Project co-financed by the European Regional Development Fund

TEESCHOOLS

Transferring Energy Efficiency in Mediterranean Schools

PRIORITY AXIS: Fostering Low-carbon strategies and energy efficiency in specific MED territories: cities, islands and remote areas

OBJECTIVE: 2.1 To raise capacity for better management of energy in public buildings at transnational level

DELIVERABLE NUMBER: **3.3.6**

TITLE OF DELIVERABLE: **Carbon Footprint**

WP n. 3: Testing

ACTIVITY n. 3.3: Energy Audits and adaptation of the tool

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PARTNERS INVOLVED: ALL PARTNERS

Summary

Executive Summary

The target of the European Union of reducing by 20% its total emissions within 2020 has promoted actions focusing on different sectors; renovation of buildings have been defined as an urgent issue, but there is still a lack of knowledge on performance of innovative components and systems for an efficient renovation of buildings. Moreover, while there are incentives for private sectors, Local Authorities face severe limitations of budget. TEESCHOOLS aims at providing new solutions to Local Authorities both in technical and financial terms to implement Nearly Zero Energy Building (NZEB) renovation activities in Mediterranean Schools. The proposed approaches consist in combining a set of user friendly but scientifically sound tools: a pre-audit tool for simplified energy audits, a carbon footprint calculator based on the building life cycle information, an innovative database of BAT for renovation of school buildings; tailored financing models and highly qualified trainings.

This report contains information utilised to define the methodological bases adopted to estimate the improvement of carbon footprint on each pilot building after renovation.

Methodological Approach

Intro

As stated in the Energy-efficient buildings for low-carbon cities (ICCG Reflection No. 47/March 2016), around one-third of global greenhouse gas (GHG) emissions derive from buildings, this value could double by 2050 if no action is taken (UNEP, 2015). Buildings account for more than 40% of global energy use; nevertheless, adopting existing best practices and technologies may significantly reduce energy use and consequently GHG emissions. Energy efficiency technologies are cost-effective with paying back periods within the building lifetime; this can have a direct advantage reducing energy use and emissions.

The building sector is characterized by an inhomogeneous variety of building types utilizing a large number of technologies for heating, cooling, and lighting, and a wide range of building materials and building techniques. The use of energy has grown in the time doubling between 1971 and 2010 driven by population increase and economic growth (IEA et al. 2013). Nevertheless, technologies and good practices to move from this "business as usual" scenario to a more sustainable one already exist. These include the policies and technologies capable of making new buildings more energy efficient than current.

There are plenty of methods available to decrease energy consumption and to reduce CO_2 emissions produced by the building that comprehend all the buildings life cycle from design, to building and operational phases. Reductions in GHG emissions can be achieved by increasing the amount of electricity generated from low-carbon technologies, retrofitting existing buildings, and by constructing new buildings to be nearly zero energy buildings.

MED regions need common and long-term strategy to remove barriers that prevent diffusion of mass Nearly

Zero Energy Building renovation activities, increases energy efficiency, reduces carbon footprint of building stock while improving the growth of local jobs. School buildings in particular, being 20% of the surface of all non-residential buildings in Europe, have a high impact on the annual costs of all communities because of their energy costs (heat, cold and electricity).

TEESCHOOLS tackle these issues making easier and less expensive to conduct energy audits on a large number of school buildings. Results of the project will be transferred and capitalized by network of partners and building on previous experiences.

Methodology

To evaluate the improvement in terms of emissions, the Carbon Footprint has been chosen for its deep connection with the use of energy. The term Carbon Footprint refers to the overall quantity of CO_2 and other greenhouse gas emissions, expressed in CO_2 equivalents, caused directly and indirectly by a product or an activity, or associated with the activities of an individual or an organisation. There are many ways to calculate the Carbon Footprint, here a list of available methodologies will be listed.

Methodologically the Carbon Footprint is generally based on International Standards on life cycle assessment (ISO 14040 and ISO 14044) series.

ISO 14067 specifies principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product (CFP) and on environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) for communication.

ISO 16745, Sustainability in buildings and civil engineering works – Carbon metric of an existing building during use stage, Parts 1 and 2, will provide, in a simple way, a set of methods for the calculation, reporting, communication and verification of a collection of carbon metrics for GHG emissions arising from the measured energy use during the activity of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals.

Product Carbon Footprint Certification calculated based on the "PAS 2050, Publicly Available Specification" standard and the "Greenhouse Gas Protocol, Corporate Accounting and Reporting Standard".

Database

An analysis of LCA databases have been performed to determinate the availability of information concerning greenhouse gas emissions connected to the production of construction materials. For this part of the study international data availability were analysed because, as stated in the article of Martínez-Rocamora “LCA databases focused on construction materials: A review”, the evaluation of the environmental impact caused by construction materials frequently presents a big variety of problems that go from a mismatch between the construction project location and where the LCA database was made, the lack of transparency and the unsuitability of the data. Analysing a list of features and criteria that go from their methodology, documentation, data quality and comprehensiveness, various databases have been compared. The study shows how GaBi and Ecoinvent Databases stand out for their integrity, usability and dedicated resources.

To evaluate the Carbon Footprint of the schools both Gabi Professional and Construction materials databases have been used; Professional database The professional database is provided with the GaBi software is derived from industry sources, scientific knowledge, technical literature, and internal patent information, while the construction materials database contains more than three thousand processes that comprehend natural and technical materials, components and devices.

Software

To calculate CF of schools and renovation solutions proposed, the GaBi Life Cycle Assessment software has been chosen as instrument for modelling. GaBi supports every stage of an LCA, from data collection to presentation of results, with a modular and parameterized architecture, allows modelling of simple and complex processes and different production options. According to the analysis made, GaBi software is completed by comprehensive, up-to-date Life Cycle Inventory databases.

Data from partner's energy audit

In the previous phase of the project, partners have been asked to compile energy audits on a series of schools. Partners were asked to estimate the CO_2 emissions applying national emission factors. Information gathered from the Energy audits allowed us to evaluate the emission profile of the analysed schools considering both the energy and fuel yearly used and an estimation of the materials used to improve the schools' performance.

Carbon Footprint

Two different approaches have been applied to evaluate the GHG emissions associated with the use of scholastic buildings before and after the proposed retrofitting actions. The first one considers only the energy and fuels yearly used and adopt emission factors to calculate the CO_2 emissions. The other one considers energy, fuels and materials used to modify the schools' energetic performances in a life cycle perspective. While the first technique has been applied in the Energy Audit, the following section will calculate the CO_2 with the second approach.

Carbon Footprint of analysed schools

This chapter will show results of Carbon Footprint of schools after the renovation process.

Bosnia And Herzegovina

Elementary school "Hamza Humo" Babino
Description
The school building of Elementary school "Hamza Humo" Babino, consists of two connected buildings: school buildings (old school and new school - upgrades) and sports halls. Total useful area of the school

complex is 1.844,54 m², i.e. school building (1.468,03 m²) and sports hall approx. (372,674 m²).
The school complex is a combination of design of the 60s and 70s in Bosnia and Herzegovina, where the elementary school building was subsequently built up, and making two different architectures of two different periods. Although the existing school buildings from these two periods spends and loses a lot of heat energy, it significantly uses of the “natural energy saving system”. That is why the design of the “Hamza Humo” school building ("T" shape), and its orientation towards the south, significantly influences its thermal condition in the winter and summer.

Initial Energy Requirement

The analysis of the actual energy consumption, water and cost indicators is based on the reference year for 335 users and the total useful floor area of the school and sports hall of 1840,70 m^2.

Table 3.9 – **An overview of the yearly consumption of electricity [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Electricity [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**
2014	22.183	0,7446 kg CO_2/kWh	**16.517**
2015	24.879	0,7446 kg CO_2/kWh	**18.525**
2016	21.166	0,7446 kg CO_2/kWh	**15.760**
Average value	22.743	0,7446 kg CO_2/kWh	**16.934**

The thermal requirements of the building are ensured through a central heating system consisting of equipment located in the boiler room with 2 boilers of 250 kW (produces in 2002 and 2008), pipelines and heating elements located in the heated spaces of the building. (Energy Source, brown coal)

Table 3.9 – **An overview of the yearly consumption of heat energy [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Heat energy [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Emission [kg CO_2/year]**
2014	275.000	0,35 kg CO_2/kWh	**96.250**
2015	300.000	0,35 kg CO_2/kWh	**105.000**
2016	310.000	0,35 kg CO_2/kWh	**108.500**
Average value	295.000	0,35 kg CO_2/kWh	**103.250**

Table 3.9 – **An overview of specific yearly energy consumption**

Indicator	**Reference year**
Delivered heat energy	295.000 kWh/year
	160,26 kWh/m^2
	1.029,4 kWh/user
Electricity	22.743 kWh/year
	12,35 kWh/m^2
	67,88 kWh/user
Total energy	317.743 kWh/year
	172,62 kWh/m^2
	948,48 kWh/user

At the reference year level, the delivered energy has a value of 295,000 kWh/year and the useful surface area of the building is 160,26 kWh/m^2. For the same number of users the supplied heat energy has a value

of 1.029,4 kWh/user.
With regards to the physics of the building, the installed thermal-technical systems, the way of their use and the fact that heat comfort is difficult to achieve, the value of the actual delivered heat energy for the heating of 160,26 kWh/m^2 for this type of building is justified but significantly high and in this context, it is necessary to make certain measurements of energy efficiency improvements to reduce this value.

Aim of the renovation plan

By analysing the condition of the building (schools and sports halls) and comparing the obtained values for the allowed specific thermal loads, it is concluded that the following measures need to be carried out to improve the energy efficiency of the school and the sports hall:
architectural-constructive measures,
measures of thermal-technical systems, and
measures of energy management system
The implementation of the Renewal Action Plan aims to improve energy efficiency through individual measures or combinations (scenarios) of energy efficiency improvement:
Improvement of the thermal characteristics of the outer envelope (measure 1 and measure 2)
Improvement of the energy performance of the heating system (measure 3.1 and measure 3.2)
Improvement of the energy performance of the DHW system (measure 3.3)
Improvement of energy performance of the electricity consumption system – lighting, (measure 3.3)
The analysis of the possibilities of using renewable energy sources (measure 3.3)
Improvement of regulation and management system (measure 3.3),
Introduction of energy management (measure 5)

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Table 4.6 – **Annual amounts of final heat energy and CO_2 emissions**

MEASURE, SCENARIO	Central space heating system			**Electricity system**		**Total CO_2 emission [tCO_2/year]**
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Direct CO_2 emissions [tCO_2/year]	Amount of electricity [kWh/year]	Indirect CO_2 emissions [tCO_2/year]	
Existing state	218.056	270.039	94,51	22.742	16,93	**111,44**
Measure 1.1	198.962	246.393	86,23	22.742	16,93	**103,16**
Measure 1.2	177.243	219.496	76,82	22.742	16,93	**93,75**
Measure 1.3	195.748	242.412	84,84	22.742	16,93	**101,77**
Measure 2.1	198.272	245.538	76,96	22.742	16,93	**93,89**
Measure 2.2	188.695	233.678	81,79	22.742	16,93	**98,72**
Measure 2.3	207.329	256.754	89,86	22.742	16,93	**106,79**
Measure 3.1	218.056	218.056	73,31	22.742	16,93	**90,24**
Measure 3.2	76.628	76.628	26,81	22.742	16,93	**43,74**
Measure 3.3	218.056	270.038	94,51	19.657	14,7	**109,21**
Scenario 1	136.420	168.941	59,12	19.657	14,7	**73,82**
Scenario 2	136.420	136.420	47,74	22.742	16,93	**64,67**
Scenario 3	158.623	196.437	68,75	22.742	16,93	**85,68**

Table 4.7 – **Total annual energy savings**

MEASURE, SCENARIO	Central space heating system			Electricity system		Total savings [kWh/year]
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Final energy savings [kWh/year]	Required heat energy [kWh/year]	Electricity savings [kWh/ year]	
Existing state	218.056	270.039	0	22.742	0,00	
Measure 1.1	198.962	246.393	23.646	22.742	0,00	**23.646**
Measure 1.2	177.243	219.496	50.543	22.742	0,00	**50.543**
Measure 1.3	195.748	242.412	27.627	22.742	0,00	**27.627**
Measure 2.1	198.272	245.538	24.501	22.742	0,00	**24.501**
Measure 2.2	188.695	233.678	36.361	22.742	0,00	**36.361**
Measure 2.3	207.329	256.754	13.285	22.742	0,00	**13.285**
Measure 3.1	218.056	218.056	51.983	22.742	0,00	**51.983**
Measure 3.2	76.628	76.628	193.411	22.742	0,00	**193.411**
Measure 3.3	218.056	270.039	0	19.657	3.085	**3.086**
Scenario 1	136.420	168.941	101.098	19.657	3.085	**104.183**
Scenario 2	76.628	76.628	193.411	22.742	0,00	**193.411**
Scenario 3	158.623	196.437	73.602	22.742	0,00	**73.602**

Materials and components

Table 5.1 – **The evaluation of total renovation costs for individual measures 1, 2 and 3**

ACTION	VOICE	Amount [UM]	Unit price [€/UM]	Unit cost [€/UM]	Total cost [€] without VAT 17%
Measure 1.1 Outer envelope of the school	The preparation of the damaged outer envelope	803,93 m^2	2,06	1.656,10	**29.230,77**
	Protection of the outer openings	346,91 m^2	0,52	180,40	
	Thermal insulation of the walls	803,93 m^2	30,77	24.736,93	
	Unforeseen works (10%).	10,00%	26.573,43	2.657,34	
Measure 1.2 Outer envelope of the school	Roof removal	764,47 m^2	2,06	1.547,81	**54.318,77**
	Roofing works	764,47 m^2	28,21	21.565,70	
	Thermal insulation of the ceiling	764,47 m^2	34,36	26.267,19	
	Unforeseen works (10%).	10,00%	49.380,70	4.938,07	
Measure 1.3 Outer envelope of the school	Removal of existing windows	340,10 m^2	1,03	350,31	**38.731,61**
	Placement of new openings, PVC windows	340,10 m^2	102,50	34.860,25	
	Unforeseen works (10%).	10,00 %	35.210,56	3.521,05	
Measure	The preparation of the damaged	452,31 m^2	2,06	931,76	**16.593,00**

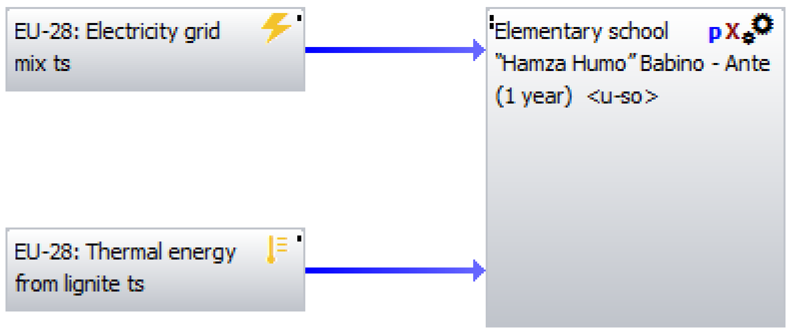
2.1 **Outer envelope of the sports hall**	outer envelope				
	Protection of outer openings	452,31 m^2	0,52	235,21	
	Thermal insulation of the outer walls	452,31 m^2	30,77	13.917,58	
	Unforeseen works (10%).	10,00%	15.084,55	1.508,45	
Measure 2.2 **Outer envelope of the sports hall**	Preparation of the base, flat roof	461,35 m^2	12,82	5.914,51	**14.321,23**
	The making of the final layer, flat roof	461,35 m^2	15,40	7.104,79	
	Unforeseen works (10%).	10,00%	13.019,30	1.301,93	
Measure 2.3 **Outer envelope of the sports hall**	Removal of existing openings	136,82 m^2	1,03	140,93	**15.581,47**
	Placement of new openings, PVC windows	136,82 m^2	102,50	14.024,05	
	Unforeseen works (10%).	10,00 %	14.164,98	1.416,49	
Measure 3.1 **Heating system**	Installation of thermostatic valves	66 pcs	30,77	2.030,82	**3.771,55**
	Installation of the calorimeter	1 pcs	512,82	512,82	
	Installation of the frequent pumps	1 pcs	1.025,65	1.025,65	
	Unforeseen works (10%).	10,00 %	2.030,82	203,08	
Measure 3.3 Renewable sources and lighting	Solar system WT20-200S	1 pcs	1.907,70	1.907.70	**2.900,17**
	Installation of the solar system WT20-200S	1 pcs	512,82	512,82	
	Installation of LED lighting 14 W	60 pcs	3,60	216	
	Unforeseen works (10%).	10,00 %	2.636,52	263,65	

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

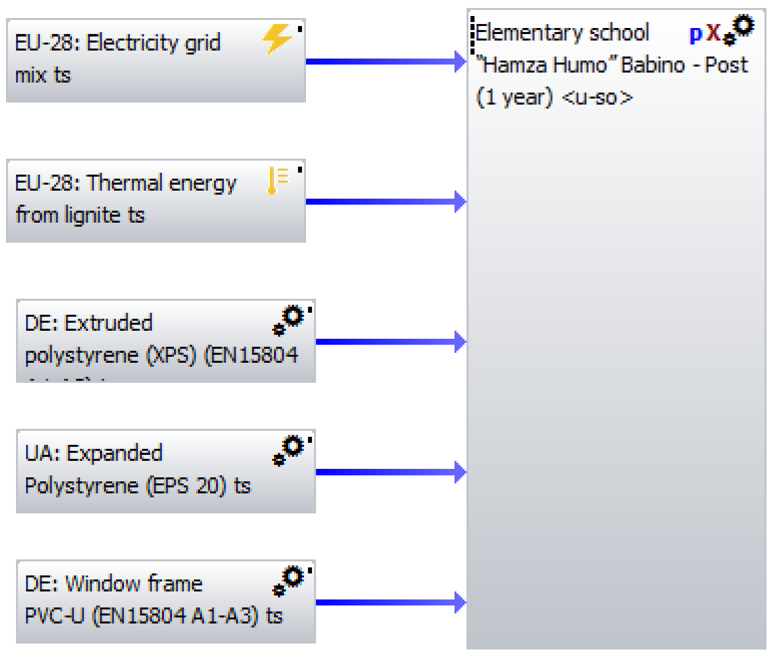
Elementary school “Hamza Humo” Babino - Ante (1 year)

Process plan:Reference quantities

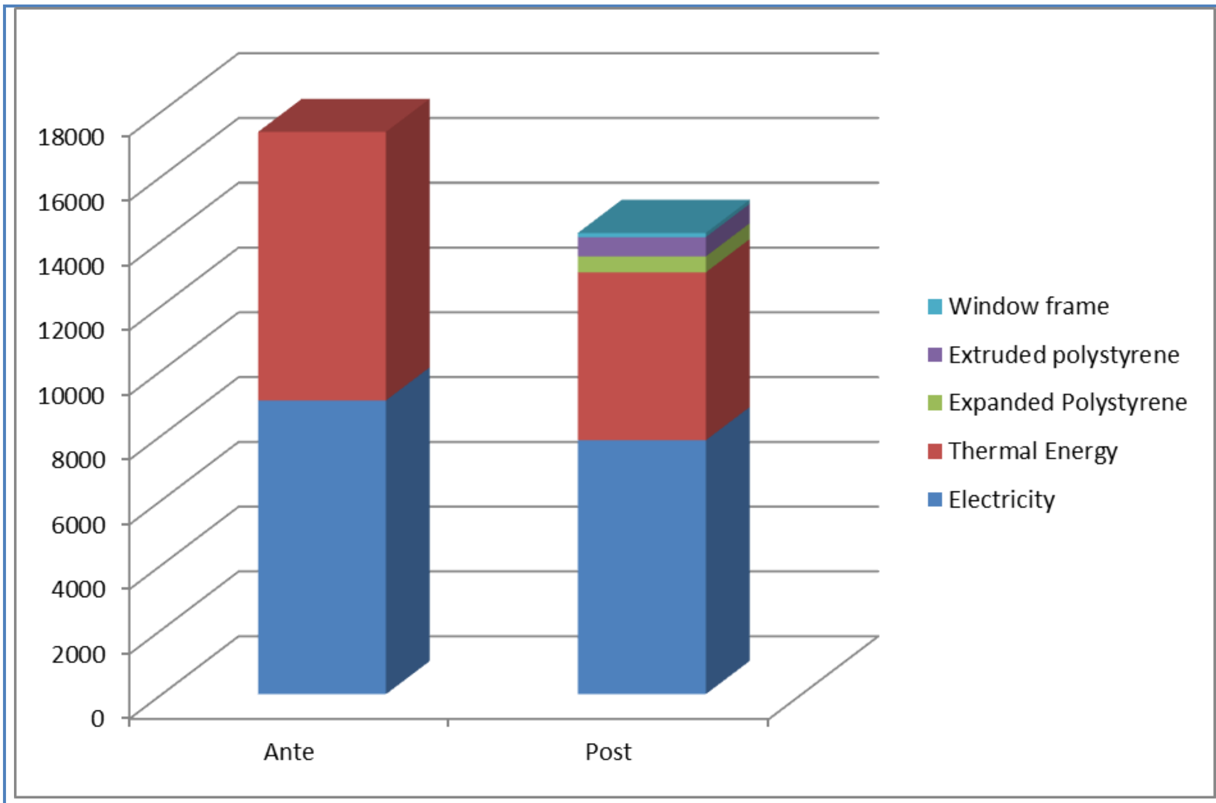


Elementary school “Hamza Humo” Babino - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 18% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 9% of the Post intervention emissions.

