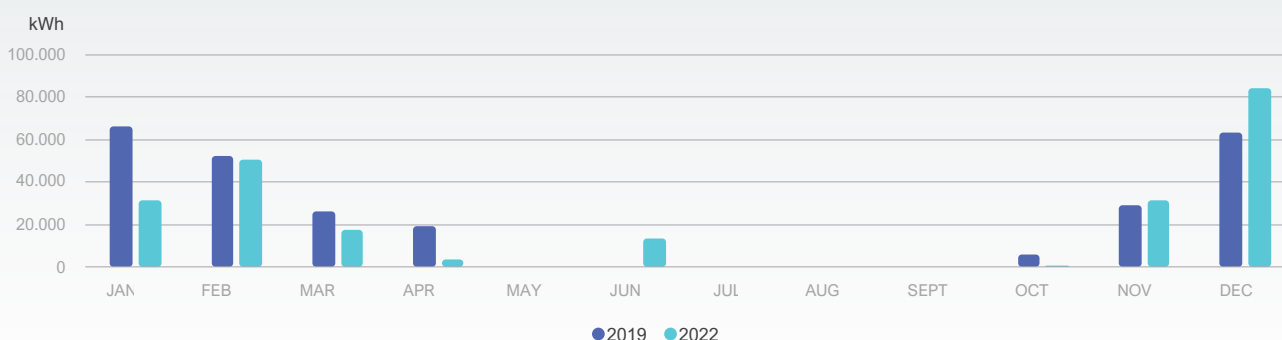
2019

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov.	Dec.
Consumption [KWh]	66.439	52.302	25.935	19.427	-	-	-	-	-	5.575	29.187	63.410
Cost [lei]	14.048	10.871	5.391	3.807	-	-	-	-	-	1.263	7.172	12.268

2022

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov.	Dec.
Consumption [KWh]	31.400	50.444	17.347	3.668	-	13.229	-	-	-	256	31.468	84.115
Cost [lei]	10.676	17.151	5.898	1.247	-	4.498	-	-	-	87	10.699	28.599

Energy consumption in different years: 2019 versus 2022



CO₂ emissions

CO₂ emissions are a key indicator of a building's environmental impact. These emissions are directly influenced by the type of energy sources used, the efficiency of the building systems, and the quality of thermal insulation in place.

Buildings that primarily rely on conventional energy sources - such as natural gas - typically exhibit significantly higher CO₂ emissions compared to those that benefit from substantial input from renewable sources, such as solar panels, wind energy, or green electricity from the national grid. CO₂ emissions are calculated using standardised conversion factors, which correlate energy consumption with the corresponding emissions, in line with national regulations.

Primary and final energy consumption in relation to the amount of CO₂ emissions generated, based on national conversion factors, as well as the share of on-site renewable energy production, and the share of green electricity supplied to the building via the national energy grid:

Total annual energy consumption [kWh/m ² ,year] *	final-t/e**	22,6	39,3	-	-	CO ₂ emission index [kgCO ₂ /m ² ,year] *	15,0
	primary	121,9		72,5			
Total annual energy consumption from renewable energy [kWh/m ² year] *	Solar thermal	Solar electric	Heat pumps	Biomass	Other RES	TOTAL RES	
	1,6	0,0	0,0	0,0	19,6	21,2	

DETAILED RENOVATION STEPS

Timeline	Energy class after implementation of measures	Measures	Energy consumption after implementation of measures	CO ₂ emissions after implementation of measures and reduction compared to baseline	Costs investment costs and maintenance costs
Year 1	B	<p>S1. Enhancement of RES</p> <p>Installation of monocrystalline solar panels, power of 60 kWp and inverters operating at >97%</p>	<p>Primary energy consumption – 95,7 kWh/ m²year</p> <p>Final energy consumption – 61,9 kWh/ m²year</p>	<p>CO₂ emissions index – 10,3 kgCO₂/m²year</p> <p>Reduction approx. 31%</p>	<p>Investment cost: 210.000 lei (excluding VAT)</p> <p>Maintenance cost: approx. 0,5 – 1% of the initial investment cost, covering periodic cleaning and technical inspections</p>
Year 2	A	<p>S2. Installation of a centralised mechanical ventilation and heat recovery system</p> <p>Centralised mechanical ventilation system with ducted air distribution; heat recovery units installed in designated technical spaces. Heat recovery units must have an efficiency of more than 85%, and include HEPA filters to ensure high indoor air quality.</p>	<p>Primary energy consumption – 65,8 kWh/ m²year</p> <p>Final energy consumption – 49,9 kWh/ m²year</p>	<p>CO₂ emissions index – 7,1 kgCO₂/m²year</p> <p>Reduction approx. 52%</p>	<p>Investment cost: 700.000 lei (excluding VAT)</p> <p>Maintenance cost: 1 – 3% of the purchase cost (filter replacement and equipment inspection)</p>
Year 3	A	<p>S3. Installation of a Building Energy Management System (BEMS)</p> <p>Integration of sensors and control equipment into the BEMS; temperature, humidity, CO₂ sensors; analysis and control software</p>	<p>Primary energy consumption – 59,8 kWh/ m²year</p> <p>Final energy consumption – 45,4 kWh/ m²year</p>	<p>CO₂ emissions index – 6,5 kgCO₂/m²year</p> <p>Reduction approx. 56%</p>	<p>Investment cost: 125.000 lei (fără TVA)</p> <p>Maintenance cost: estimated at approx. 1% of the purchase cost (it includes software updates and technical inspections)</p>