PI Elementary School "Alija Nametak"

Description

The school building complex where the PI Elementary School "Alija Nametak" is located consists of two connected buildings: school buildings and sports hall. The total usable area of the PI elementary school complex Alija Nametak is 1904.35 m^2: school building (1.603,00 m^2) and sports hall (301.35 m^2).
The school complex is a design from the 70's in Bosnia and Herzegovina, the architecture that is characteristic for this construction period. Though the existing school buildings from this time consume and lose a lot of heat energy, they use the natural energy saving system considerably, because the orientation towards the south side significantly influences its thermal behaviour in the winter and summer.

Initial Energy Requirement

The electricity supply of the school building is carried out through the public electricity distribution network system. The power grid system supplies energy-consuming systems for hot water preparation, lighting, IT equipment, kitchen equipment and other consumables. An analysis of total electricity consumption was carried out for the years 2014, 2015 and 2016.

Table 3.8 – **An overview of the consumption of electrical energy [kWh]**

Year	2014	2015	2016
Month	**Total [kWh]**	**Total [kWh]**	**Total [kWh]**
January	2.410	3.216	3.181
February	2.987	3.867	2.899

March	2.822	3.884	1.813
April	2.234	3.317	1.577
May	1.545	2.705	650
June	1.131	1.636	458
July	1.555	1.124	904
August	784	1.035	1.025
September	3.039	2.050	1.994
October	3.196	3.381	2.337
November	3.463	3.528	2.197
December	4.442	4.821	2.131
Total	**29.609**	**34.565**	**21.166**
Reference – average value [kWh]			**22.742**

Based on the analysis of the data collected for 2014, 2015 and 2016, the mean value of the annual electricity consumption for different expenditures is presented in Table 3.9.

Table 3.9 - **An overview of the consumption of electrical energy system [kWh]**

	Energy source	**Electricity**
Electrical energy consumers system	Yearly real electrical energy of the PTV system consumption	5.200 kWh/year
	Yearly real electrical energy of the lighting system consumption	11.536 kWh/year
	Yearly real electrical energy of the IT equipment consumption	1.684 kWh/year
	Yearly real electrical energy of the kitchen equipment consumption	5.920 kWh/year
	Yearly real electrical energy of the other consumers consumption	4.106 kWh/year
	Total yearly real electrical energy consumption	**28.446 kWh/**year

Based on the above-mentioned analysis of the energy consumption of the energy source within the system used in the school, it can be seen that 40,55% of the consumption of electricity has the highest share in the total electricity consumption.

The heat requirements of the school building are provided through a central heating system consisting of equipment located in the boiler room, piping and heating elements located in the heated spaces of the object. The furnace in the boiler as an energy source uses brown coal. Coal consumption is monitored on an annual level of consumed tons, and monthly consumption data are not available because they depend on the periodic acquirements. The heat needs shown in the table are calculated on the basis of the reduced calorific value of brown coal (20.8 [MJ / kg]) of Kakanj and Banovići – B&H sites.

Table 3.10 – **An overview of the annual consumption of heat energy [kWh]**

An overview of the monthly and annual consumption of delivered heat energy						
Year	**2014**		**2015**		**2016**	
Month	**[t]**	**[kWh]**	**[t]**	**[kWh]**	**[t]**	**[kWh]**
January	* There is no precise record of monthly		* There is no precise record of monthly		* There is no precise record of monthly	
February						
March						

April	consumptions		consumptions		consumptions	
October						
November						
December						
Total	**53,44**	**267.200**	**53,54**	**267.700**	***66,68***	**333.400**

On the basis of accumulated heat energy consumption bills for three consecutive years (2014, 2015 and 2016), the average annual consumption of the brown coal fuels for the needs of heating system in the amount of 57,88 t/y or 289,433 kWh/year.
The analysis of the actual energy consumption, water and cost indicators is based on the reference year for 478 users and the total useful floor area of the school and sports hall of 1.904,35 m^2.

Table 3.11 – **An overview of the yearly consumption of electricity [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Electricity [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**
2014	29.609	0,7446 kg CO_2/kWh	**22.047**
2015	34.565	0,7446 kg CO_2/kWh	**25.737**
2016	21.166	0,7446 kg CO_2/kWh	**15.760**
Average value	**28.446**	0,7446 kg CO_2/kWh	**21.181**

Table 3.12 – **An overview of the yearly consumption of heat energy [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Heat energy [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Emission [kg CO_2/year]**
2014	267.200	0,35 kg CO_2/kWh	**93.520**
2015	267.700	0,35 kg CO_2/kWh	**93.695**
2016	333.400	0,35 kg CO_2/kWh	**116.690**
Average value	289.433	0,35 kg CO_2/kWh	**101.301**

Table 3.13 – **An overview of specific yearly energy consumption**

Indicator	**Reference year**
Delivered heat energy	289.433 kWh/year
	152,01 kWh/m^2
	605,50 kWh/user
Electricity	28.446 kWh/year
	14,93 kWh/m^2
	59,51 kWh/user
Total energy	317.879 kWh/year
	166,92 kWh/m^2
	665,01 kWh/user

At the reference year level, the delivered energy has a value of 289,433 kWh/year and the usable area of the object is 152,01 kWh/m^2. For the same number of users the supplied heat energy has a value of 605,50

kWh/user.
With regard to the physics of the building, the installed thermal-technical systems, the way of their use and the fact that the heat comfort is difficult to realize, the value of the actual heat energy supplied in the amount of 152,01 kWh/m^2 for this type of building is justified but significantly high and in this context, it is necessary to make certain measurements of energy efficiency improvements to reduce this value.

Aim of the renovation plan

By analysing the condition of the building (schools and sports halls) and comparing the obtained values for the allowed specific thermal loads, it is concluded that the following measures need to be carried out to improve the energy efficiency of the school and the sports hall:
architectural-constructive measures,
measures of thermal-technical systems, and
measures of energy management system
The implementation of the Renewal Action Plan aims to improve energy efficiency through individual measures or combinations (scenarios) of energy efficiency improvement:
Improvement of the thermal characteristics of the outer envelope (measure 1 and measure 2)
Improvement of the energy performance of the heating system (measure 3.1 and measure 3.2)
Improvement of the energy performance of the DHW system (measure 3.3)
Improvement of energy performance of the electricity consumption system – lighting, (measure 3.3)
The analysis of the possibilities of using renewable energy sources (measure 3.3)
Improvement of regulation and management system (measure 3.3),
Introduction of energy management (measure 5)

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Table 4.6 – **Annual amounts of final heat energy and CO_2 emissions**

MEASURE, SCENARIO	Central space heating system			**Electricity system**		**Total CO_2 emission [tCO_2/year]**
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Direct CO_2 emissions [tCO_2/year]	Amount of electricity [kWh/year]	Indirect CO_2 emissions [tCO_2/year]	
Existing state	102.632	127.098	44,48	28.446	21,18	**65,66**
Measure 1.1	98.396	112.581	39,40	28.446	21,18	**60,58**
Measure 1.2	94.093	107.658	37,68	28.446	21,18	**58,86**
Measure 1.3	93.096	106.517	37,28	28.446	21,18	**58,46**
Measure 2.1	103.509	118.431	41,45	28.446	21,18	**62,63**
Measure 2.2	99.331	113.651	39,78	28.446	21,18	**60,96**
Measure 3.1	102.632	102.632	35,92	28.446	21,18	**57,10**
Measure 3.2	98.457	98.457	34,46	28.446	21,18	**55,64**
Measure 3.3	102.632	127.098	44,48	19.146	14,25	**58,73**
Scenario 1	83.537	95.580	33,45	19.146	14,25	**47,70**
Scenario 2	56.686	56.686	19,84	28.446	21,18	**41,02**
Scenario 3	44.608	44.608	15,61	28.446	21,18	**36,79**

Table 4.7 – **Total annual energy savings**

MEASURE, SCENARIO	Central space heating system			Electricity system		Total savings [kWh/year]
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Final energy savings [kWh/year]	Required heat energy [kWh/year]	Electricity savings [kWh/ year]	
Existing state	102.632	127.098	0	28.446	0,00	**0**
Measure 1.1	98.396	112.581	14.517	28.446	0,00	**14.517**
Measure 1.2	94.093	107.658	19.440	28.446	0,00	**19.440**
Measure 1.3	93.096	106.517	20.581	28.446	0,00	**20.581**
Measure 2.1	103.509	118.431	8.667	28.446	0,00	**8.667**
Measure 2.2	99.331	113.651	13.447	28.446	0,00	**13.447**
Measure 3.1	102.632	102.632	24.466	28.446	0,00	**24.466**
Measure 3.2	44.608	44.608	82.490	28.446	0,00	**82.490**
Measure 3.3	102.632	127.098	0	19.146	9.300	**9.300**
Scenario 1	83.537	95.580	31.518	19.146	9.300	**40.818**
Scenario 2	56.686	56.686	70.412	28.446	0,00	**70.412**
Scenario 3	44.608	44.608	82.490	28.446	0,00	**82.490**

Materials and components

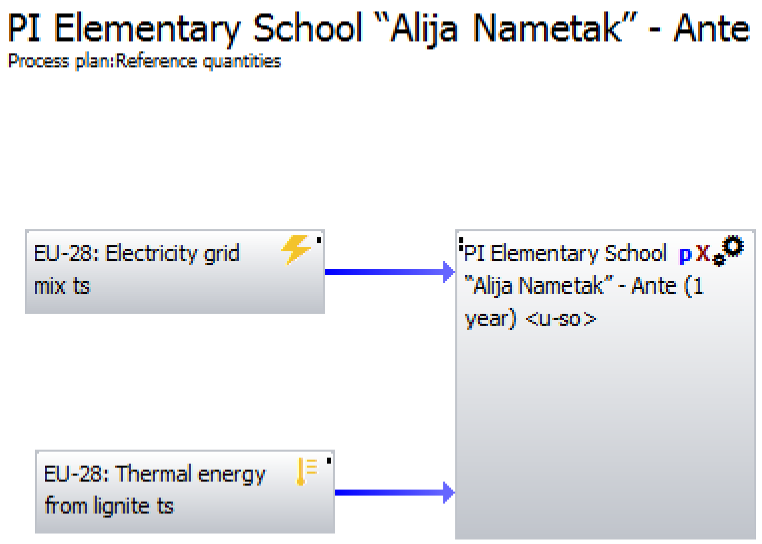
Table 5.1 – **The evaluation of total renovation costs for individual measures 1, 2 and 3**

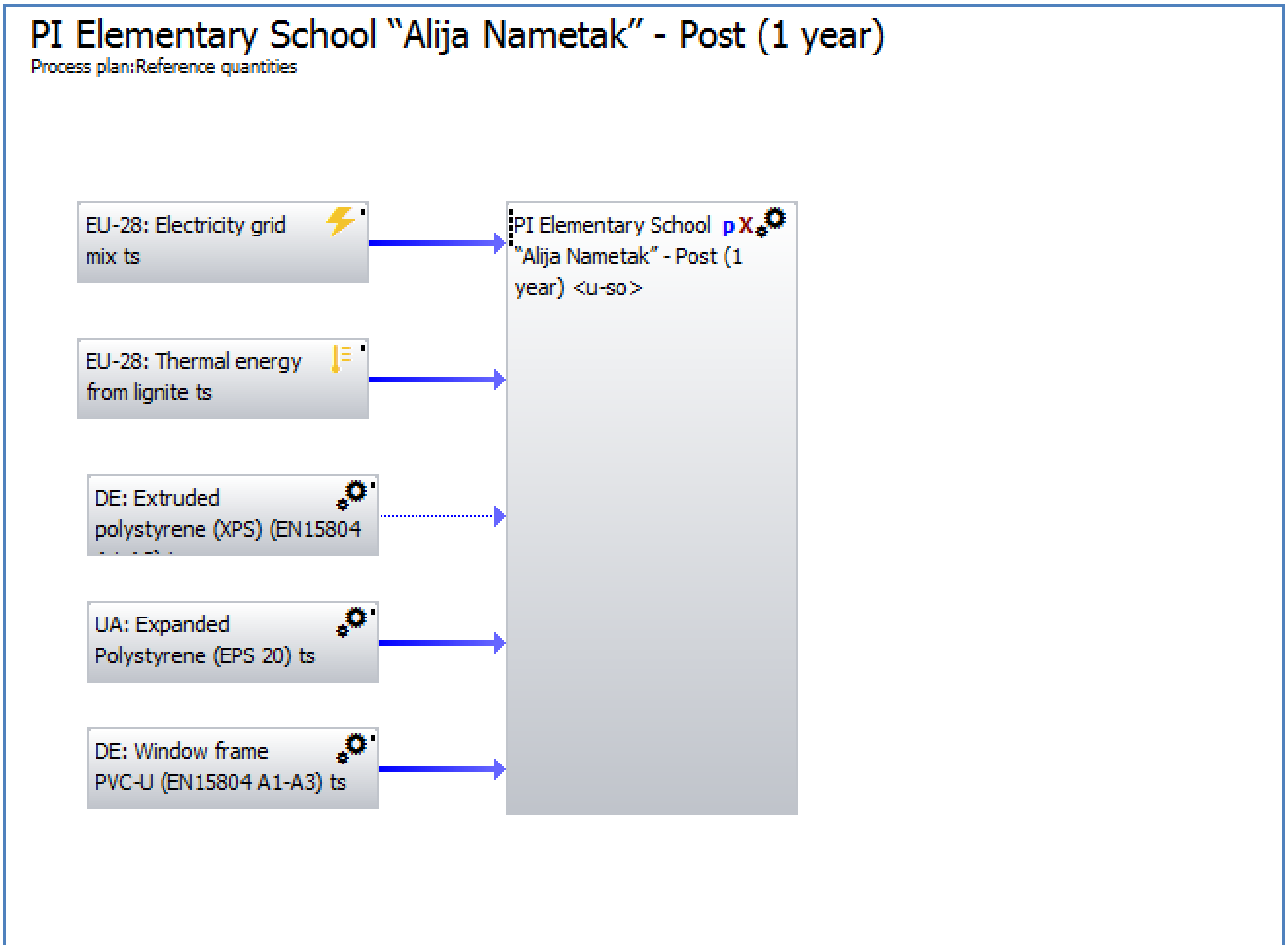
ACTION	VOICE	Amount [UM]	Unit price [€/UM]	Unit cost [€/UM]	Total cost [€] without VAT 17%
Measure 1.1 Outer envelope of the school	The preparation of the damaged outer envelope	698,87 m^2	4,00	2.795,48	**49.571,14**
	Protection of the outer openings	337,00 m^2	1,00	337,00	
	Thermal insulation of the walls	698,87 m^2	60,00	41.935,20	
	Unforeseen works (10%).	10,00%	45.064,48	4.506,44	
Measure 1.2 Outer envelope of the school	Substrate preparation, the flat roof	151,31 m^2	25,00	3.782,75	**9.154,25**
	Making of the finishing layer	151,31 m^2	30,00	4.539,30	
	Unforeseen works (10%).	10,00%	8.322,05	832,20	
Measure 1.3 Outer envelope of the school	Removal of existing windows	337,00 m^2	2,00	674,00	**74.881,40**
	Placement of new openings, PVC windows	337,00 m^2	200,00	67.400,00	
	Unforeseen works (10%).	10,00 %	68.074,00	6.807,40	
Measure	The preparation of the damaged outer envelope	301,32 m^2	4,00	1.205,28	**21.099,76**

2.1	Protection of outer openings	77,12 m^2	1,00	77,12	
	Thermal insulation of the outer walls	301,32 m^2	60,00	18.079,20	
Outer envelope of the sports hall	Unforeseen works (10%).	10,00%	19.181,60	1.918,16	
Measure 2.2	Removal of existing windows	77,12 m^2	2,00	154,24	
	Placement of new openings, PVC windows	77,12 m^2	200,00	15.424,00	**17.136,06**
Outer envelope of the sports hall	Unforeseen works (10%).	10,00 %	15.578,24	1.557,82	
Measure 3.1/2	Installation of thermostatic valves	86 pcs	60,00	5.676,00	
	Installation of the calorimeter	1 pcs	1.000,00	1.000,00	
	Installation of the frequent pumps	1 pcs	2.000,00	2.000,00	**9.543,60**
Heating system	Unforeseen works (10%).	10,00 %	8.676,00	867,60	
Measure 3.3 Renewable sources and lighting	Solar system WT20-200S	1 pcs	3.720,00	3.720,00	
	Installation of the solar system WT20-200S	1 pcs	1.000,00	1.000,00	
	Installation of LED lighting 14 W	57 pcs	7,00	399	**5.630,90**
	Unforeseen works (10%).	10,00 %	5.119,00	511,90	