Timeline	Energy class after implementation of measures	Measures	Energy consumption after implementation of measures	CO ₂ emissions after implementation of measures and reduction compared to baseline	Cost investment costs and maintenance costs
Year 4	A+	S4. Upgrade of the heating and cooling system (air-to-water heat pumps) Installation of heat pumps with SCOP > 3,5; auxiliary equipments for distribution and temperature control	Primary energy consumption – 46,9 kWh/ m ² year Final energy consumption – 44 kWh/ m ² year	CO₂ emissions index – 4,5 kgCO ₂ /m ² year Reduction - approx. 70%	Investment cost: 212.000 lei (excluding VAT) Investment cost for distribution equipment 125 400 lei (excluding VAT) Maintenance cost: estimated at 4-6% of the purchase cost (routine inspections, filter cleaning)
Year 5		S5. Upgrade of the lighting system with highly efficient, smart control solutions Installation of presence and daylight sensors; integration into BEMS. The system includes: Passive Infrared (PIR) sensors, dimming controls, LED light fittings, automated control interface.	Primary energy consumption – 36,8 kWh/ m ² year Final energy consumption – 39,9 kWh/ m ² year	CO₂ emissions index – 3,4 kgCO ₂ /m ² year Reduction - approx. 77%	Investment cost: 37.500 lei (excluding VAT) Maintenance cost: estimated at 0,5% of investment cost (periodic replacement of components, calibration of control systems)
Year 5	A+	S6. Energy performance monitoring and verification Installation of smart meters for real-time monitoring of energy consumption, full integration into BEMS. The system will include: smart meters for both electricity and heating/cooling, data analysis software, and automated performance reporting tools.			Investment cost 12.500 lei (excluding VAT) Maintenance cost estimated at 1-2% of investment cost (subscriptions for monitoring software, technical inspections)

Implementation sequence of the renovation measures

The proposed renovation plan has a phased implementation of measures over a 5-year period. This timeline is indicative and may vary depending on the complexity of each measure and availability of funding. The staging of the works should follow a logical sequence of interventions, aimed at progressively improving indoor comfort and reducing energy consumption from one stage to the next.

YEAR 1 Energy class B

Enhancement of renewable energy sources



The first step is to expand the PV system in order to reduce electricity consumption from the national energy grid and lower operational costs. The generation of on-site energy will establish a sustainable framework for the subsequent renovation measures. At this stage, the PV system should be properly sized to match the projected energy demand, including the anticipated consumption of the equipment and technologies to be integrated as part of the renovation package.

- **Installation process:** the optimal orientation and tilt of the panels will be assessed; a south-facing placement, with a tilt of 8-10 degrees is recommended for flat roof configurations (terrace-type roofs). The system will then be connected to the building's electrical infrastructure and integrated into the BEMS.
- **Materials and technical specifications:** monocrystalline PV panels with a total installed capacity of 60kWp, paired with high-efficiency inverters having a conversion efficiency of over 97%.
- **Investment and maintenance costs:** the estimated investment is 210 000 RON (excluding VAT), with low annual maintenance costs due to the high durability of the equipment.
- **Procurement, permits, and contract requirements:** procurement of PV panels and inverters, grid connection permits from the distribution system operators, maintenance contracts for the PV system.

YEAR 2 Energy class A

Installation of a centralised mechanical ventilation and heat recovery system

Mechanical ventilation with heat recovery will ensure a constant flow of fresh air, reducing energy losses from heating the incoming airflow. The system not only improves air quality but also decreases the energy required for heating and cooling. This system is necessary for enhancing indoor comfort and improving occupants' educational performance by providing an optimal amount of clean air for all activities.

- **Installation details:** installation of the centralised ventilation system with ductwork routes for the even distribution of air. Heat recovery units will be installed in the designated technical spaces.
- **Materials and technical specifications:** heat recovery units with an efficiency of >85%, sound insulated ductwork, and HEPA filters for air quality.
- **Investment and maintenance costs:** the estimated investment is 700 000 RON (excluding VAT), with additional moderate maintenance costs for filter replacement and equipment checks.
- **Procurement, permits, and contract requirements:** purchase of ventilation equipment, permits for adapting the technical spaces.

ANUL 3 Energy class A

Installation of a Building Energy Management System (BEMS)

Once the unit begins producing electricity locally, in self-consumption mode, and a ventilation system is activated, the next step is the integration and automation of these systems through a BEMS. The system will enable precise monitoring and control of energy consumption optimising the operation of equipment and ensuring smart resource management. At this stage, the sensors will be installed to monitor CO2 concentration levels and PPM 2.5. The control of the ventilation units must be directly connected to this system, which will communicate with the sensors installed in each classroom, thus enabling precise control over the air handling units, further reducing energy consumption.

- **Installation details:** integration of sensors and control equipment into BEMS, which will automatically manage energy consumption and indoor comfort.
- **Materials and technical specifications:** temperature, humidity, and CO₂ sensors, analysis and control software, a user friendly interface.
- **Investment and maintenance costs:** estimated investment of 125 000 RON, with potential energy savings of 10-15% and minimal maintenance costs due to high level of automation.
- **Procurement, permits, and contracts:** acquisition of hardware and software components, software implementation contract, and integration with the existing infrastructure.

YEAR 4 Energy class A+



Upgrade of the heating and cooling system using air-to-water heat pumps

With smart energy control and a well-ventilated indoor environment, the fourth stage of the renovation consists of upgrading the heating and cooling systems. As part of this phase, it is proposed to implement an air-to-water heat pump system, while retaining the existing gas boilers to cover peak demand periods. Traditional distribution systems—based on static radiators—are less efficient in combination with heat pumps, as they require high-temperature operation (typically 70/60°C). In contrast, heat pumps achieve optimal efficiency when operating within a lower thermal range (30–40°C). Therefore, replacing the existing heat distribution system with high-efficiency floor-mounted fan coil units will significantly reduce thermal energy consumption, allowing the heat pumps to operate within their optimal performance range.

- **Implementation details:** Retention of the existing wall mounted gas boilers and installation of air-to-water heat pumps, optimised for the local climate. The building service installations will be adjusted to ensure compatibility with the new equipment.
- **Materials and technical specifications:** Air-to-water heat pumps, with SCOP > 3,5 auxiliary equipment for heat distribution and temperature control.
- **Investment and maintenance costs:** investment estimated at 337,400 lei, with significant savings in operating costs due to on-site electricity generation.
- **Procurement, permits, and contracts:** Procurement of heat pumps, permits for modification of the of the heating system, maintenance contract.

YEAR 5 Energy class A+

In the final stage, the renovation plan involves a comprehensive upgrade of the lighting system. The installation of high-efficiency LED fixtures, along with the integration of presence and daylight sensors, will generate additional energy savings. Concurrently, the energy performance will continue to be monitored through the previously installed systems, enabling continuous optimisation of equipment operation to ensure the highest possible level of energy efficiency.



Upgrade of the lighting system with highly efficient, smart control solutions

- **Implementation method:** automation of the existing lighting system by installing presence and daylight sensors, with integration into the (BEMS) for optimal control.
- **Materials and technical specifications:** PIR sensors, dimming control system, and high-efficiency LED light fittings, automated control interfaces.
- **Investment and maintenance costs:** estimated investment: 37,500 RON (excluding VAT), delivering energy savings and minimal maintenance costs due to the long service life and durability of LED technology.
- **Procurement, permits, and contracts:** procurement of sensors and control systems; contract for system installation and integration.



Energy performance monitoring and verification

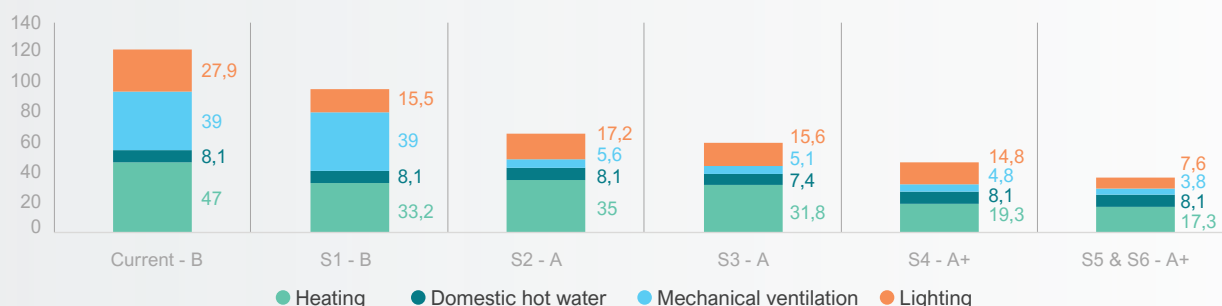
- **Implementation method:** installation of smart meters to monitor energy consumption, with integration of data into the BEMS for continuous performance analysis.
- **Materials and technical specifications:** smart meters for both electrical and thermal energy, accompanied by data analysis software and performance reporting tools.
- **Investment and maintenance costs:** 12 500 and 1-2% of the investment cost, estimated as an annual subscription cost with a specialised service provider. Alternatively, this cost can be significantly reduced or eliminated by training and appointing a staff member for system operation and data analysis.
- **Procurement, permits, and contracts:** procurement of smart metering devices, and a service contract for system integration and configuration.