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software




PI Elementary School "Alija Nametak" - Post (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
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DE: Extruded polystyrene (XPS) (EN15804
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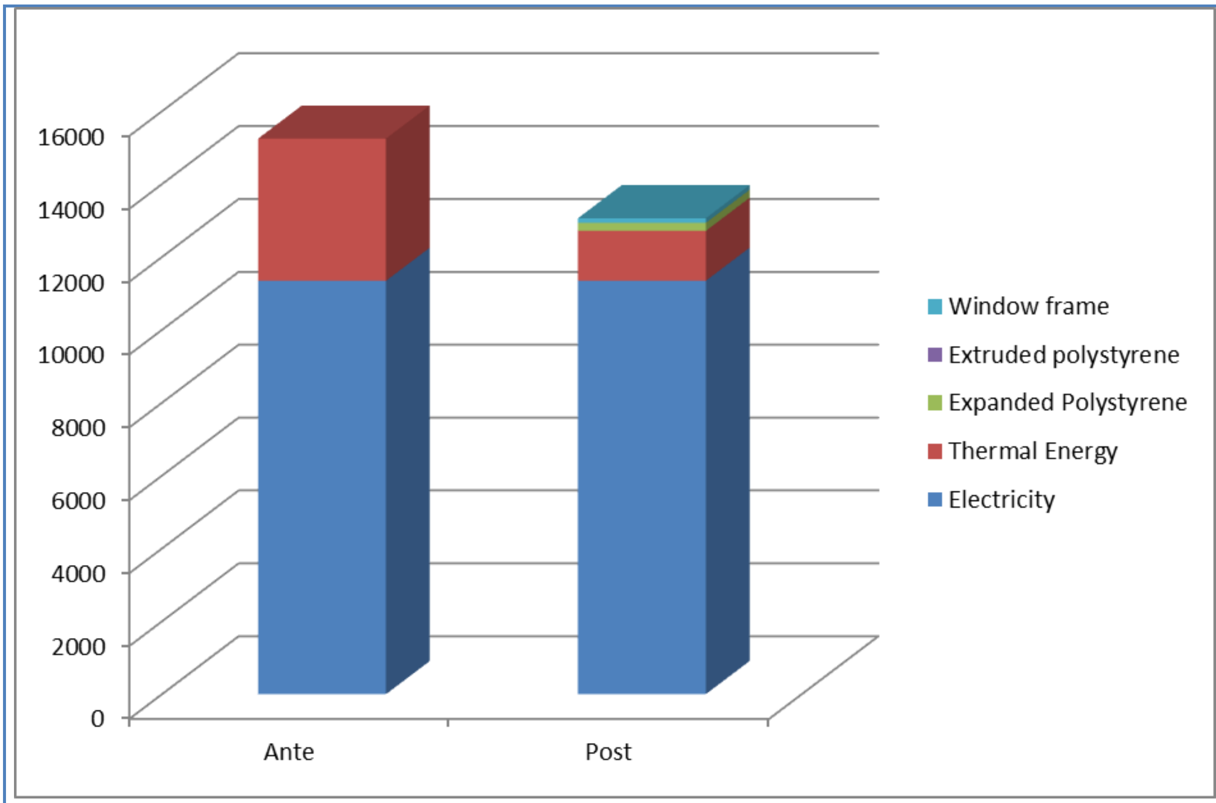
DE: Window frame PVC-U (EN15804 A1-A3) ts
PI Elementary School "Alija Nametak" - Post (1 year) <u-so>

Results



After the proposed renovation, the school overall emissions decreased of around 15% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 3% of the Post intervention emissions.

PI elementary school Kulin Ban

Description

The complex within which is located the PI elementary school Kulin Ban consists of two separate buildings: school building and a sports hall. The total usable area of the school building and sports hall is 1.633,50 m^2. Elementary school Kulin Ban is a frequent combination of design of the 60s and 70s in Bosnia and Herzegovina. The school building is built in 1909, which was subsequently expanded in 1967, the architecture of monolithic blocks characteristic of that period of construction. The school is not connected to the sports hall that was built in 1978. Although the existing school building from these two periods spend and loses a lot of heat energy, it is a significant use of the natural energy saving system. That is why the design of the school building Kulin Ban, its location, orientation towards the south, significantly influences its thermal behaviour in winter and summer.

Initial Energy Requirement

The electricity supply of the school building is carried out through the public electricity distribution network system. The power grid system supplies energy-consuming systems for hot water preparation, lighting, IT equipment, kitchen equipment and other consumables. An analysis of total electricity consumption was carried out for the years 2014, 2015 and 2016.

Table 3.8 – **An overview of the consumption of electrical energy [kWh]**

Year	2014	2015	2016
Month	Total [kWh]	Total [kWh]	Total [kWh]

January	1.936	2.964	2.778
February	2.162	2.950	2.219
March	1.517	2.347	1.917
April	1.125	1.438	1.174
May	683	856	1.124
June	487	165	559
July	0	371	365
August	523	443	493
September	862	837	948
October	1.102	1.609	1.712
November	1.462	1.763	2.116
December	2.280	3.089	3.559
Total	**14.139**	**18.832**	**18.964**
Reference – average value [kWh]			**17.312**

By comparing spending for 2014, 2015 and 2016, there is a reduction in electricity consumption during the period from June to August, during the period of reduced school activities; a trend of increased consumption over the same period of three years is noticeable.

Table 3.9 – **An overview of the consumption of electrical energy system [kWh]**

Electricity consumables system	**Energy source**	**Electricity**
	Yearly real electrical energy of the PTV system consumption	1.942 kWh/year
	Yearly real electrical energy of the lighting system consumption	5.126 kWh/year
	Yearly real electrical energy of the IT equipment consumption	5.218 kWh/year
	Yearly real electrical energy of the kitchen equipment consumption	2.500 kWh/year
	Yearly real electrical energy of the other consumers consumption	5.020 kWh/year
	Total yearly real electrical energy consumption	**19.806 kWh/year**

An overview of the annual consumption of the system of electricity within the system used in the school shows that the consumption of electricity for lighting has the highest share in electricity consumption.

Table 3.9 – **An overview of the annual consumption of heat energy [kWh]**

An overview of the monthly and annual consumption of delivered heat energy			
Year	**2014**	**2015**	**2016**
Month	**Total [kWh]**	**Total [kWh]**	**Total [kWh]**
January	61.165	70.653	65.039
February	48.700	56.255	51.784
March	43.424	50.160	46.174
April	19.943	23.037	21.207
October	18.059	20.861	19.203

November	41.453	47.883	44.078
December	57.425	66.334	61.063
Total	**290.169**	**335.186**	**308.551**
Reference value [kWh]			**311.300**

The theoretical amount of coal required is 125 t/year, while the building consumes an average of 80 t/year of coal and it is evident that the building is not heated enough. Based on the collected data of coal consumption over the three consecutive years (2014, 2015 and 2016), the values of average annual heat consumption for the needs of the district heating system are calculated in the amount of 311.300 kWh/year.

The analysis of the actual energy consumption, water and cost indicators is based on the reference year for 528 users and the total useful floor area of the school and sports hall of 1.633,50 m^2.

Table 3.11 – **An overview of the yearly consumption of electricity [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Electricity [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**
2014	14.139	0,7446 kg CO_2/kWh	10.528
2015	18.832	0,7446 kg CO_2/kWh	14.022
2016	18.964	0,7446 kg CO_2/kWh	14.121
Average value	**17.312**	0,7446 kg CO_2/kWh	**12.891**

Table 3.12 – **An overview of the yearly consumption of heat energy [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Heat energy [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**
2014	290.169	0,35 kg CO_2/kWh	101.559
2015	335.186	0,35 kg CO_2/kWh	117.315
2016	308.551	0,35 kg CO_2/kWh	107.993
Average value	311.300	0,35 kg CO_2/kWh	**108.955**

Table 3.13 – **An overview of specific yearly energy consumption**

Indicator	**Reference year**
Delivered heat energy	311.300 kWh/year
	190,57 kWh/m^2
	589,58 kWh/user
Electricity	17.312kWh/year
	10,59 kWh/m^2
	32,78 kWh/user
Total energy	328.612 kWh/year

	201,17 kWh/m^2
	622,37 kWh/user

At the reference year level, the supplied heat energy has a value of 311.300 kWh/year and the useful surface of the building is 190,57 kWh/m^2. For the same number of users, the supplied heat energy has a value of 58,58 kWh/user.
With regard to the physics of the building, the installed thermal-technical systems, the way of their use and the fact that the heat comfort is difficult to realize, the value of the actual delivered heat energy for the heating of 190,57 kWh/m^2 for this type of building is justified but significantly high and in this context, it is necessary to make certain measurements of energy efficiency improvements to reduce this value.

Aim of the renovation plan

By analysing the condition of the building (schools and sports halls) and comparing the obtained values for the allowed specific thermal loads, it is concluded that the following measures need to be carried out to improve the energy efficiency of the school and the sports hall:
architectural-constructive measures,
measures of thermal-technical systems, and
measures of energy management system
The implementation of the Renewal Action Plan aims to improve energy efficiency through individual measures or combinations (scenarios) of energy efficiency improvement:
Improvement of the thermal characteristics of the outer envelope (measure 1 and measure 2)
Improvement of the energy performance of the heating system (measure 3.1 and measure 3.2)
Improvement of the energy performance of the DHW system (measure 3.3)
Improvement of energy performance of the electricity consumption system – lighting, (measure 3.3)
The analysis of the possibilities of using renewable energy sources (measure 3.3)
Improvement of regulation and management system (measure 3.3),
Introduction of energy management (measure 5)

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Table 4.6 – **Annual amounts of final heat energy and CO_2 emissions**

MEASURE, SCENARIO	Central space heating system			**Electricity system**		**Total CO_2 emission [tCO_2/year]**
	Required heat energy [kWh/year]	**Required final energy [kWh/year]**	**Direct CO_2 emissions [tCO_2/year]**	**The amount of electricity [kWh/ year]**	**Indirect CO_2 emissions [tCO_2/year]**	
Existing state	339.188	485.967	170,09	19.806	14,75	**184,84**
Measure 1.1	286.812	410.905	143,82	19.806	14,75	**158,56**
Measure 1.2	334.055	478.588	167,51	19.806	14,75	**182,25**
Measure 1.3	189.853	271.995	95,20	19.806	14,75	**109,95**
Measure 2.1	339.188	339.188	118,72	19.806	14,75	**133,46**
Measure 2.2	73.228	73.228	25,63	19.806	14,75	**40,38**
Measure 3	339.188	485.967	170,09	13.652	10,17	**180,25**
Scenario 1	82.864	118.716	41,55	13.652	10,17	**51,72**
Scenario 2	73.228	73.228	25,63	19.806	14,75	**40,38**

Table 4.7 – **Total annual energy savings**

MEASURE, SCENARIO	Central space heating system			Electricity system		Total savings [kWh/year]
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Final energy savings [kWh/year]	Required heat energy [kWh/year]	Electricity savings [kWh/ year]	
Existing state	339.188	485.967	0	19.806	0,00	0
Measure 1.1	286.812	410.905	75.062	19.806	0	**75.062**
Measure 1.2	334.055	478.588	7.379	19.806	0	**7.379**
Measure 1.3	189.853	271.995	213.972	19.806	0	**213.972**
Measure 2.1	339.188	339.188	146.779	19.806	0	**146.779**
Measure 2.2	73.228	73.228	412.739	19.806	0	**412.739**
Measure 3	339.188	485.967	0	13.652	6.154	**6.154**
Scenario 1	82.864	118.716	367.251	13.652	6.154	**373.405**
Scenario 2	73.228	73.228	412.739	19.806	0	**412.739**

Materials and components

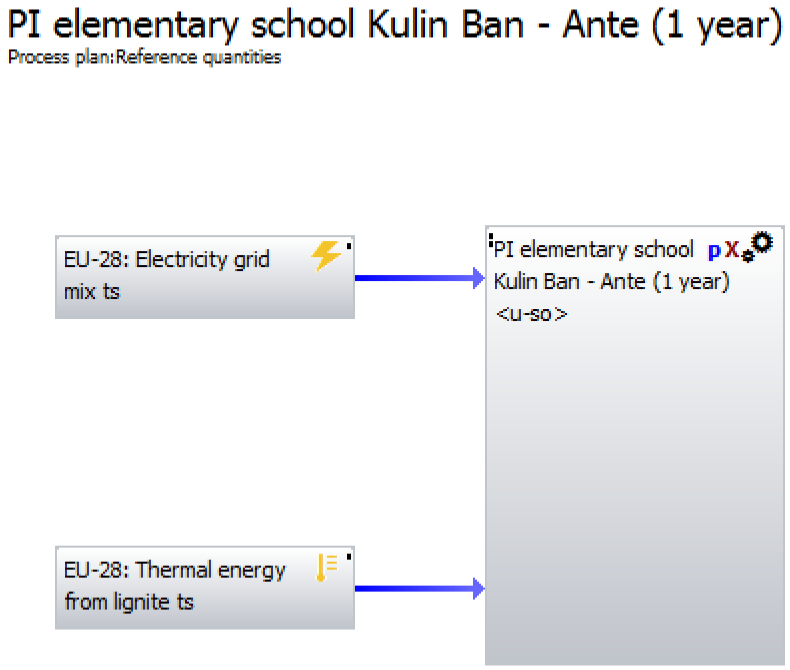
Table 5.1 – **Evaluation of the total renovation price for individual measures 1, 2 and 3**

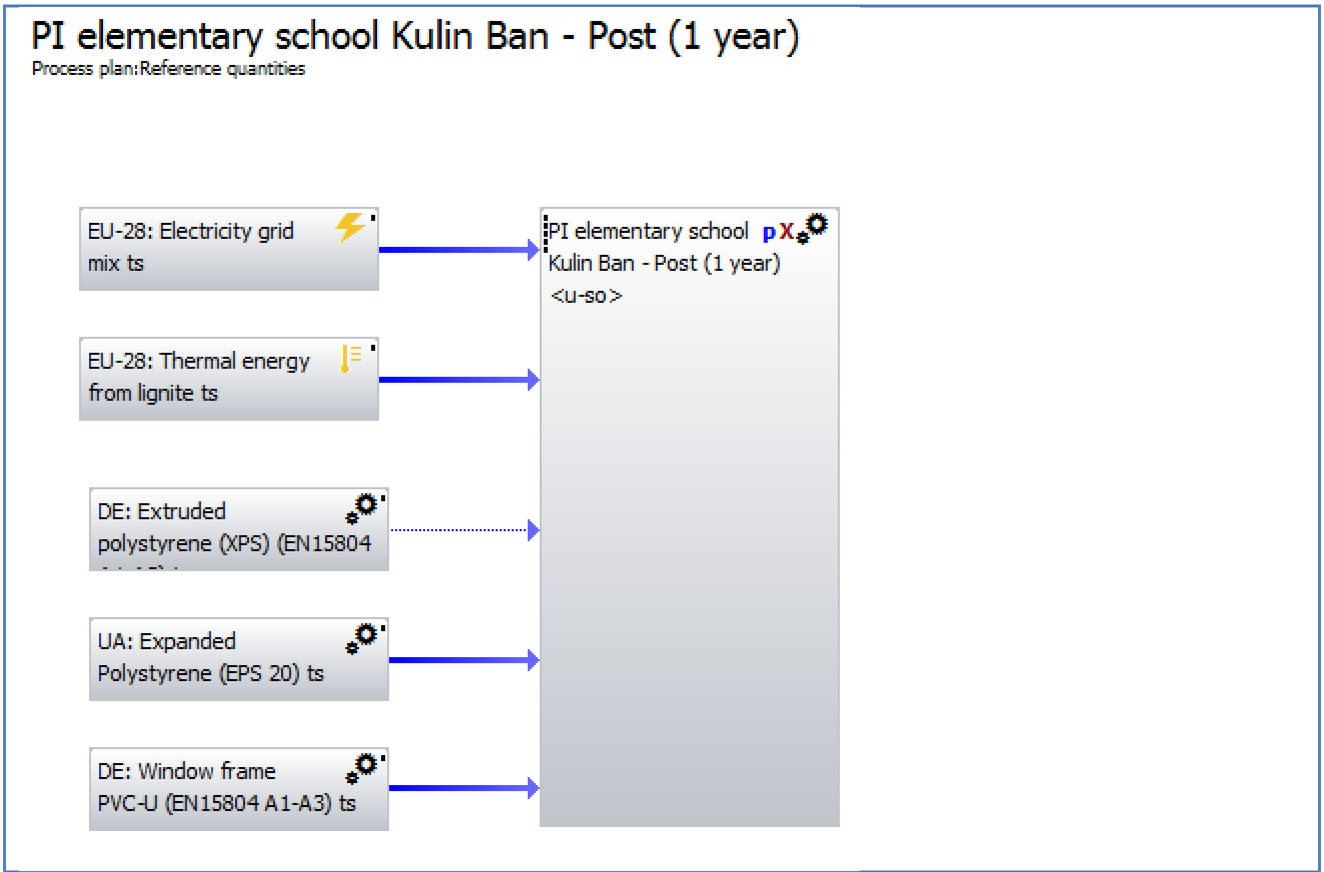
ACTION	VOICE	Amount [UM]	Unit price [KM/UM]	Unit cost [KM/UM]	Total cost [KM] without VAT 17%
Measure 1.1 Outer school envelope	The preparation of the damaged outer envelope	1.085,52 m^2	4,00	4.342,08	**76.968,48**
	Protection of the outer openings	497,16 m^2	1,00	497,16	
	Thermal insulation of the walls	1.085,52 m^2	60,00	65.132,20	
	Unforeseen works (10%).	10,00%	69.970,44	6.997,04	
Measure 1.2 Outer school envelope	Disassembling of the roof	675,00 m^2	4,00	2.700,00	**98.656,41**
	Roof covering works	675,00 m^2	55,00	37.125,00	
	Thermal insulation of the attic – ceiling	744,30 m^2	67,00	49.868,10	
	Unforeseen works (10%).	10,00%	89.693,10	8.963,31	
Measure 1.3 Outer school envelope	Removal of existing openings	497,16 m^2	2,00	994,32	**110.468,95**
	Installation of openings, PVC windows	497,16 m^2	200,00	99.432,00	
	Unforeseen works (10%).	10,00 %	100.426,32	10.042,63	
Measure 2.2 Heating system	Installation of thermostatic valves	78 pcs	60,00	4.680,00	**11.748,00**
	Installation of the calorimeter	2 pcs	1.000,00	2.000,00	
	Installation of the frequent pumps	2 pcs	2.000,00	4.000,00	
	Unforeseen works (10%).	10,00 %	10.680,00	1.068,00	
Measure 3.	Installation of solar systems WT20-	1 pcs	3.720,00	3.720,00	

Renewable sources and lighting	200S				**5.938,90**
	Installation of solar systems WT20-200S	1 pcs	1.000,00	1.000,00	
	Installation of LED lighting 10 W	97 pcs	7,00	679,00	
	Unforeseen works (10%).	10,00 %	5.399,00	539,90	