Energy class following the renovation steps

The gradual implementation of the proposed measures will result in a progressive increase of the building's energy efficiency while significantly contributing to the improvement of the indoor microclimate. Each renovation step may not necessarily lead to an immediate upgrade in the building's energy class, but it will enhance indoor environmental quality and contribute to the reduction of the building's carbon footprint. In the table below, the first row presents the evolution of primary energy consumption alongside the variation in the building's energy class as the proposed solutions are implemented.

	Current		Year1/ S1		Year2 / S2		Year3 / S3		Year4 / S4		Year5 / S5 & S6	
	[kWh/m ² y]	Class	[kWh/m ² y]	Class	[kWh/m ² y]	Class	[kWh/m ² y]	Class	[kWh/m ² y]	Class	[kWh/m ² y]	Class
Primary energy consumption	121,9	B	95,7	B	65,8	A	59,8	A	46,9	A+	36,8	A+
Final energy consumption	61,9	-	61,9	-	49,9	-	45,4	-	44	-	39,9	-
CO ₂ emissions index [kgCO ₂ /m ² y]	15,0	B	10,3	A	7,1	A+	6,5	A+	4,5	A+	3,4	A+
Heating	47	B	33,2	A	35	A	31,8	A	19,3	A+	17,3	A+
Domestic hot water	8,1	A	8,1	A	8,1	A	7,4	A	8,1	A	8,1	A
Cooling	-	-	-	-	-	-	-	-	-	-	-	-
Mechanical ventilation	39	E	39	E	5,6	A	5,1	A	4,8	A	3,8	A+
Lighting	27,9	C	15,5	B	17,2	B	15,6	B	14,8	B	7,6	A
RER	17,39%	-	31,28%	-	36,42%	-	40,10%	-	48,48%	-	68,67%	-
Renewable energy [kWh/m ² an]	1,56	-	19,03	-	23,9	-	25,15	-	24,15	-	24,15	-