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software




PI elementary school Kulin Ban - Post (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from lignite ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
PI elementary school Kulin Ban - Post (1 year)
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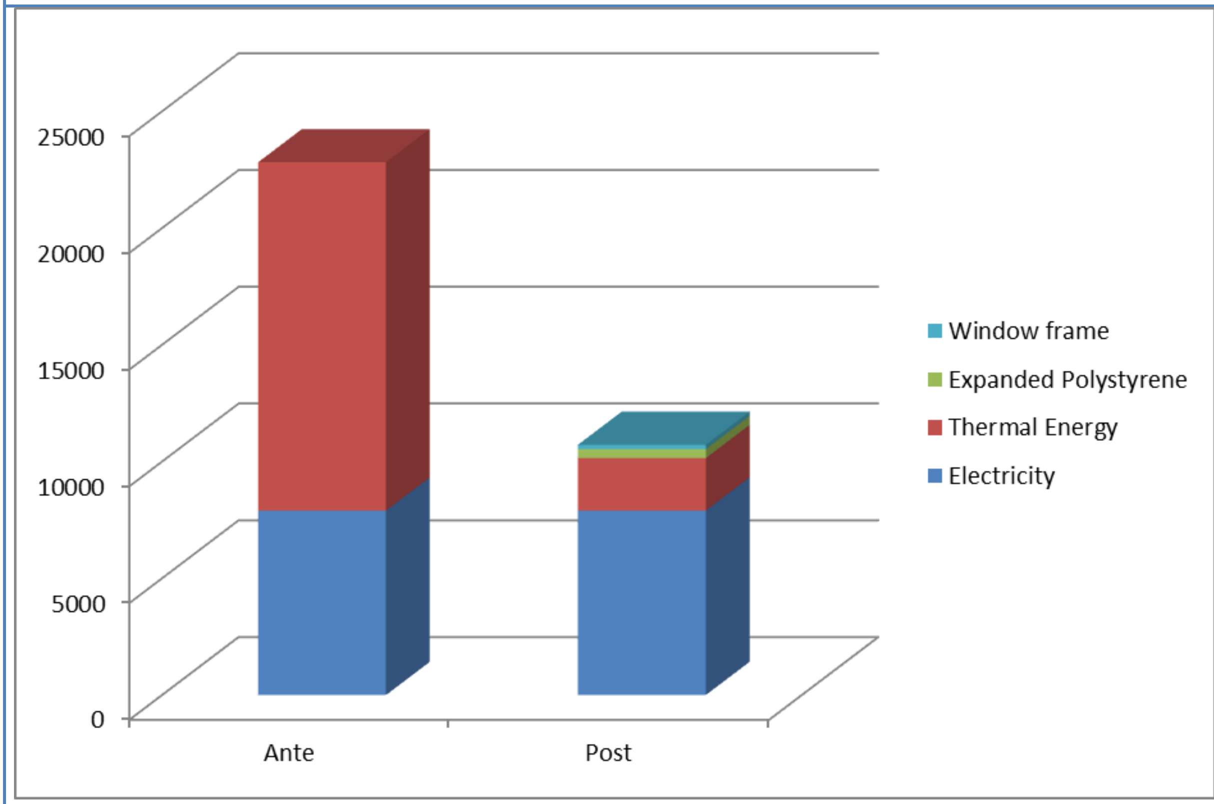
Results


25000
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Expanded Polystyrene
Thermal Energy
Electricity

After the proposed renovation, the school overall emissions decreased of around 53% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 5% of the Post intervention emissions.

PI elementary school "Žepče"

Description

Complex PI elementary school "Žepče" consists of two connected buildings: school building (small and large school) and sports hall. Total usable area of the buildings of the PI complex of elementary school "Žepče" is 2.065,67 m^2 (small school building: 1.279,22 m^2 and sports hall: 786,45 m^2).
The school complex is a frequent design of the 60s in Bosnia and Herzegovina, where the school building "small school" was later upgraded to the existing "big school". The school building of the small school was once again upgraded in 2016 to give the appearance and design of a modern building. By the reconstruction of the school building, it no longer spends and loses heat energy, which compensates for the lack of a natural energy saving system due to its orientation towards the East / West.

Initial Energy Requirement

The electricity supply of the school building is carried out through the public electricity distribution network system. The power grid system supplies energy-consuming systems for hot water preparation, lighting, IT equipment, kitchen equipment and other consumables. An analysis of total electricity consumption was carried out for the years 2014, 2015 and 2016.

Table 3.8 – **An overview of the consumption of electrical energy [kWh]**

An overview of the monthly and yearly costs for the delivered electrical energy [kWh]						
Year	**2014**		**2015**		**2016**	
Object	**Small school**	**Sports hall**	**Small school**	**Sports hall**	**Small school**	**Sports hall**
January	1.768	930	723	1.429	571	1.716
February	2.567	1.260	1.011	1.861	153	2.520
March	1.626	1.245	940	1.822	165	2.565
April	1.160	1.487	780	1.314	364	1.546
May	776	1.101	739	1.077	483	1.314
June	438	808	287	662	129	535
July	1	114	1	298	110	135
August	566	234	142	431	115	254
September	1.416	1.520	326	1.154	622	1.354
October	1.881	1.890	1.088	2.734	1.280	2.020
November	1.664	1.537	534	2.708	1.082	187
December	841	1.826	853	2.708	1.710	2.023
Total	**14.704**	**13.952**	**7.424**	**18.198**	**6.784**	**16.169**

An overview of electricity consumption at the level of the reference year of individual systems is given in the table 3.9 (Note: for the reference year 2016 has been taken, when the reconstruction of the small school was finished where the total consumption of electricity amounts to 22.953 kWh).

Table 3.9 – **An overview of the consumption of electrical energy system [kWh]**

Energy source: Electrical energy	Small school [kWh/year]	Sports hall [kWh/year]	Total [kWh/year]
Yearly real electrical energy of the PTV system consumption	1.760	1.760	3.520
Yearly real electrical energy of the lighting system consumption	4.589	14.409	18.998
Yearly real electrical energy of the IT equipment consumption	435	0	435
Total yearly real electrical energy consumption	**6.784**	**16.169**	**22.953**

Based on the above analysis of the consumption of energy products within the system used in the school building, it is evident that the consumption of electricity for lighting has the largest share in the consumption of electricity (18.998 kWh).
The thermal requirements of the object are provided through a district heating system consisting of equipment located in the basement, in the heat substation, piping and heating elements are located in the heated areas of the object.
Supplier of heat energy JP Komunalno d.o.o. Žepče carries out monthly calculations at the mentioned price according to the delivered amount of heat shown by calorimeters.
Table 3.10 – **An overview of the annual consumption of heat energy [MW]**

An overview of the monthly and yearly costs for the delivered heat energy [MW]						
Year	**2014**		**2015**		**2016**	
Month	**Small school**	**Sports hall**	**Small school**	**Sports hall**	**Small school**	**Sports hall**
January	19	37	21	43	25	48
February	17	34	20	42	22	36
March	11	26	19	43	25	39
April	8	16	8	18	7	6
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	7	18	9	20	12	26
November	14	31	15	37	19	24
December	20	42	15	49	27	48
Total	**96**	**204**	**107**	**252**	**137**	**227**

Based on accumulated heat energy consumption bills for three consecutive years (2014, 2015 and 2016), the average annual energy consumption for the requirements of the district heating system in the amount of 341,000 MW/year: small school 113,333 MW/year and sports hall 227,666 MW/year.
By observing the available periods, the upper average value of the delivered heat energy object cannot be taken into account, as a reference value (mean value of the observed period) but the year 2016 was taken, after the reconstruction of the small school and the thermal insulation of the envelope.
Based on the modelled state of the heat requirements of the building, data on the heat demand of 92,656

kWh/year and data on the delivered heat of 98,130 kWh/year according to the total utilization factor of the heating system (Ƞu = 87,40%).

Table 3.11 – **An overview of modelled required energy and final heating energy**

Energy source: Brown coal			
Object	**Small school**	**Sports hall**	**Total**
Required, modelled heating energy	64.583 [kWh]	28.073 [kWh]	92.656 [kWh]
Required, modelled final heating energy	67.812 [kWh]	30.318 [kWh]	98.130 [kWh]
Heating system efficiency degree	95%	92%	87,40 %

Based on available data for three consecutive years (2014, 2015 and 2016) and installed energy consumers in the buildings of the small school and sports hall, the energy (heat and electricity) shown in Figure 3.12, it shows that the total energy consumption in the buildings are dominated by the delivered heat energy for space heating.

Table 3.12 – **An overview of the yearly consumption of electricity [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Object	Electricity [kWh]	**CO_2 emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**	**Total indirect CO_2 emission [kgCO_2/ year]**
2014	Small school	14.704	0,7446 kg CO_2/kWh	10.948	21.337
	Sports hall	13.952		10.388	
2015	Small school	7.424	0,7446 kg CO_2/kWh	5.528	19.078
	Sports hall	18.198		13.550	
2016	Small school	6.784	0,7446 kg CO_2/kWh	5.051	17.090
	Sports hall	16.169		12.039	

Table 3.13 – **An overview of the yearly consumption of heat energy [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Object	Heat energy [kWh]	**CO_2 emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**	**Total indirect CO_2 emission [kgCO_2/ year]**
2014	Small school	96.000	0,26 kg CO_2/kWh	24.960	**78.000**
	Sports hall	204.000		53.040	
2015	Small school	107.000	0,26 kg CO_2/kWh	27.820	**93.340**
	Sports hall	252.000		65.520	
2016	Small school	137.000	0,26 kg CO_2/kWh	35.620	**94.640**
	Sports hall	227.000		59.020	

Table 3.14 – **An overview of the specific yearly consumption of energy**

Year	**Reference year, 2016**	
Object	**Small school**	**Sports hall**
Heat energy	137.000 kWh/year	227.000 kWh/year
	107 kWh/m^2	288 kWh/m^2

	778 kWh/user	780 kWh/user
Total	**176 kWh/m²**	
	732 kWh/user	
Electricity	6.784 kWh/year	16.169 kWh/year
	5,3 kWh/m²	20 kWh/m²
	38 kWh/user	55 kWh/user
Total	**11,11 kWh/m²**	
	46,18 kWh/user	
Specific consumption	143.784 kWh/year	243.169 kWh/year
	112 kWh/m²	309,19 kWh/m²
	817 kWh/user	835 kWh/user
Total	**187 kWh/m²**	
	778 kWh/user	

At the reference year level, the average delivered heat energy per useful area for both buildings (small school and sports hall) is 176 kWh/m^2 and for the same number of users the delivered energy is 732 kWh/user.
With regard to the physics of both buildings, the installed thermal-technical systems, the way of their use and the fact that heat comfort is difficult to achieve in the sports hall, the average value of the actual delivered heat energy for 176 kWh/m^2 for this type of building is justified, but significantly high. In this context, it is necessary to make certain measurements of energy efficiency improvements to reduce this value.

Aim of the renovation plan

By analysing the condition of the building (schools and sports halls) and comparing the obtained values for the allowed specific thermal loads, it is concluded that the following measures need to be carried out to improve the energy efficiency of the school and the sports hall:
architectural-constructive measures,
measures of thermal-technical systems, and
measures of energy management system
The implementation of the Renewal Action Plan aims to improve energy efficiency through individual measures or combinations (scenarios) of energy efficiency improvement:
Improvement of the thermal characteristics of the outer envelope (measure 1 and measure 2)
Improvement of the energy performance of the heating system (measure 3.1 and measure 3.2)
Improvement of the energy performance of the DHW system (measure 3.3)
Improvement of energy performance of the electricity consumption system – lighting, (measure 3.3)
The analysis of the possibilities of using renewable energy sources (measure 3.3)
Improvement of regulation and management system (measure 3.3),
Introduction of energy management (measure 5)

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Table 4.6 – **Annual amounts of final heat energy and CO_2 emissions**

	District space heating system	**Electricity system**	**Total**	**CO_2**

MEASURE, SCENARIO	Required heat energy [kWh/year]	Required final energy [kWh/year]	Direct CO_2 emissions [tCO_2/year]	The amount of electricity [kWh/ year]	Indirect CO_2 emissions [tCO_2/year]	emission [tCO_2/year]
Existing state	345.999	371.741	96,65	22.953	17,09	**113,74**
Measure 1.1	92.656	98.130	25,51	22.953	17,09	**42,60**
Measure 1.2	301.929	320.657	83,37	22.953	17,09	**100,46**
Measure 2.1	345.999	345.999	89,96	22.953	17,09	**109,39**
Measure 2.2	92.954	92.954	24,17	22.953	17,09	**41,26**
Measure 3	345.999	371.741	96,65	19.897	14,81	**111,47**
Scenario 1	195.663	209.393	54,44	22.953	17,09	**71,53**
Scenario 2	92.954	92.954	24,17	19.897	14,81	**38,98**

Table 4.7 – **Total annual energy savings**

MEASURE, SCENARIO	District space heating system			**Electricity system**		**Total energy savings [kWh/year]**
	Required heat energy [kWh/year]	**Required final energy [kWh/year]**	**Final energy savings [kWh/year]**	**Required electricity [kWh/year]**	**Electricity savings [kWh/ year]**	
Existing state	345.999	371.741	0,00	22.953	0,00	**0,00**
Measure 1.1	92.656	98.130	273.611	22.953	0,00	**273.611**
Measure 1.2	301.929	320.657	51.084	22.953	0,00	**51.084**
Measure 2.1	345.999	345.999	25.742	22.953	0,00	**25.742**
Measure 2.2	92.954	92.954	278.787	22.953	0,00	**278.787**
Measure 3	345.999	371.741	0	19.897	3.056	**3.056**
Scenario 1	195.663	209.393	162.348	22.953	0,00	**162.348**
Scenario 2	92.954	92.954	278.787	19.897	3.056	**281.843**

Materials and components

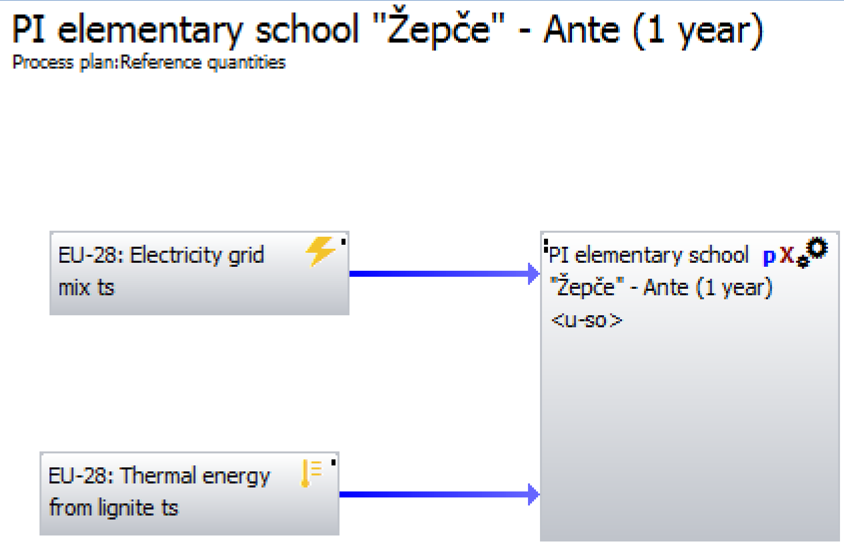
Table 5.1 – **Evaluation of the total renovation price for individual measures 1, 2 and 3**

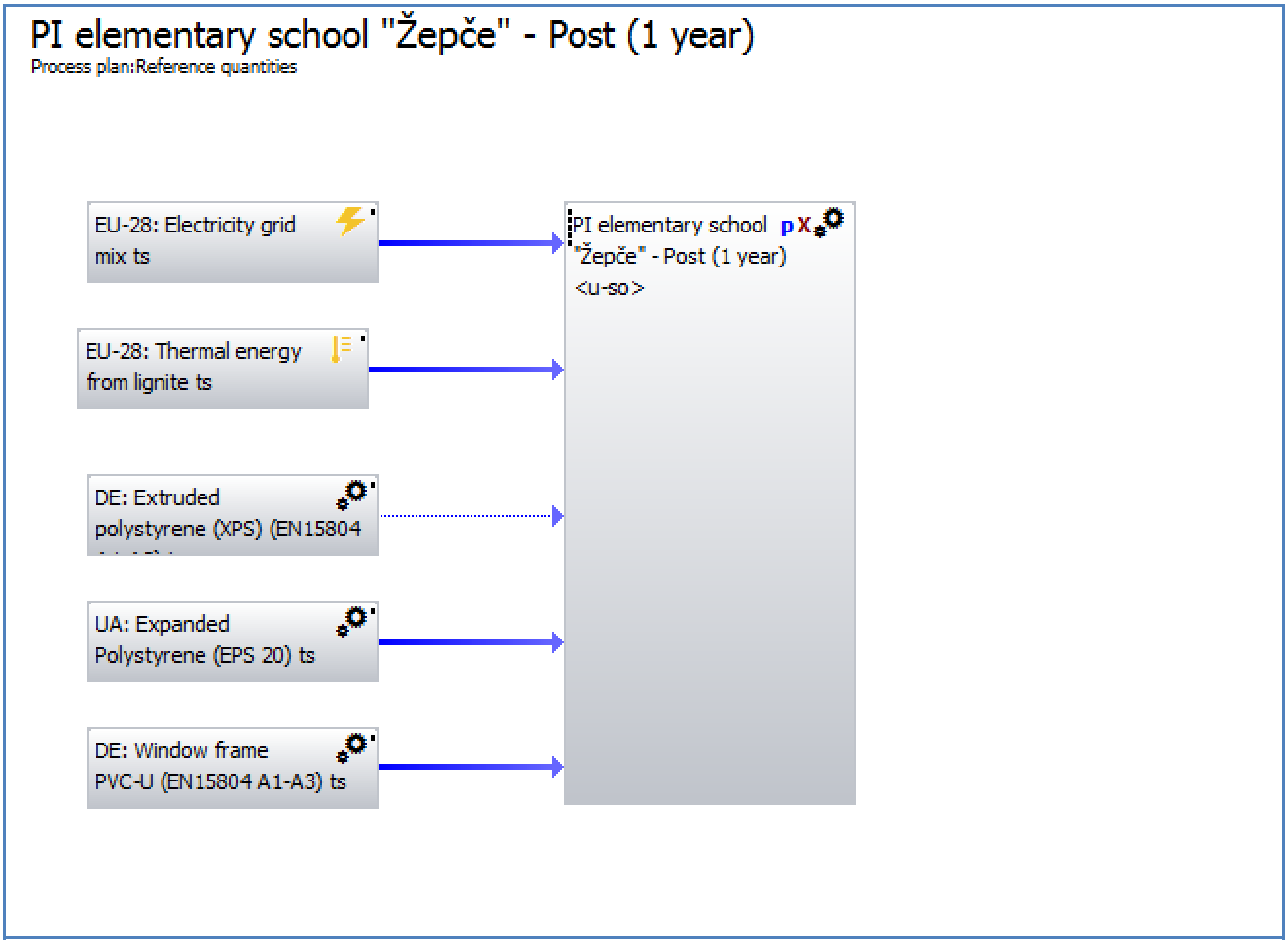
ACTION	VOICE	Amount [UM]	Unit price [KM/UM]	Unit cost [KM/UM]	Total cost [KM] without VAT 17%
Measure 1.1 Outer envelope of the sports hall and „annex“	The preparation of the outer envelope	884,00 m^2	4,00	3.536,00	**77.364,60**
	Protection of the outer openings	113,30 m^2	1,00	113,30	
	Thermal insulation of the outer walls	884,00 m^2	60,00	53.040,00	
	Thermal insulation of the attic - ceiling	203,75 m^2	67,00	13.651,25	
	Unforeseen works (10%).	10,00%	70.340,55	7.024,05	
Measure 1.2 Outer envelope of the sports hall and „annex“	Removal of existing openings	113,30 m^2	2,00	226,60	**67.098,46**
	Installation of the openings, PVC windows	113,30 m^2	200,00	58.000,00	
	Chain engine GEZE ECchain, run 200/400 mm, 230V	9 pcs	308,00	2.772	
	Unforeseen works (10%).	10,00 %	60.998,60	6.099,86	

Measure 2.2 **Heating systems**	Installation of thermostatic valves	52 pcs	60,00	3.000,00	**3.300,00**
	Unforeseen works (10%).	10,00 %	3.000,00	300,00	
Measure 3. Renewable sources and lighting	Installation of solar systems WT20-200S	1 pcs	3.720,00	3.720,00	**5.500,00**
	Installation of solar systems WT20-200S	1 pcs	1.000,00	1.000,00	
	Installation of LED lighting 10W	40 pcs	7,00	280,00	
	Unforeseen works (10%).	10,00 %	5.000,00	500,00	

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software




PI elementary school "Žepče" - Post (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from lignite ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
PI elementary school "Žepče" - Post (1 year) <u-so>
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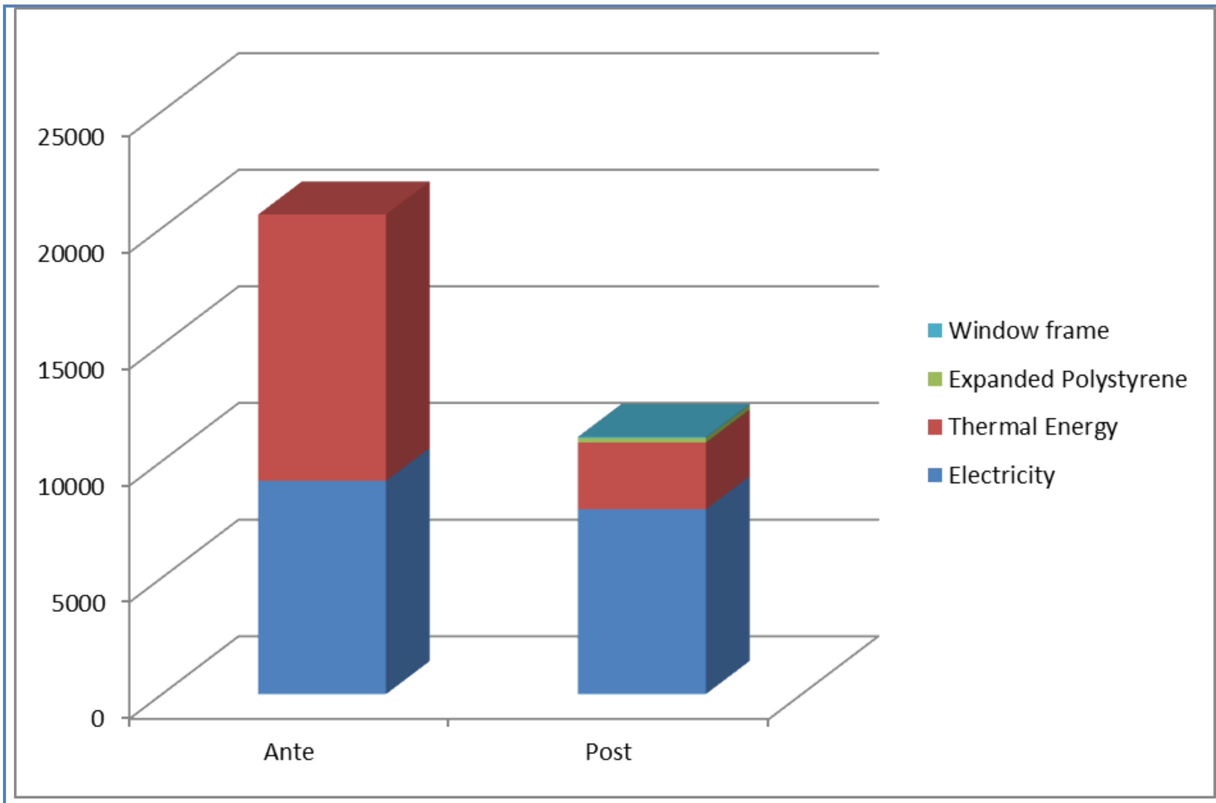
Results



After the proposed renovation, the school overall emissions decreased of around 47% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 2% of the Post intervention emissions.

PI Grammar School Muhsin Rizvić

Description

The building complex within the PI Grammar School Muhsin Rizvić consists of two separate buildings: school building and sports hall. The total useful area of the PI Grammar school Muhsin Rizvić is 2.240,00 m2, that is, school building (1.860,00 m2) and sports hall approx. (380,00 m2)
The school complex has the design of a monolithic building block of the 80's in Bosnia and Herzegovina, architecture characteristic to school building from this period. The school building is an example of the first buildings from this construction period with a layer of thermal insulation of the outer envelope. The design of the school building of the Grammar school Muhsin Rizvić, a good position at the entrance to the urban settlement, orientation towards the south and west, significantly influences its thermal behaviour in the winter and summer.

Initial Energy Requirement

The electricity supply of the school building is carried out through the public electricity distribution network system. The power grid system supplies energy-consuming systems for hot water preparation, lighting, IT equipment, kitchen equipment and other consumables. An analysis of total electricity consumption was carried out for the years 2014, 2015 and 2016.

Table 3.8 – **An overview of the consumption of electrical energy [kWh]**

An overview of the consumption of electrical energy [kWh]

Year	2014	2015	2016
Month	Total [kWh]	Total [kWh]	Total [kWh]
January	1.800,057	1.918,901	1.099,063
February	2.380,013	2.570,649	3.444,324
March	2.251,197	2.306,174	3.903,187
April	1.818,681	1.492,157	2.627,343
May	2.033,500	1.144,261	1.713,673
June	31,903	565,449	646,099
July	104,094	243,715	432,093
August	232,830	237,943	354,847
September	2.122,176	991,580	1.782,099
October	2.596,836	2.850,360	2.843,034
November	2.416,000	2.626,104	3.407,061
December	2.971,806	3.471,752	3.114,467
Total	**20.759,09**	**20.419,05**	**25.367,29**

Table 3.10 – **An overview of the annual consumption of heat energy [KM]**

An overview of the monthly and annual consumption of delivered heat energy [KM]			
Year	2014	2015	2016
Month	Total [KM]	Total [KM]	Total [KM]
January	9.319,10	9.319,10	9.319,10
February	9.319,10	9.319,10	9.319,10
March	9.319,10	9.319,10	9.319,10
April	7.144,64	8.387,19	4.659,55
May	0,00	0,00	0,00
June	0,00	0,00	0,00
July	0,00	0,00	0,00
August	0,00	0,00	0,00
September	0,00	0,00	0,00
October	4.659,55	4.659,55	7.765,91
November	9.319,10	9.319,10	8.884,83
December	9.319,10	9.319,10	9.319,10
Total	**58.399,69**	**59.642,24**	**58.586,69**

Based on the collected heat consumption bills for the three consecutive years (2014, 2015 and 2016), the average annual cost of heating energy for the needs of the heating system was in the amount of 58.876,21 KM/year (with VAT value). By observing the available period, the values of the delivered heat energy cannot be determined at the building, at the level of the reference year (mean values of the observed period) because the supplier of heat energy JP GRIJANJE d.o.o. Kakanj performs monthly calculations on the heated surface of the building and heat meter (calorimeter) is not installed, and therefore there is no insight into the amount of heat supplied. Also, it is not possible to separately analyse energy consumption in school and sports hall.
Based on the thermal conditions in the building, it can be presumed that the thermal requirements of the building are met with respect to the prescribed internal temperatures. Based on the modelled state of the thermal requirements of the building, the data on the thermal requirements of the building from 268.336 kWh/year and the delivered heat energy of 297.622 kWh/year according to the total factor of exploitation of the heating system (ηu = 90,16%) is given.

The analysis of the actual energy consumption, water and cost indicators is based on the reference year for 396 users and the total useful floor area of the school and sports hall of 2.240 m^2.

Table 3.11 – **An overview of the yearly consumption of electricity [kWh] and indirect CO_2 emission [kg CO_2/year]**

Year	Electricity [kWh]	**CO_2 Emission [kg CO_2/kWh]**	**Indirect CO_2 emission [kg CO_2/year]**
2014	20.759	0,7446 kg CO_2/kWh	**15.457**
2015	20.419	0,7446 kg CO_2/kWh	**15.203**
2016	25.367	0,7446 kg CO_2/kWh	**18.888**
Average value	**22.181**	0,7446 kg CO_2/kWh	**16.515**

Based on available bills for three consecutive years (2014, 2015 and 2016) and installed energy consumers at the Grammar school Muhsin Rizvić, the consumption of energy (heat and electricity) at the level of the reference year, shows that the total energy consumption in the building is dominated by the delivered heat energy for space heating (Figure 3.12).

Aim of the renovation plan

By analysing the state of the school building and comparing the obtained values for the allowed specific heat loads, it is concluded that for the improvement of the energy efficiency of the school building, the following measures are to be implemented:

- architectural and construction measures,
- measures of thermo-technical systems, and
- measures of the energy management system

The implementation of the renovation plan measures aims to improve energy efficiency through individual measures or combinations (scenarios) of energy efficiency improvement:
improvements of the thermal characteristics of the outer envelope (measures 1 and 2)
improvements of the energy properties of the space heating system (measures 2.1 and 2.2)
improvements of the energy performance of the hot water supply system (measure 2.3)
improvements of the energy performance of the power consumption system - lighting, (measure 2.3)
analysis of the possibility of using renewable energy sources (measure 2.3)
improvements in regulation and management systems (measures 2.1 and 2.2),
improvements to the organization and education system (measure 3)
introduction of energy management (measure 4)

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Taking into account the degree of efficiency of the district heating system (installed system of production, distribution and exchange of heat), total utilization rate of 90,16% at the reference year level, the final heat energy quantities were calculated to meet the thermal requirements of the school building after the implementation of measure 1 and 2 and following the implementation of scenario 1 and 2. According to the state of final energy delivered for individual measures and a specific scenario, total annual direct and indirect CO_2 emissions [t/year] are calculated. The direct CO_2 emission per unit of energy source for the district heating system 0,35 kgCO_2/kWh, for indirect electricity output is 0,7446 kgCO_2/kWh.

Table 4.6 – **Annual amounts of final heat energy and CO_2 emissions**

MEASURE, SCENARIO	District space heating system			Electricity system		Total CO_2 emission [tCO_2/year]
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Direct CO_2 emissions [tCO_2/year]	Required final energy [kWh/year]	Indirect CO_2 emissions [tCO_2/year]	
Existing state	268.336,00	297.622,01	77,38	22.181	16,52	93,90
Measure 1.1	259.205,00	287.494,45	74,75	22.181	16,52	91,27
Measure 1.2	207.557,00	230.209,63	59,85	22.181	16,52	76,37
Measure 1.3	245.594,00	272.397,96	70,82	22.181	16,52	87,34
Measure 2.1	268.336,00	268.336,00	69,77	22.181	16,52	86,28
Measure 2.2	81.088,00	81.088,00	21,08	22.181	16,52	37,60
Measure 2.3	268.336,00	297.622,01	77,38	19.331	14,39	91,77
Scenario 1	175.684,00	194.858,03	50,66	19.331	14,39	65,05
Scenario 2	81.088,00	81.088,00	21,08	22.181	14,79	35,87

Taking into account the required final and electric energy at the reference year level, total final energy and final energy savings of the school building have been calculated after the implementation of measures 1,2 and 3 and following the implementation of scenarios 1 and 2.

Table 4.7 – **Total annual energy savings**

MEASURE, SCENARIO	District space heating system			Electricity system		Total savings [kWh/year]
	Required heat energy [kWh/year]	Required final energy [kWh/year]	Final energy savings [kWh/year]	Required heat energy [kWh/year]	Electricity savings [kWh/ year]	
Existing state	268.336,00	297.622,01	0	22.181	0	0
Measure 1.1	259.205,00	287.494,45	10.127,55	22.181	0	10.127,55
Measure 1.2	207.557,00	230.209,63	67.412,38	22.181	0	67.412,38
Measure 1.3	245.594,00	272.397,96	25.224,05	22.181	0	25.224,05
Measure 2.1	268.336,00	268.336,00	29.286,01	22.181	0	29.286,01
Measure 2.2	81.088,00	81.088,00	216.534,01	22.181	0	216.534,01
Measure 2.3	268.336,00	297.622,01	0	19.331	2.850	2.850
Scenario 1	175.684,00	194.858,03	102.763,98	19.331	2.850	105.613,98
Scenario 2	81.088,00	81.088,00	216.534,01	22.181	0	216.534,01

Based on the energy evaluation of proposed energy efficiency improvement scenarios, it is apparent that the highest annual energy savings in [kWh] are achieved by applying scenario 2, and fewer saving by applying scenario 1.

Materials and components

Table 5.1 – **Evaluation of the total renovation price for individual measures 1, 2 and 3**

ACTION	VOICE	Amount [UM]	Unit price [KM/UM]	Unit cost [KM/UM]	Total cost [KM] without VAT 17%

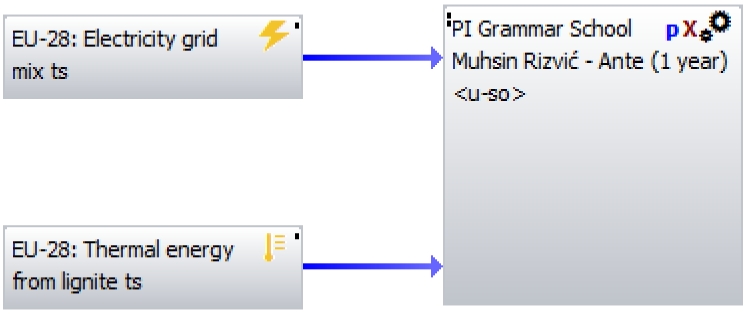
Measure 1.1 Outer school envelope	Vertical drainpipes	1 pcs	flat - rate	2.000,00	**64.625,00**
	The preparation of the damaged outer envelope	880,00 m^2	4,00	3.520,00	
	Protection of the outer openings	430,00 m^2	1,00	430,00	
	Thermal insulation of the walls	880,00 m^2	60,00	52.800,00	
	Unforeseen works (10%).	10,00%	58.750,00	5.875,00	
Measure 1.2 Outer school envelope	Disassembling of the roof	760,00 m^2	4,00	3.057,88	**99.503,66**
	Roof covering works	760,00 m^2	55,00	41.800,00	
	Thermal insulation of the attic – celling	760,00 m^2	60,00	45.600,00	
	Unforeseen works (10%).	10,00%	90.457,88	9.045,78	
Measure 1.3 Outer school envelope	Removal of existing openings	290,00 m^2	2,00	580,00	**64.438,00**
	Installation of openings, PVC windows	290,00 m^2	200,00	58.000,00	
	Unforeseen works (10%).	10,00 %	58.580,00	5.858,00	
Measure 2.2 Lighting and heating system	Installation of thermostatic valves	97 pcs	60,00	5.820,00	**11.352,00**
	Installation of the calorimeter	1 pcs	1.000,00	1.000,00	
	Installation of the frequent pumps	1 pcs	2.000,00	2.000,00	
	Installation of LED lighting 14 W	60 pcs	7,00	720	
	Installation of LED lighting 30 W	12 pcs	65	780	
	Unforeseen works (10%).	10,00 %	10.320,00	1.032,00	
Measure 2.3 Renewable sources and lighting	Installation of solar systems WT20-200S	1 pcs	3.720,00	3.720,00	**5.630,90**
	Installation of solar systems WT20-200S	1 pcs	1.000,00	1.000,00	
	Installation of LED lighting 14 W	57 pcs	7,00	399	
	Unforeseen works (10%).	10,00 %	5.119,00	511,90	

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

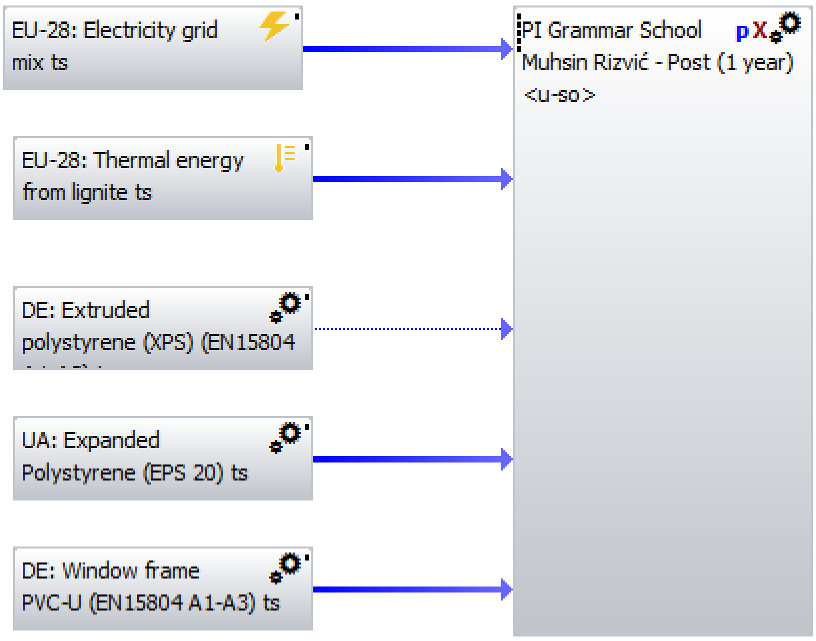
PI Grammar School Muhsin Rizvić - Ante (1 year)

Process plan:Reference quantities

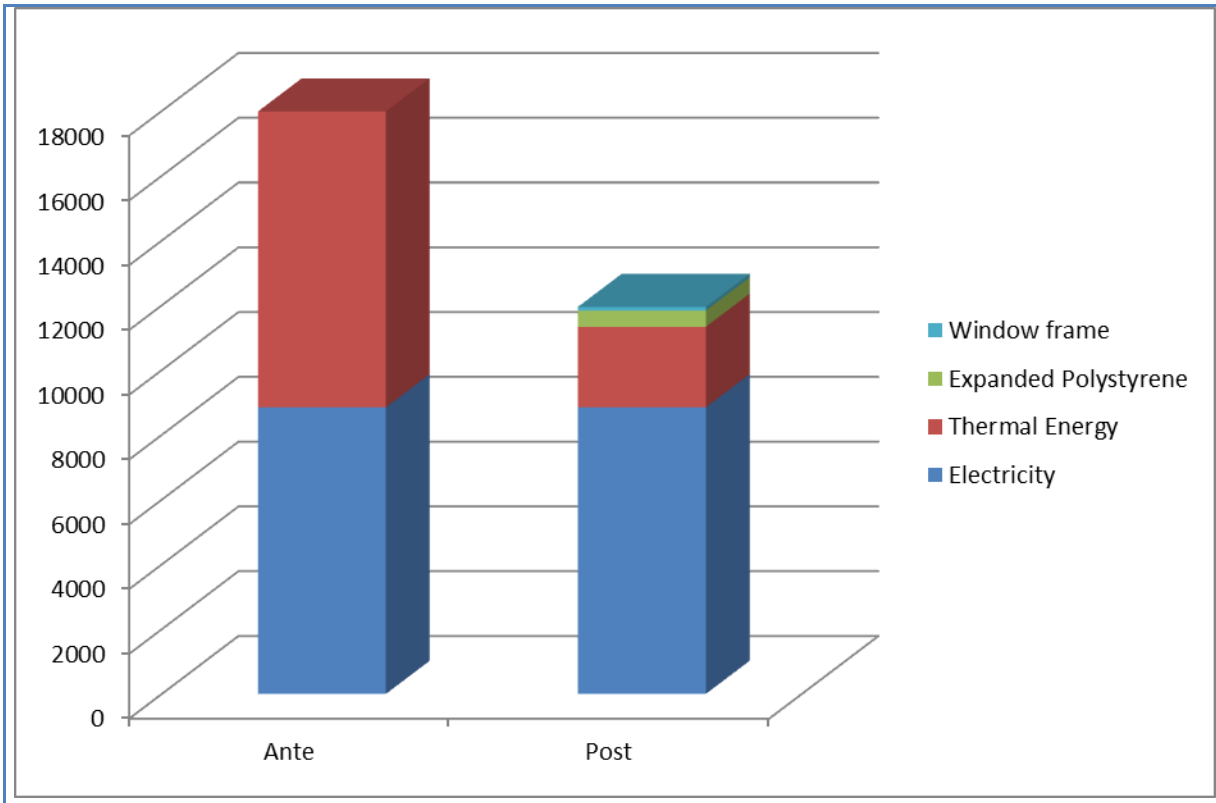


PI Grammar School Muhsin Rizvić - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 33% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 5% of the Post intervention emissions.