Energy class following the renovation steps

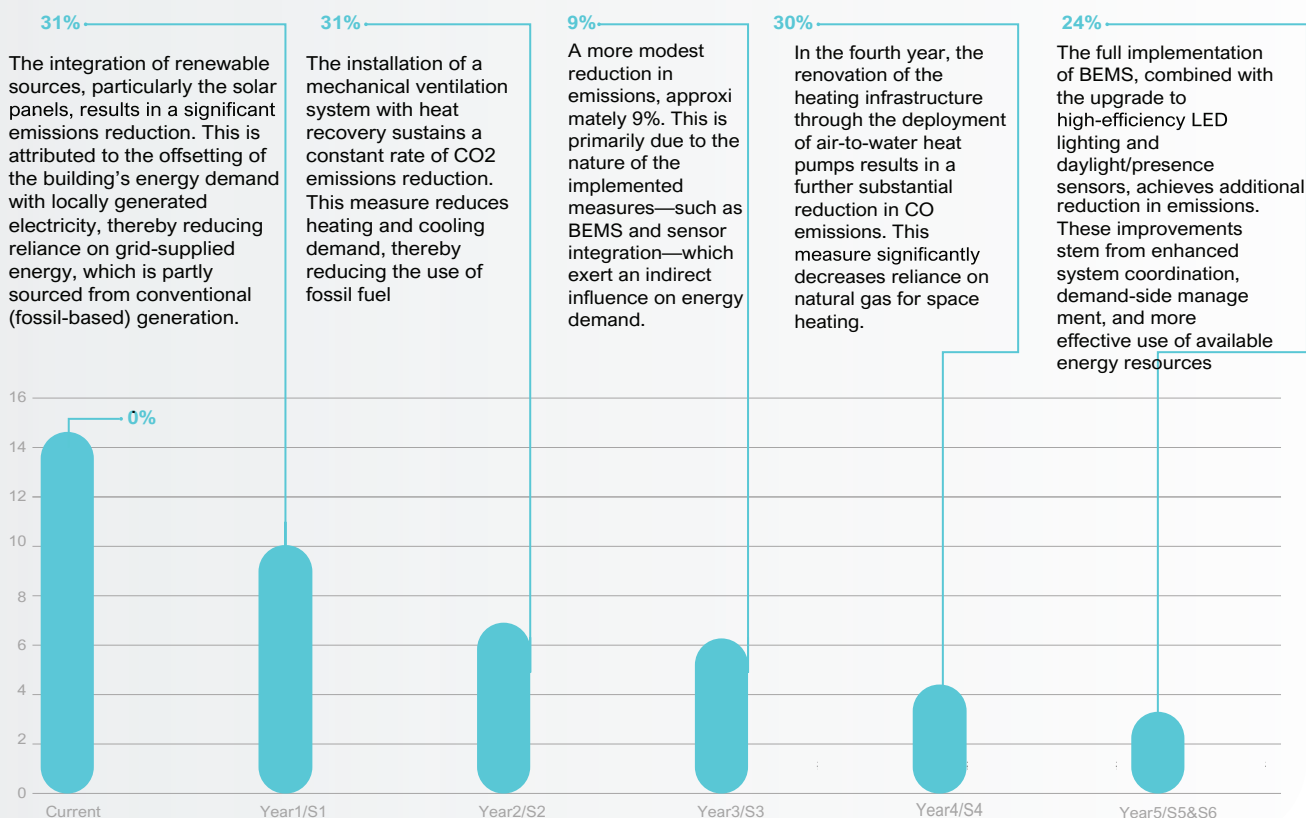


CO₂ emissions after the implementation of each step

The phased implementation of renovation measures results in a substantial reduction in CO₂ emissions. However, this reduction does not occur evenly over time. The chart below illustrates how each renovation step contributes to the overall decline in emissions, highlighting the specific impact of each solution implemented.

Although the reduction in emissions is considerable throughout the renovation process, it does not follow a strictly linear trend. Instead, it depends on the specific impact of each renovation measure. The greatest emissions savings are achieved during the first and final years of the renovation, when the measures with the highest potential for energy efficiency are implemented.

Variation of CO₂ emissions



Energy sources post-renovation

Following the implementation of all proposed renovation measures, the building's energy mix will be substantially recalibrated to reduce dependency on conventional energy sources and increase the share of renewables.

PV Solar Energy

A significant portion of the building's electricity demand will be met through the installation of photovoltaic panels on the roof. These panels will generate electricity for lighting, equipment operation, and the powering of the mechanical ventilation system. Any surplus energy generated will be either fed back into the national grid or stored.

Natural Gas

Post-renovation, the use of natural gas will be minimised, serving only as a backup source for exceptional situations. On a regular basis, the operation of the heat pumps and ventilation systems will eliminate the need for intensive natural gas usage.

Aero-Thermal Energy (Air-to-Water Heat Pumps)

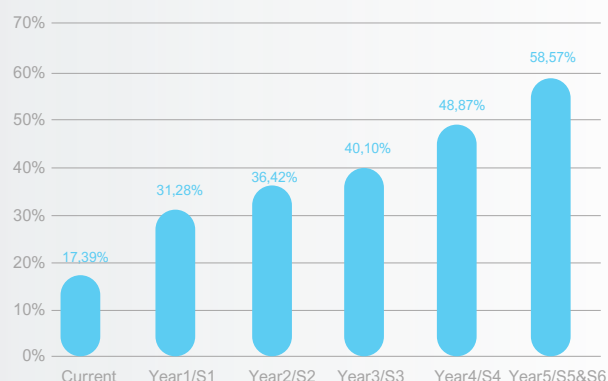
The building's heating and cooling system will be upgraded through the installation of air-to-water heat pumps, which extract thermal energy from the outside air to provide heating during the cold season and cooling in the warmer months. This technology is energy-efficient and versatile, which reduces methane gas consumption and CO emissions. The heat pumps will be integrated with the mechanical ventilation system and the building's automation systems.

Electricity from the National Grid

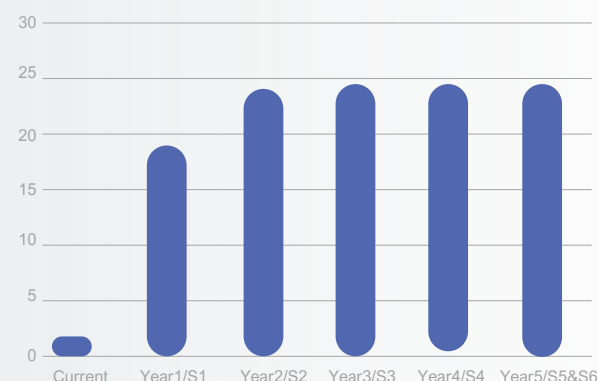
Although a significant portion of the required energy will be covered by renewable sources, the building will remain connected to the national electricity grid to ensure continuity of supply during periods of low production from on-site generation. Suppliers will be selected based on the share of green energy into their energy mix.