Croatia

Elementary school Bol Split

Description

The school was built in 1968 and in 1983 it was upgraded with one additional floor. The school building has a rectangular ground plan, its longer sides oriented to the north and south. The school building and school sports hall are connected on the west side of the school building.
The sports hall is also rectangular with the long side of the building facing east and west. The sport hall is one storey high; the central part or school building is two storeys high, and the classrooms wings are three storeys high.
The building has been reconstructed several times. Over time, the windows have been replaced and the hydro-insulation on the roof has been renovated.

Initial Energy Requirement

There is one Power Meter in the Main Electrical Box and for the purposes of this report, data on electricity consumption have been collected for the past three years, and the data on consumption and related costs are given below:

TABLE 0-1 CONSUMPTION OF ELECTRICITY BY MONTHS

Year	Electricity consumption per month (kWh)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
2015.	8.588	9.019	8.176	6.010	4.897	2.971	1.441	1.292	3.664	6.624	7.421	7.698	**67.801**
2016.	7.988	9.443	7.558	6.192	5.964	2.833	1.678	1.604	4.039	7.795	8.796	7.694	**71.584**
2017.	7.184	7.982	7.110	4.987	5.109	3.088	1.806	1.992	5.335	6.849	9.280	8.424	**69.146**
Average	**7.920**	**8.815**	**7.615**	**5.730**	**5.323**	**2.964**	**1.642**	**1.629**	**4.346**	**7.089**	**8.499**	**7.939**	**69.510**

The energy source for space heating is fuel oil extra light (FOEL). Consumption data was taken from the Energy Management Information System (EMIS).
The EMIS is a web-based application for supervision and analysis of energy and water consumption in the public buildings. The fuel consumption data (measured data) for the previous three years is listed in the table below:

TABLE 0-2 FOEL CONSUMPTION IN 2015 AND 2016

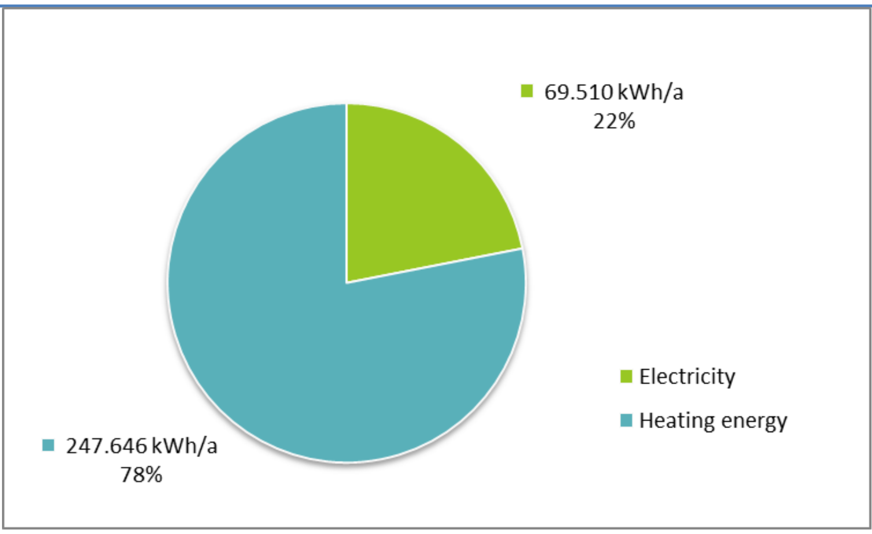
	2015.			2016.		
	Consumption [l]	Consumption [kWh]	Total cost (VAT included)	Consumption [l]	Consumption [kWh]	Total cost (VAT included)
Month	[l]	[kW]	[kn]	[l]	[kW]	[kn]
1	1.022	10.424	4.770	679	6.926	2.619,00
2	923	9.415	4.308	635	6.477	2.450,00
3	1.022	10.424	4.770	679	6.926	2.619,00
4	989	10.088	4.616	657	6.701	2.534,00
5	1.022	10.424	4.770	679	6.926	2.619,00
6	989	10.088	4.616	657	6.701	2.534,00
7	1.022	10.424	4.770	679	6.926	2.619,00
8	1.022	10.424	4.770	679	6.926	2.619,00
9	989	10.088	4.616	657	6.701	2.534,00
10	9.027	92.075	43.720	9.993	101.929	46.451,00
11	4.302	43.880	17.524	3.751	38.260	18.238,00
12	3.999	40.790	15.354	3.751	38.260	18.238,00
Total	**26.328**	**268.545,60**	**118.604,00**	**23.496**	**239.659,20**	**106.074,00**

Reference consumption was determined on the basis of average consumption over the previous three years. FOEL reference consumption amounts to 24.279 litres per year, i.e. 247.646 kWh per year. Calculation is done using the lower heating value of H_D=10,2 kWh/l.

Measured consumption represents the average actual consumption of energy carriers (electricity and fuel), which is also defined as reference consumption.

TABLE 0-3 MEASURED ENERGY CONSUMPTION AND CO_2 EMISSION

	Energy consumption		CO_2 Emission	
Electricity	69.510,00	kWh/a	16.321,64	kg/a
Heating energy - FOEL	247.645,80	kWh/a	74.187,25	kg/a
TOTAL	**317.155,80**	**kWh/a**	**90.508,90**	**kg/a**



PICTURE 0-1 MEASURED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS

Aim of the renovation plan

The aim of the renovation plan is to improve energy efficiency of the school building in a way that the building meets the requirements for Nearly Zero Energy Building (nZEB). Improving the energy performance of the building will ensure savings in energy consumption and energy costs, and will also positively impact the carbon footprint.
Requirements for nZEB standards in Croatia are determined by the following values:
Maximum permitted energy need for heating per square meter of heated space,
Maximum permitted primary energy per square meter of conditioned floor area and
The share of renewable energy use produced on site or nearby.

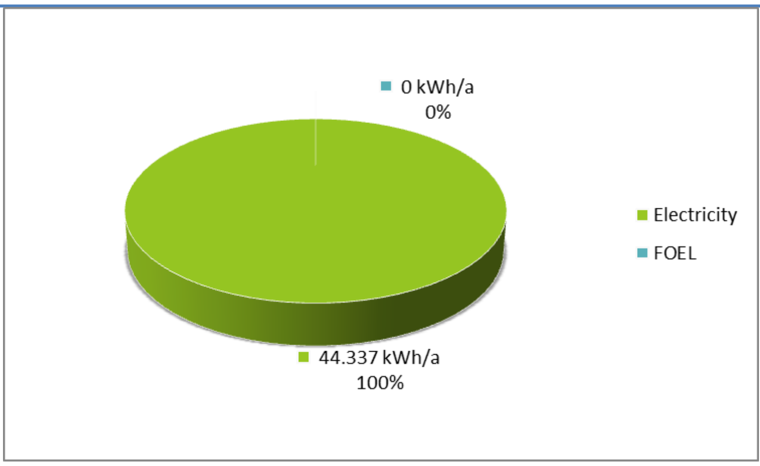
The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Estimated final energy consumption, cost and CO_2 emission after recommended improvement actions:

TABLE 0-4 ESTIMATED ENERGY CONSUMPTION AND CO_2 EMISSION AFTER IMPROVEMENT ACTION

Energy carrier	Energy consumption		CO_2 Emission	
Electricity	44.336,77	kWh/a	10.411	kg/a
Heating energy - FOEL	0,00	kWh/a	0	kg/a
TOTAL	**44.336,77**	**kWh/a**	**10.411**	**kg/a**



PICTURE 0-2 ESTIMATED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS AFTER IMPROVEMENT ACTION

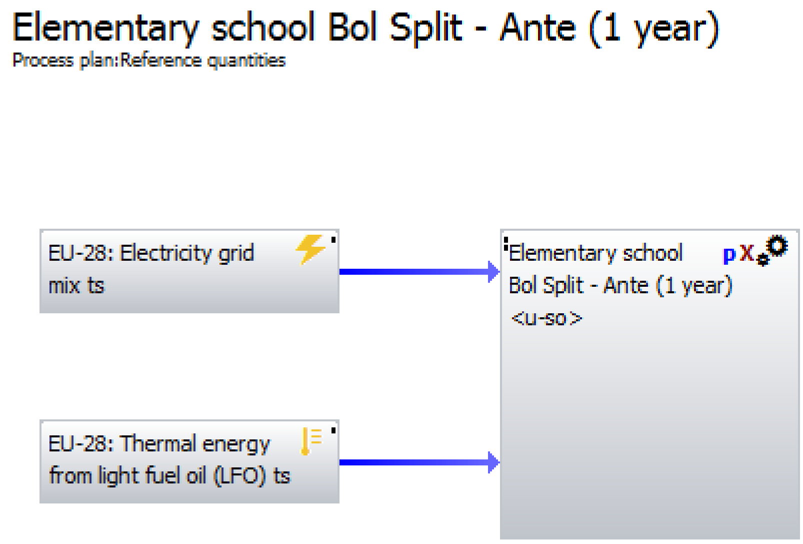
Materials and components

All prices and costs are expressed without VAT.

ACTION	*VOICE*	*U.M.*	*Unit Cost [EUR]*	*Total Cost [EUR]*
Building Envelope	Insulation of external walls	1520 m^2	108	164.160
	Windows	1060 m^2	420	445.200
	Insulation of roof	1800 m^2	73	131.400
Technical system (Plants)	Lighting	590 pcs.	109	64.015
	Heat pump for heating			354.000
TOTAL				**1.158.775**

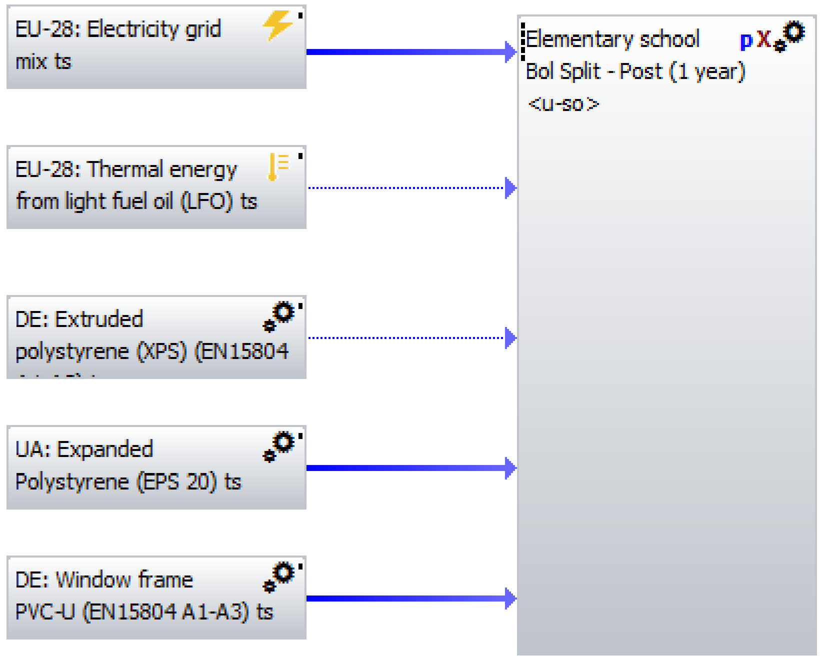
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

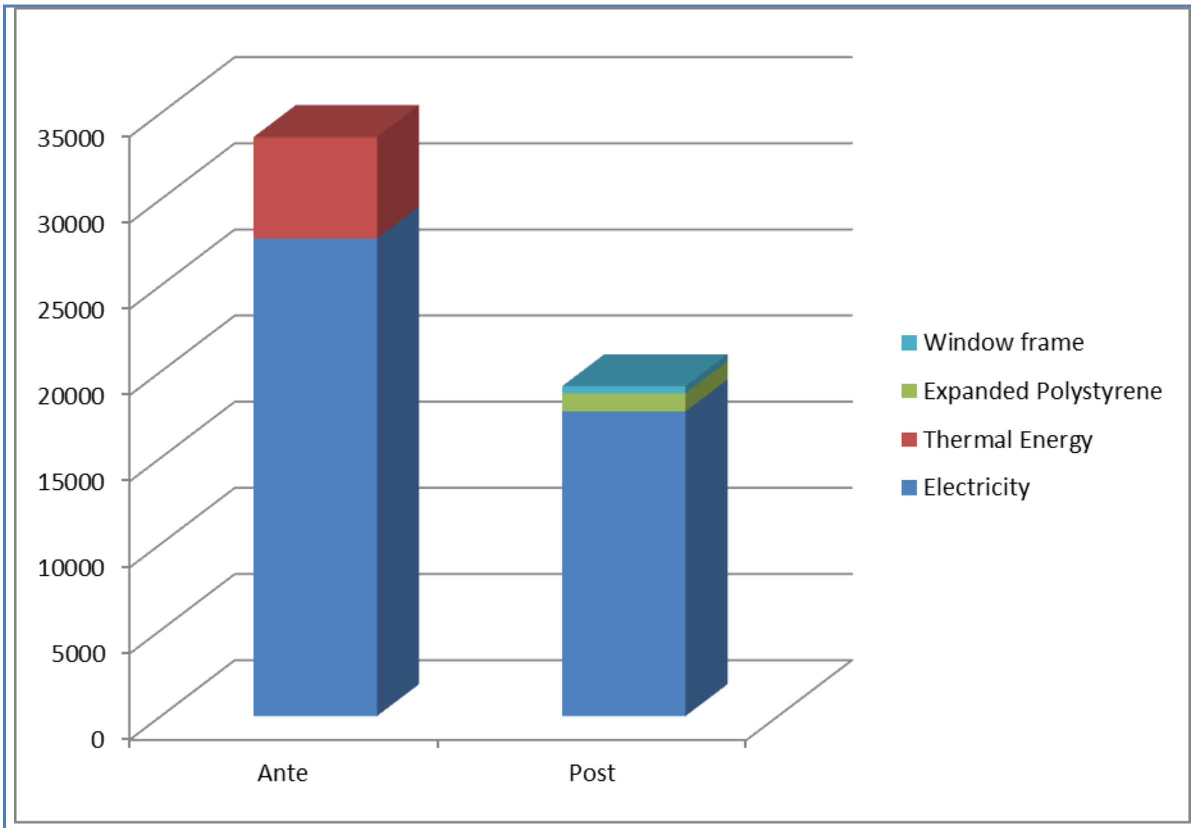


Elementary school Bol Split - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 43% respect the initial conditions. The impact due to the materials used for the restoration contributes for an 8% of the Post intervention emissions.

Elementary school Gripe in Split

Description

The school was built in 1978 and the sports hall in 2010. The school was built on hip grounds, and because of that, there is difference between its floors. The north part of the school has two floors - partially buried basement and ground floor, and south part of the school has two floors – ground floor and first floor. Main entrance to the school is on the north side of the school on the ground floor. The school has three parts: 1/ classrooms in the south part of the school; 2/ multifunctional hall with auditorium, entrance hall and school administration in the north part of the school; and 3/ the sports hall which is separate unit on north-east side of the school.
The sports hall has a rectangular ground plan, its longer sides oriented to the west and east and connected with the school in west side by passage. The sports hall has one floor with height of 10,00 m.
The building has been reconstructed several times. Over time, some of the windows have been replaced and the hydro-insulation on the flat roof has been renovated.