- **The installation of photovoltaic panels on the building’s roof will enable the generation of electricity from solar energy.** The electricity produced will cover a significant portion of the building's electricity consumption for lighting, equipment, and the operation of automated systems. Any surplus energy can either be stored in batteries or fed back into the national grid, depending on the demand and operational conditions.
- **The existing solar thermal panels will continue to contribute to the production of domestic hot water,** thereby reducing the energy required for heating water. This system will be optimised to work efficiently in conjunction with the new heat pumps and other modern equipment.
- **The air-to-water heat pumps will harness renewable energy from the ambient air to provide heating and cooling for the building.**

Variation in RERp following the implementation of the proposed solutions



Renewable energy produced [kWh/m²an]



Energy demand after each renovation step

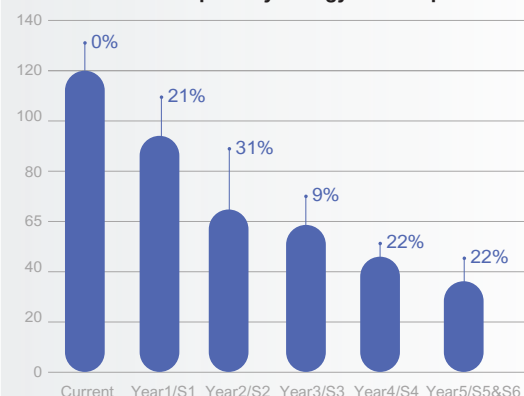
Primary energy demand

Following the completion of all proposed renovation measures, the building’s primary energy demand will be substantially reduced. This improvement will result from both enhanced energy efficiency and the integration of renewable energy sources. The adoption of advanced systems and high-performance equipment will ensure better energy transfer and utilisation, minimising losses and reducing the overall demand for primary resources.

The inclusion of a mechanical ventilation system with heat recovery, along with BEMS, will further contribute to an optimised use of available energy. These systems will enable more precise control and dynamic adjustment of energy flows, ensuring that a significant portion of the energy used originates from renewable sources.

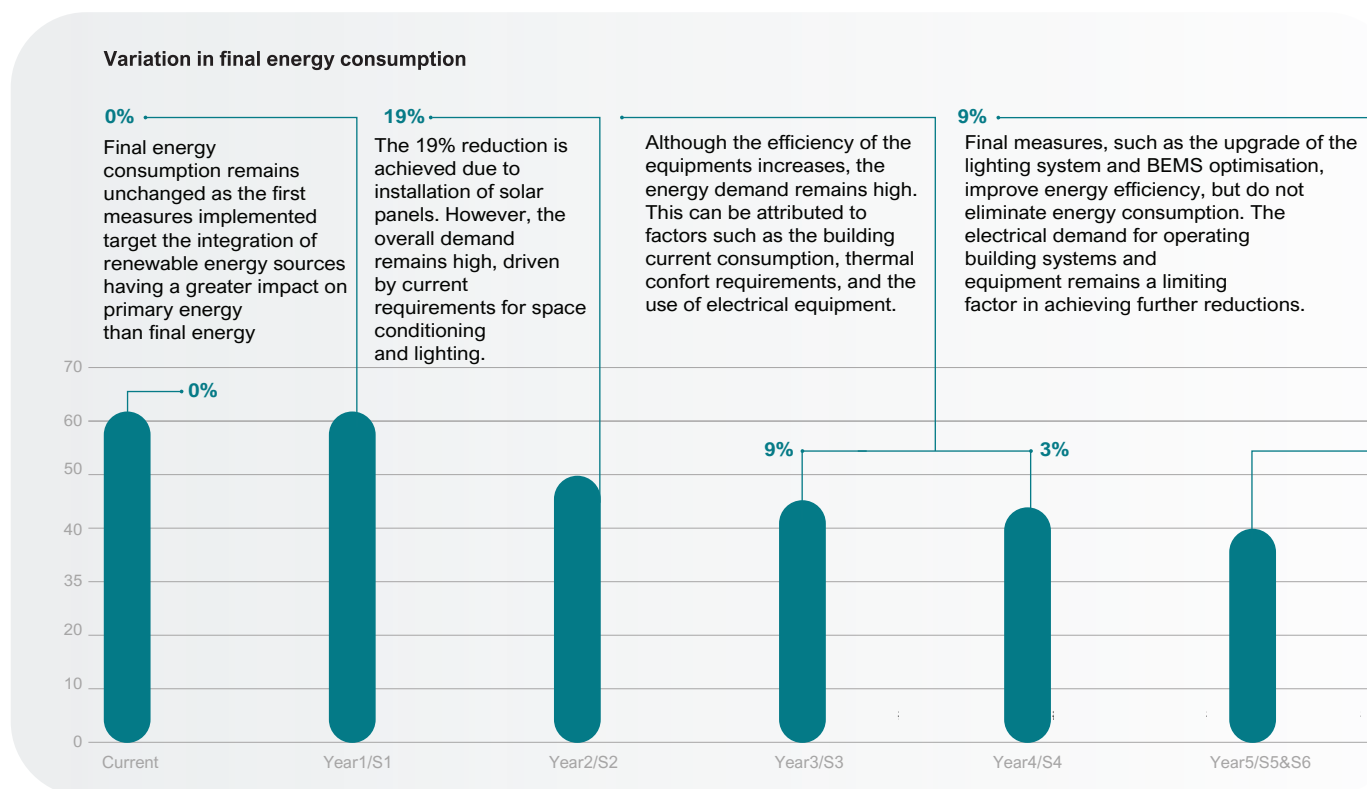
By combining renewable energy generation with energy-efficient technologies, the building’s primary energy demand will be reduced to a level compliant with current energy efficiency and sustainability standards. Depending on actual performance outcomes, the building may qualify for NZEB classification.

Variation in primary energy consumption



Final energy demand

Following the implementation of the proposed renovation measures, the building's final energy consumption exhibits notable variation. The rate of reduction is not linear and does not directly mirror the decline in primary energy demand.



Energy costs following the implementation of the renovation plan

Following the implementation of the proposed renovation measures, a progressive reduction in energy bills is anticipated, although this decrease is not expected to follow a linear pattern. The evolution of operational costs is influenced by multiple factors, including the integration of renewable energy sources, the efficiency of upgraded systems, fluctuations in energy market prices, and—most significantly—the efficiency and usage patterns of

- **In Year 1**, energy costs remain relatively stable, as initial investments focus on the integration of photovoltaic panels. The financial benefits of this measure accrue gradually over time, as the solar generation system offsets a portion of electricity consumption. A substantial reduction is observed in **Year 2**, driven by the installation of a centralised mechanical ventilation system with heat recovery. This significantly reduces the demand for space heating, leading to noticeable savings.
- **In subsequent years**, the deployment of air-to-water heat pumps and the optimisation of climate control systems contribute to further cost reductions. These technologies lessen reliance on fossil fuels and enhance overall system efficiency. However, the decrease in energy bills does not always align proportionally with the reduction in primary energy consumption. This discrepancy arises because a significant share of the energy demand is met by electricity, which is subject to volatile market tariffs. Additionally, the overall energy demand remains relatively constant. Historically, the cost parity between electricity and natural gas has been constant, around 3. Therefore, to ensure stable operating costs, heat pumps must achieve a SCOP of at least 3.
- **In the final stages** of the renovation plan, the implementation of a BEMS and the modernisation of lighting system lead to additional optimisation. However, the financial impact of these measures is more modest compared to earlier interventions. This is primarily due to the diminishing returns of energy savings once a base level of demand is reached.
- **Overall**, while energy costs are expected to decline following the full implementation of the renovation strategy, the rate of reduction will be determined by the balance between achieved efficiencies and the ongoing cost of electrical energy use.

Costs per renovation step

A phased cost assessment for each proposed measure is important for effective financial planning and for identifying potential funding streams. The estimated costs below encompass materials, labour, and where applicable, the acquisition and installation of specialised equipment.

Measure	Cost per unit RON/unit	Measurement unit	Power/demand	Total cost excl. VAT	Total cost incl. TVA
Photovoltaic monocrystalline panels, power of 60 kWp, inverters operating at >97%	3.500	kWp	60	210.000	249.900
Centralised mechanical ventilation and heat recovery system, efficiency of more than 85%	35	m ³ /hr	20.000	700.000	833.000
Building energy management system (BEMS)	50	m ²	2.500	125.000	148.750
Air-to-water heat pumps	-	unit	1	212.000	252.280
Upgrade of the heating and cooling system	50	m ²	2.500	125.400	149.226
Upgrade of the lighting system	15	m ²	2.500	37.500	44.625
Energy performance monitoring and verification	5	annual	2.500	12.500	14.875
Total				1.422.400	1.692.656

These values are indicative and may be subject to variation based on market fluctuations in construction materials and service rates. Additionally, certain measures may qualify for grant funding or financial incentives through national and EU-level schemes aimed at promoting energy efficiency in buildings.

These **annual maintenance costs** reflect the requirement for regular servicing to ensure the optimal operation of the systems and to maintain the desired level of energy performance.

Enhancement of renewable energy sources (PV panels)

Approx. **0.5–1% of the initial investment cost**, covering the periodic cleaning of the panels and technical inspections.

Centralised mechanical ventilation and heat recovery system, efficiency of > 85%

Maintenance includes filter replacement every six months and equipment checks, **estimated at 1–3% of the purchase cost**

Upgrade of the heating and cooling system (air-to-water heat pumps)

Technical inspections and preventive maintenance, estimated at **4–6% of the equipment value**

Installation of building energy management system (BEMS)

Software updates and technical inspections, estimated at **1% of the initial purchase cost**

Upgrade of the lighting system

Occasional component replacement and control system recalibration, estimated at **0.5% of the investment cost**

Energy performance monitoring and verification

Subscriptions for monitoring software and potential technical inspections, estimated at **1–2% of the purchase cost**.