Initial Energy Requirement

There is one Power Meter in the Main Electrical Box and for the purposes of this report, data on electricity consumption have been collected for the past three years, and the data on consumption and related costs are given below:

Table 0-5 Consumption of electricity by months

Year	Electricity consumption per month (kWh)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
2015.	12.385	12.763	11.735	9.379	9.485	7.991	4.163	3.145	8.005	10.370	11.539	12.123	**113.083**
2016.	13.477	13.640	19.477	9.788	9.832	6.683	3.321	2.606	6.949	9.647	12.312	11.181	**118.913**
2017.	11.970	11.412	11.093	7.224	7.811	4.709	1.739	1.738	5.462	8.223	11.550	11.652	**94.583**
Average	**12.611**	**12.605**	**14.102**	**8.797**	**9.043**	**6.461**	**3.074**	**2.496**	**6.805**	**9.413**	**11.800**	**11.652**	**108.860**

The energy source for space heating is fuel oil extra light (FOEL). Consumption data was taken from the Energy Management Information System (EMIS).
The EMIS is a web-based application for supervision and analysis of energy and water consumption in the public buildings. The fuel consumption data (measured data) for the previous three years is listed in the table below:

Table 0-6 FOEL Consumption in 2015 and 2016

	2015.			2016.		
	Consumption [l]	Consumption [kWh]	Total cost (VAT included)	Consumption [l]	Consumption [kWh]	Total cost (VAT included)
Month	**[l]**	**[kW]**	**[kn]**	**[l]**	**[kW]**	**[kn]**
1	5000	51.000	23.109,00	0	0	
2	0	0	0,00	0	0	
3	0	0	0,00	15011	153.112	59.683
4	0	0	0,00	0	0	
5	0	0	0,00	0	0	
6	0	0	0,00	0	0	
7	0	0	0,00	0	0	
8	0	0	0,00	0	0	
9	0	0	0,00	0	0	
10	10021	102.214	45.609,00	0	0	
11	4.996	50.959	19.280,00	0	0	
12	4996	50.959	19.280,00	9995	101.949	50.941
Total	**25.013**	**255.132,60**	**107.278,00**	**25.006**	**255.061,20**	**110.624,00**

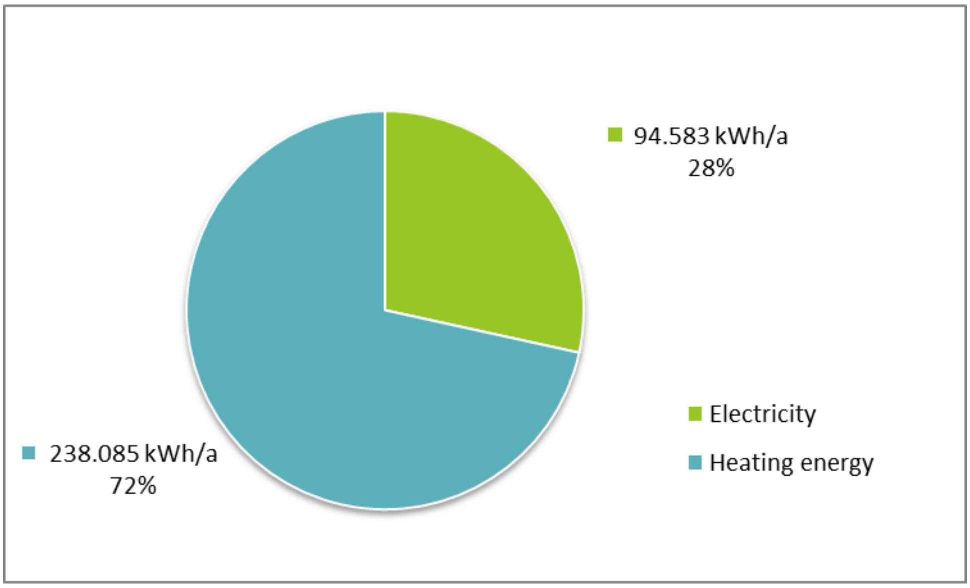
Reference consumption was determined on the basis of average consumption over the previous three years. FOEL reference consumption amounts to 23.343 litres per year, i.e. 238.085,00 kWh per year. Calculation is done using the lower heating value of HD=10,2 kWh/l.

Measured consumption represents the average actual consumption of energy carriers (electricity and fuel), which is also defined as reference consumption.

Table 0-7 Measured Energy Consumption and CO_2 Emission

	Energy consumption		CO_2 Emission	
Electricity	94.583,00	kWh/a	22.209,03	kg/a
Heating energy - FOEL	238.085,00	kWh/a	71.323,12	kg/a

TOTAL	332.668,00	kWh/a	93.532,16	kg/a



PICTURE 0-3 MEASURED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS

Aim of the renovation plan

The aim of the renovation plan is to improve energy efficiency of the school building in a way that the building meets the requirements for Nearly Zero Energy Building (nZEB). Improving the energy performance of the building will ensure savings in energy consumption and energy costs, and will also positively impact the carbon footprint.
Requirements for nZEB standards in Croatia are determined by the following values:
Maximum permitted energy need for heating per square meter of heated space,
Maximum permitted primary energy per square meter of conditioned floor area and
The share of renewable energy use produced on site or nearby.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Estimated final energy consumption, cost and CO_2 emission after recommended improvement actions:

TABLE 0-8 ESTIMATED ENERGY CONSUMPTION AND CO_2 EMISSION AFTER IMPROVEMENT ACTION

Energy carrier	Energy consumption		CO_2 Emission	
Electricity	81.717	kWh/a	19.188	kg/a
Heating energy - FOEL	0,00	kWh/a	0	kg/a
TOTAL	**81.717**	**kWh/a**	**19.188**	**kg/a**

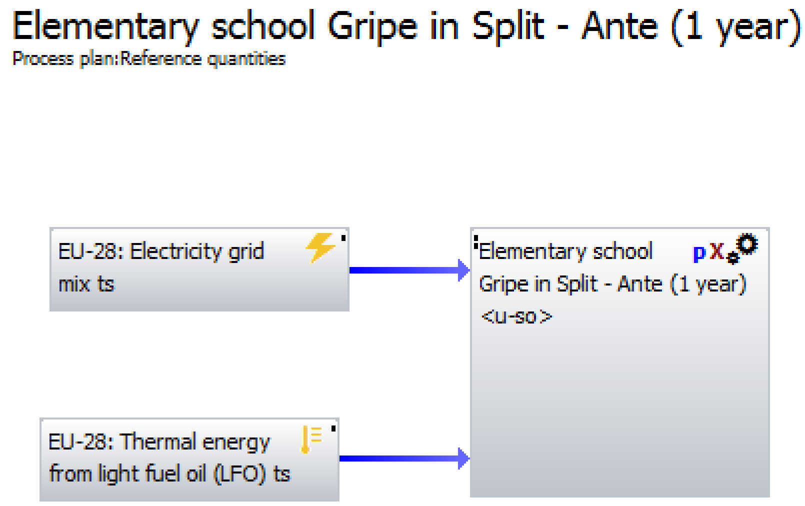
Materials and components

All prices and costs are expressed without VAT.

ACTION	VOICE	U.M.	Unit Cost [EUR]	Total Cost [EUR]
Building Envelope	Insulation of external walls	830 m^2	105	87.150
	Windows	1.048 m^2	376	393.676
	Insulation of roof	2.077 m^2	67	140.101
Technical system (Plants)	Lighting	558 pcs.	99	55.151
	Heat pump for heating			335.000
TOTAL				**1.011.078**

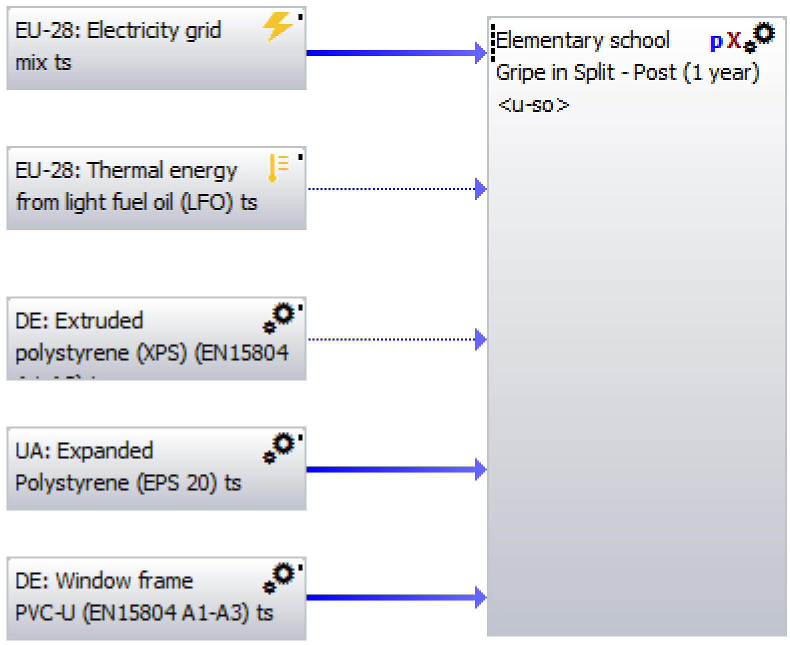
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software



Elementary school Gripe in Split - Post (1 year)

Process plan:Reference quantities



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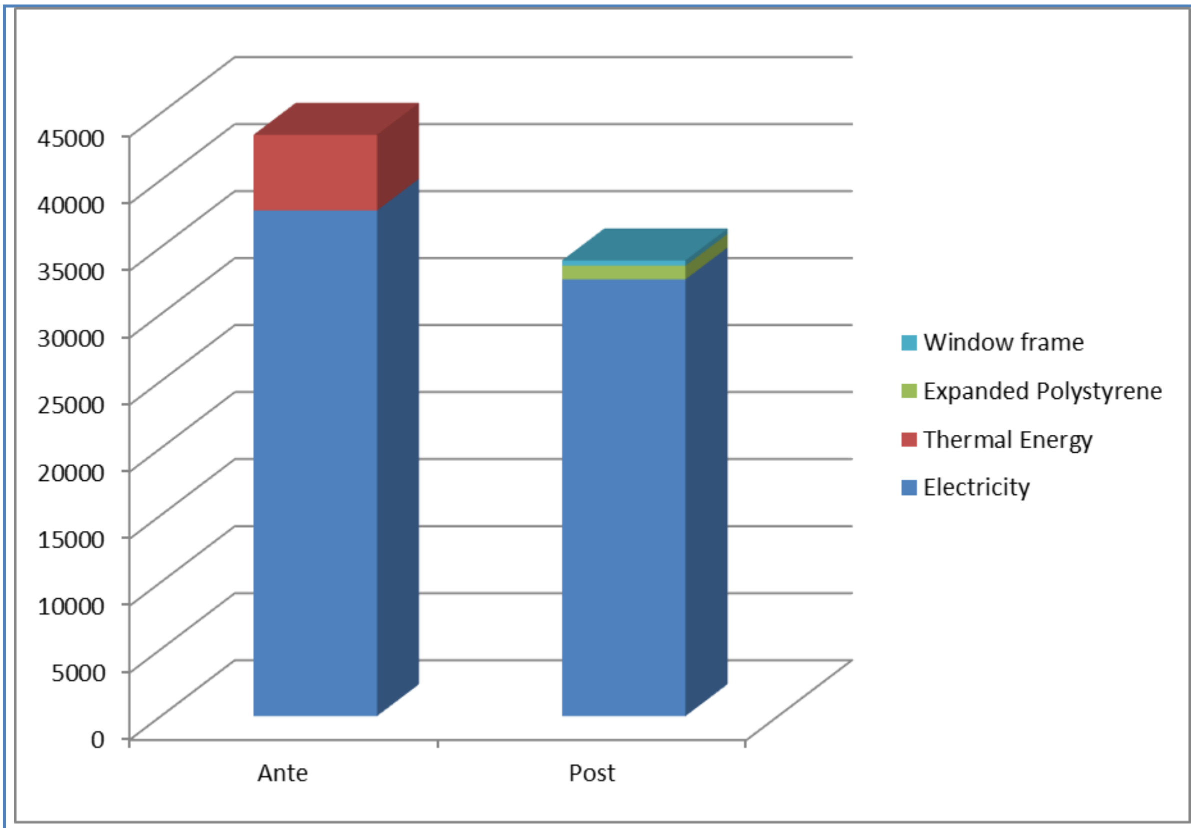


After the proposed renovation, the school overall emissions decreased of around 21% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 4% of the Post intervention emissions.

Elementary school Kman-Kocunar Split

Description

The building has an indented ground plan. The maximum height is three storeys: ground floor and two storeys. It consists of three wings, interconnected by a central entrance hall. The North wing features a gym and changing rooms, oriented along the long North-South axis. The West wing is ground floor and one-storey high, also oriented along the long North-South axes. The entrance hall is at the ground floor level, West-oriented along the long axis.
The school was built in 1976 and reconstructed in 2007, when the external windows was replaced, while the 2012 renovation included additional hydro-insulation on the roof.

Initial Energy Requirement

There is one Power Meter in the Main Electrical Box and for the purposes of this report, data on electricity consumption have been collected for the past three years, and the data on consumption and related costs are given below:

TABLE 0-9 CONSUMPTION OF ELECTRICITY BY MONTHS

Year	Electricity consumption per month (kWh)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	

2015.	8.602	8.599	7.576	5.555	4.530	3.112	1.994	2.010	4.170	7.903	8.916	8.224	**71.191**
2016.	9.322	10.236	7.296	5.544	5.457	3.063	1.632	1.789	5.021	7.238	9.393	8.337	**74.328**
2017.	6.904	7.233	6.126	3.956	4.044	2.770	1.955	2.084	4.299	5.206	7.831	7.342	**59.750**
Average	**8.276**	**8.689**	**6.999**	**5.018**	**4.677**	**2.982**	**1.860**	**1.961**	**4.497**	**6.782**	**8.713**	**7.968**	**68.423**

The energy source for space heating is fuel oil extra light (FOEL). Consumption data was taken from the Energy Management Information System (EMIS).
The EMIS is a web-based application for supervision and analysis of energy and water consumption in the public buildings. The fuel consumption data (measured data) for the previous three years is listed in the table below:

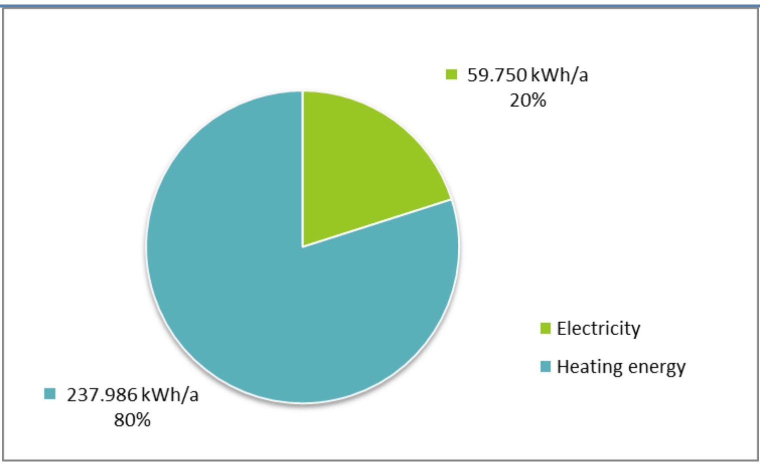
TABLE 0-10 FOEL CONSUMPTION IN 2015 AND 2016

	2015.			**2016.**		
	Consumption [l]	**Consumption [kWh]**	**Total cost (VAT included)**	**Consumption [l]**	**Consumption [kWh]**	**Total cost (VAT included)**
Month	**[l]**	**[kW]**	**[kn]**	**[l]**	**[kW]**	**[kn]**
1						
2	10.007	102.089,41	51.685,00			
3	10.007	102.089,41	52.075,00	9.991	101.926,18	37.095,00
11						
12	9.988	101.895,58	30.525,00	9.999	102.007,80	47.259,00
Total	**30.002**	**306.074,40**	**134.285,00**	**19.990**	**203.933,98**	**84.354,00**

Reference consumption was determined on the basis of average consumption over the previous three years. FOEL reference consumption amounts to 23.332 litres per year, i.e. 238.028 kWh per year. The calculation is based on the lower heating value of H_D=10,2 kWh/l.
Measured consumption represents the average actual consumption of energy carriers (electricity and fuel), which is also defined as reference consumption.

TABLE 0-11 MEASURED ENERGY CONSUMPTION AND CO_2 EMISSION

	Energy consumption		**CO_2 Emission**	
Electricity	59.750,00	kWh/a	14.030	kg/a
Heating energy - FOEL	237.986,40	kWh/a	71.294	kg/a
TOTAL	**306.409,40**	**kWh/a**	**87.360**	**kg/a**



Picture 0-4 Measured Energy Consumption – Share of Energy Carriers

Aim of the renovation plan

The aim of the renovation plan is to improve energy efficiency of the school building in a way that the building meets the requirements for Nearly Zero Energy Building (nZEB). Improving the energy performance of the building will ensure savings in energy consumption and energy costs, and will also positively impact the carbon footprint.
Requirements for nZEB standards in Croatia are determined by the following values:
Maximum permitted energy need for heating per square meter of heated space,
Maximum permitted primary energy per square meter of conditioned floor area and
The share of renewable energy use produced on site or nearby.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Estimated final energy consumption, cost and CO_2 emission after recommended improvement actions:

Table 0-12 Estimated Energy Consumption and CO_2 Emission After improvement action

Energy carrier	Energy consumption		CO_2 Emission	
Electricity	52.715	kWh/a	12.378	kg/a
Heating energy - FOEL	0	kWh/a	0	kg/a
TOTAL	**52.715**	**kWh/a**	**12.378**	**kg/a**

Materials and components

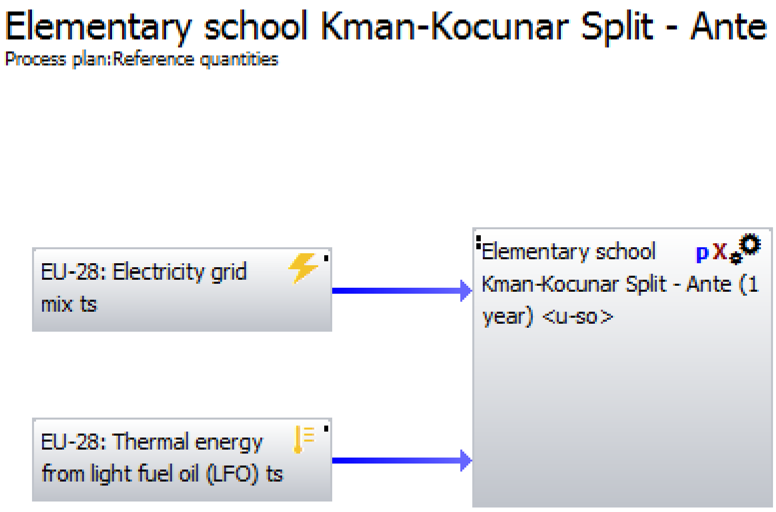
All prices and costs are expressed without VAT.