Securing funding for the renovation measures

In order to financially support the implementation of the proposed renovation measures, it is important to identify and leverage a range of diverse funding sources. These may derive from both public and private streams, depending on the specific requirements of each renovation phase and the availability of financial resources

a. European and National funding schemes

European financing programmes such as the Modernisation Fund, the Regional Operational Programme (ROP), or the National Recovery and Resilience Plan (NRRP) offer financial support for energy efficiency projects. Additionally, national schemes like the Environmental Fund Administration (AFM) provide grants for the installation of photovoltaic systems and other renewable technologies.

b. Public–Private Partnerships (PPPs)

Collaborative arrangements between public authorities and private sector investors can facilitate the delivery of complex renovation projects by attracting private capital in exchange

c. Green Loans and bank financing

Financial institutions offer tailored credit products for energy efficiency investments, often under the “green loan” framework, with preferential interest rates and flexible repayment terms. However, access to commercial financing is subject to specific eligibility criteria, such as creditworthiness, debt capacity, and collateral requirements.

Not all local authorities (UAT) may be eligible to access these funds directly, and conditions should be negotiated individually with financial institutions. For optimal results, local authorities may also organise competitive tendering procedures to obtain the most advantageous financing offers.

d. Own-source financing

Local budgets can be allocated to cover specific components of the renovation, particularly where the required capital investment is relatively modest.

e. Sponsorships and donations

In some instances, contributions from private entities or philanthropic donations may provide additional financial support, particularly for projects with strong community or social value.

Blended Financing Approach

Combining these multiple funding sources—grants, loans, PPPs, and internal resources—can enable the implementation of the proposed renovation plan.

Monitoring and verification

The monitoring and verification of each renovation stage are the necessary to ensure that the implemented measures meet their intended energy efficiency targets. The proposed approach is systematic and data-driven, involving the continuous collection and analysis of performance data at every phase of implementation.

Performance indicators to assess the impact of each measure:

- **Final and primary energy consumption (kWh/m²/year)**
- **Efficiency of heating, cooling, and ventilation systems**
- **CO₂ emissions (kg CO₂/m²/year)**
- **Indoor thermal comfort and air quality parameters (temperature, humidity, CO₂ levels)**
- **Financial savings achieved through reduced energy consumption**

Smart meters and environmental sensors will be installed to enable real-time monitoring of electrical consumption, indoor climate parameters, and the operational efficiency of installed equipment. This will not only track system performance but will also facilitate early detection and prevention of faults or system failures. All monitoring data will be integrated into a Building Energy Management System (BEMS), enabling prompt identification of deviations from expected performance and optimisation of system operation.

Energy performance testing

- ***Thermographic imaging to detect heat loss and potential thermal bridging***
- ***Airtightness testing of the mechanical ventilation system***
- ***Verification of lighting and automation system efficiency***

Technical Reporting. Each renovation step will be documented in a technical report that includes:

- ***A description of the works carried out***
- ***Baseline and post-implementation performance data***
- ***Evaluation of performance outcomes and achieved savings***
- ***Recommendations for further improvements***

Following the completion of all renovation phases, ongoing performance monitoring will be maintained for a period of 2–3 years to assess the persistence of the benefits achieved and to recommend corrective actions if needed. After this initial period, the monitoring process may transition to a passive mode, involving periodic inspections.

This comprehensive monitoring and verification plan ensures that investments lead to measurable and lasting results, maximising the energy, financial, and occupant comfort benefits of the renovation programme.

Additional benefits of implementing the renovation measures

In addition to reducing energy consumption and lowering CO₂ emissions, the implementation of renovation measures brings a wide range of secondary benefits that significantly improve the quality of life for building occupants and enhance the value of the property.

The introduction of a mechanical ventilation system with heat recovery (MVHR) ensures a constant supply of fresh air, maintaining optimal indoor temperatures and appropriate humidity levels. This contributes to the prevention of mould growth, supports healthier indoor environments, and enhances both thermal comfort and indoor air quality.

The integration PV panels and air-to-water heat pumps helps reduce reliance on conventional energy sources, thereby lowering exposure to volatile energy prices and improving energy independence. These measures decrease dependency on traditional energy infrastructure and increase building resilience. Upgrading the lighting system to high-efficiency LED technology, along with the implementation of BEMS, contributes to the optimisation of energy use, leading to lower utility bills and easier equipment maintenance. These improvements help reduce operational and maintenance costs in the long term. An energy efficient building, equipped with modern technologies become more attractive on the property market, benefitting from higher capital value and extended service life.

Through the use of renewable energy sources and optimised consumption patterns, the building also helps reduce its carbon footprint, aligning with EU-level sustainability objectives.

The BEMS facilitates smart control of building systems, allowing for automatic adjustment of operating parameters based on user needs and real-time conditions. This leads to more efficient resource use and better operational performance. The added benefits show that renovation process not only improves energy efficiency, but also greatly enhances the user experience by creating a healthier, more comfortable, and more sustainable environment.