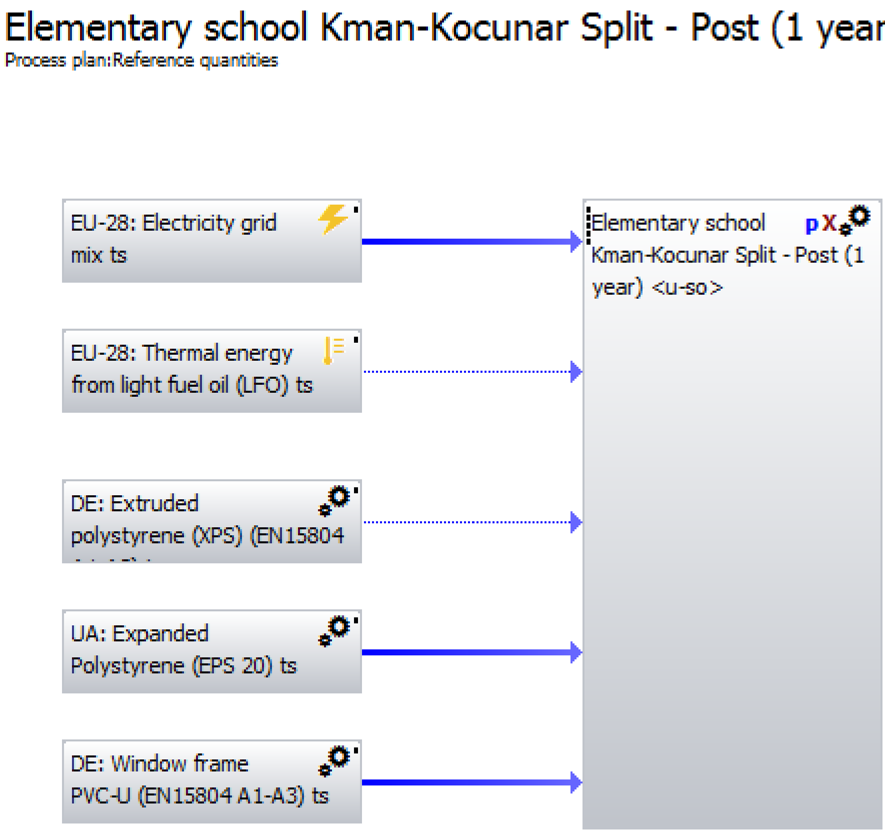
ACTION	*VOICE*	*U.M.*	*Unit Cost [EUR]*	*Total Cost [EUR]*
Building Envelope	Insulation of external walls	2000 m^2	105	210.000
	Windows	1340 m^2	420	562.800
	Insulation of roof	2550 m^2	73	186.150

Technical system (Plants)	Lighting			55.900
	Heat pump for heating			374.700
TOTAL				**1.389.550,00**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software





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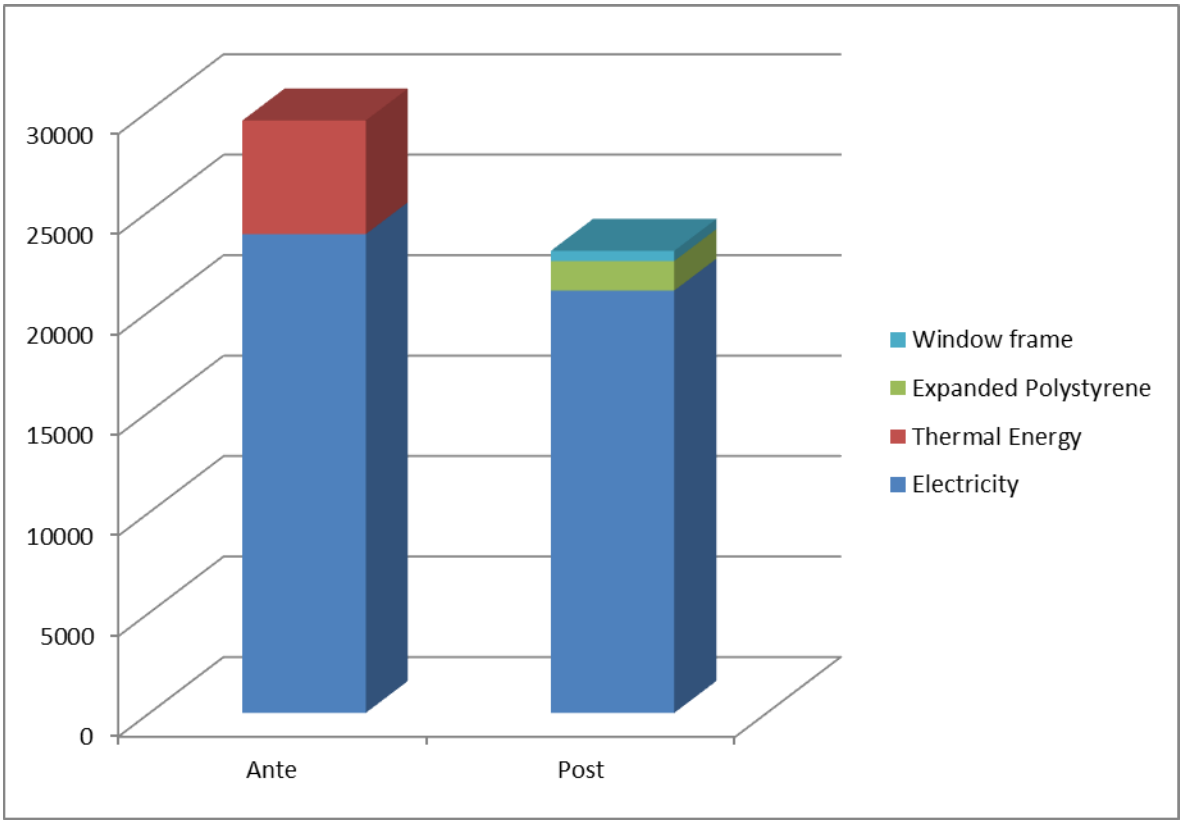


After the proposed renovation, the school overall emissions decreased of around 22% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 9% of the Post intervention emissions.

Elementary school Trstenik Split

Description

The school was built in 1978 and the sports hall in 2003. The school building has a rectangular ground plan; its longer sides are oriented to the north and south. It is consisted of four parts: the central part of the building with school administration and the foyers; the east and west wings with the classrooms and the multifunctional hall with main entrance to the school. The sports hall is separate unit on north-east side of the school, connected with the east wing.

The central part of the school with school administration and the foyers has one floor. The multifunctional hall has also one floor, but it is 5,20 m high. The multifunctional hall is oriented to the south. The main entrance is oriented to the west. The school administration is oriented to the south and north. The foyers which connect the administration part with multifunctional hall are oriented to the east and west and make the atrium inside the building. The east and the west wings have two floors with the classrooms and their longer sides are oriented to the south and to the north. The sports hall is connected with the corridor to the east wing and has one floor, which is max 12,00 m high, while the wardrobe has one floor and its height is of 2,65 m.

The building has been reconstructed several times. Over time, the windows have been replaced and the hydro-insulation on the flat roof has been renovated. In 2016 *brise soleil* were built-in on the south side of the ground floor.

Initial Energy Requirement

There is one Power Meter in the Main Electrical Box and for the purposes of this report, data on electricity consumption have been collected for the past three years, and the data on consumption and costs are given below:

TABLE 0-13 CONSUMPTION OF ELECTRICITY BY MONTHS

Year	Electricity consumption per month (kWh)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
2015.	11.127	11.447	9.416	7.090	5.434	5.147	1.441	3.442	3.563	5.985	9.288	11.064	**84.444**
2016.	10.701	12.172	9.443	7.465	6.962	4.724	2.657	3.357	8.023	9.798	12.165	10.222	**97.689**
2017.	9.628	10.748	10.124	6.842	7.181	4.737	2.069	2.836	6.990	9.015	12.392	10.566	**93.128**
Average	**10.485**	**11.456**	**9.661**	**7.132**	**6.526**	**4.869**	**2.056**	**3.212**	**6.192**	**8.266**	**11.282**	**10.617**	**91.754**

The energy source for space heating is fuel oil extra light (FOEL). Consumption data was taken from the Energy Management Information System (EMIS).
The EMIS is a web-based application for supervision and analysis of energy and water consumption in the public buildings. The fuel consumption data (measured data) for the previous three years is listed in the table below:

TABLE 0-14 FOEL CONSUMPTION IN 2015 AND 2016

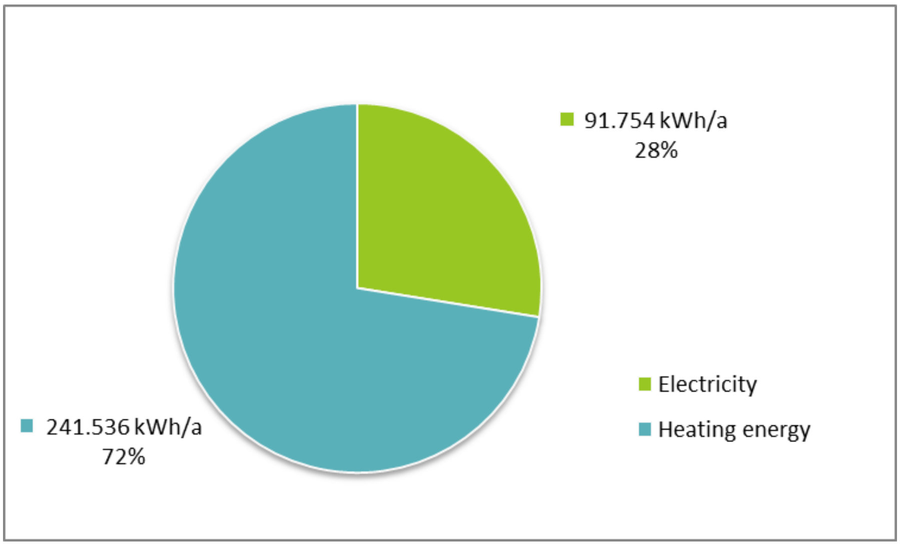
	2015.			2016.		
	Consumption [l]	Consumption [kWh]	Total cost (VAT included)	Consumption [l]	Consumption [kWh]	Total cost (VAT included)
Month	**[l]**	**[kW]**	**[kn]**	**[l]**	**[kW]**	**[kn]**
1	0	0		5.875	59.925	22.441
2	10.004	102.041	47.669,00	5.043	51.439	20.093
3	0	0		838	8.548	4.221
4	4011	40.912	20.951,00	811	8.272	4.085
5	0	0		838	8.548	4.221
6	0	0		811	8.272	4.085
7	0	0		838	8.548	4.221
8	0	0		838	8.548	4.221
9	0	0		811	8.272	4.085
10	0	0		13.835	141.117	61.723
11	10.020	102.204	46.092,00	811	8.272	4.085
12	0	0		838	8.548	4.221
Total	**24.035**	**245.157,00**	**114.712,00**	**32.187**	**328.307,40**	**141.702,00**

Reference consumption was determined on the basis of average consumption over the previous three years. FOEL reference consumption amounts to 23.680 litres per year, i.e. 241.536 kWh per year. Calculation is done using the lower heating value of H_D=10,2 kWh/l.

Measured consumption represents the actual consumption of energy carriers (electricity and fuel), which is also defined as reference consumption.

TABLE 0-15 MEASURED ENERGY CONSUMPTION AND CO_2 EMISSION

	Energy consumption		CO_2 Emission	
Electricity	91.754,00	kWh/a	21.544,76	kg/a
Heating energy - FOEL	241.536,00	kWh/a	72.356,94	kg/a
TOTAL	**333.290,00**	**kWh/a**	**93.901,70**	**kg/a**



PICTURE 0-5 MEASURED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS

Aim of the renovation plan

The aim of the renovation plan is to improve energy efficiency of the school building in a way that the building meets the requirements for Nearly Zero Energy Building (nZEB). Improving the energy performance of the building will ensure savings in energy consumption and energy costs, and will also positively impact the carbon footprint.
Requirements for nZEB standards in Croatia are determined by the following values:
Maximum permitted energy need for heating per square meter of heated space,
Maximum permitted primary energy per square meter of conditioned floor area and
The share of renewable energy use produced on site or nearby.

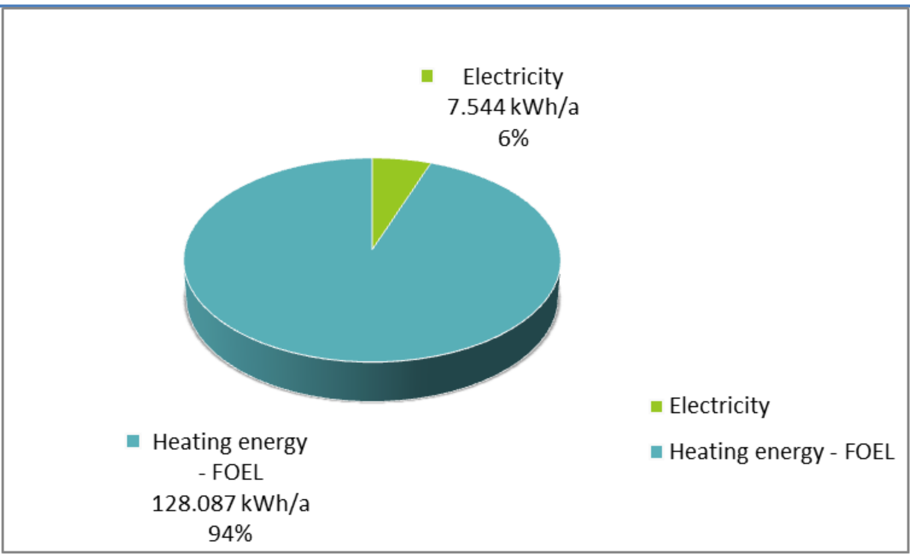
The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Estimated final energy consumption and CO_2 emission after recommended improvement actions:

TABLE 0-16 ESTIMATED ENERGY CONSUMPTION AND CO_2 EMISSION AFTER IMPROVEMENT ACTION

Energy carrier	Energy consumption		CO_2 Emission	
Electricity	7.544	kWh/a	1.771	kg/a
Heating energy - FOEL	128.087	kWh/a	38.371	kg/a
TOTAL	**135.631**	**kWh/a**	**40.142**	**kg/a**



PICTURE 0-6 ESTIMATED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS AFTER IMPROVEMENT ACTION

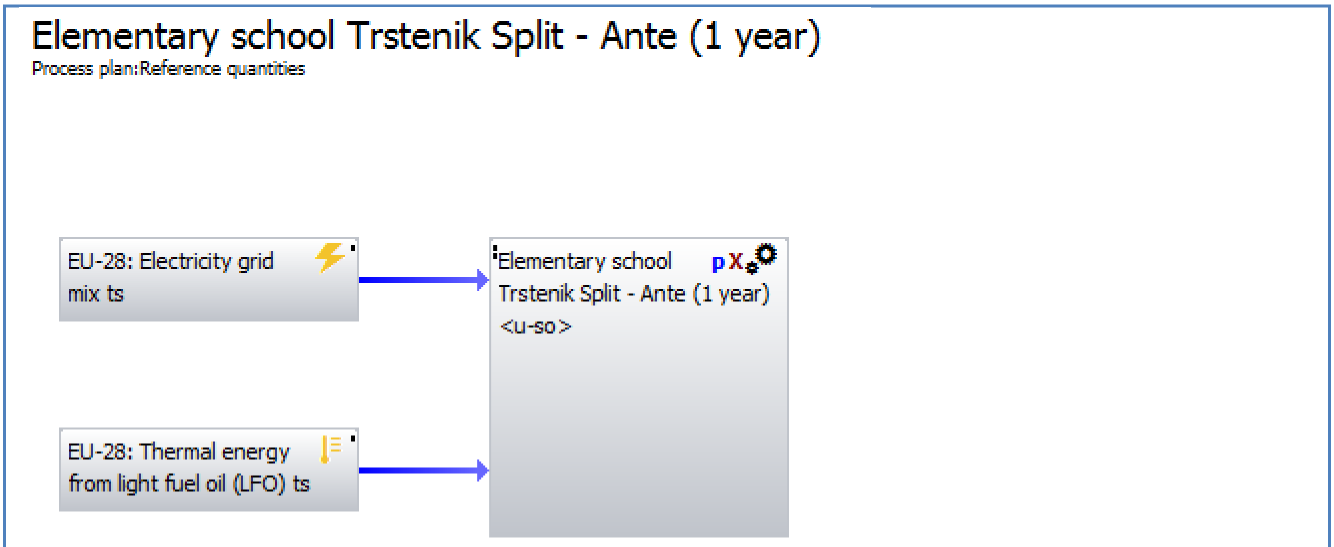
Materials and components

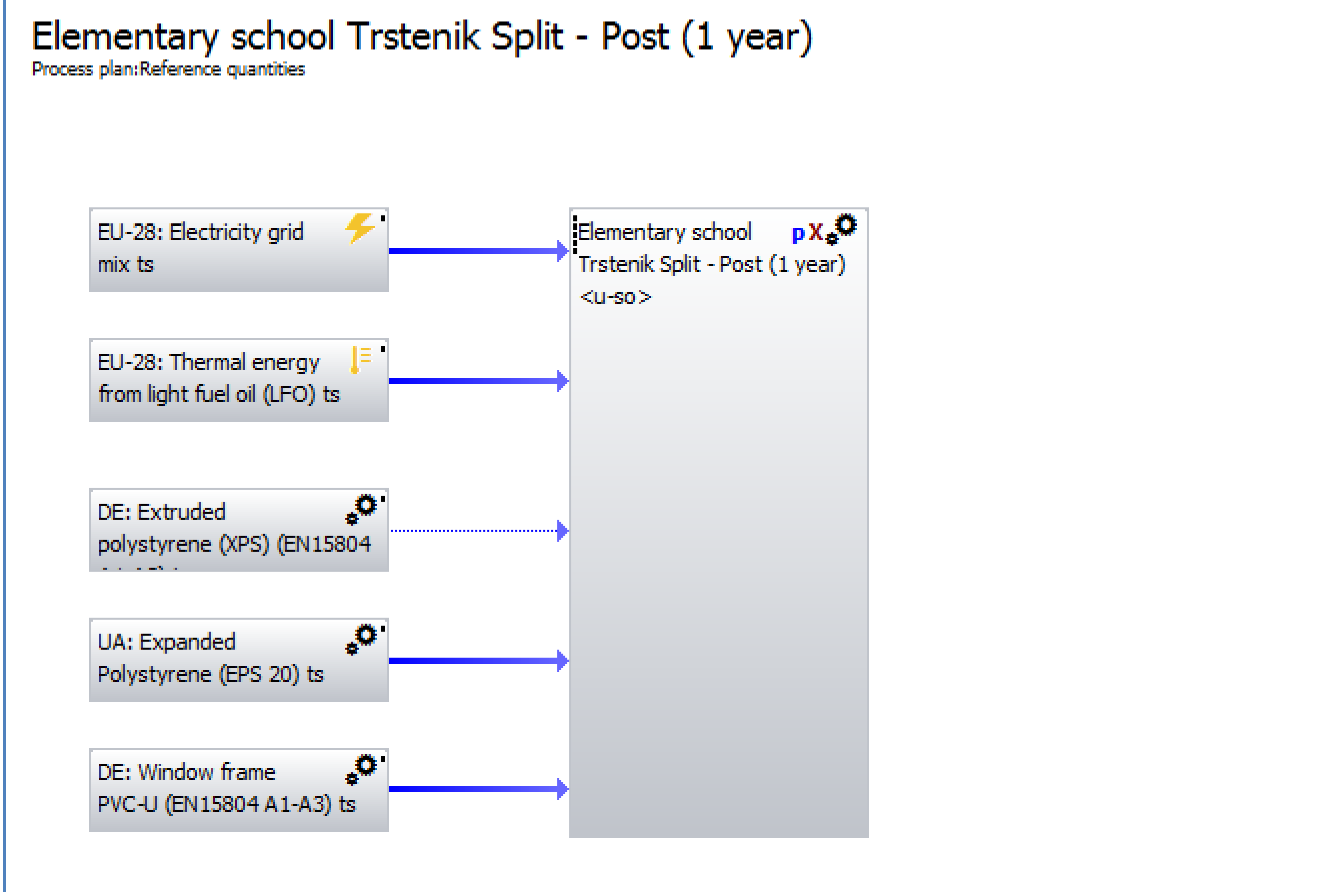
All prices and costs are expressed without VAT.

ACTION	*VOICE*	*U.M.*	*Unit Cost [EUR]*	*Total Cost [EUR]*
Building Envelope	Thermal insulation of external walls	2.133 m^2	93	198.369
	Windows reconstruction	764 m^2	420	320.880
	Thermal insulation of the flat roof	1.110 m^2	73	81.030
Technical system (Plants)	LED Lighting	600 pcs.	86	51.632
	TRV Valves	140 pcs.	40	5.600
	PV Generation system	38,88 kWp	1.929	75.000
TOTAL				**732.511**

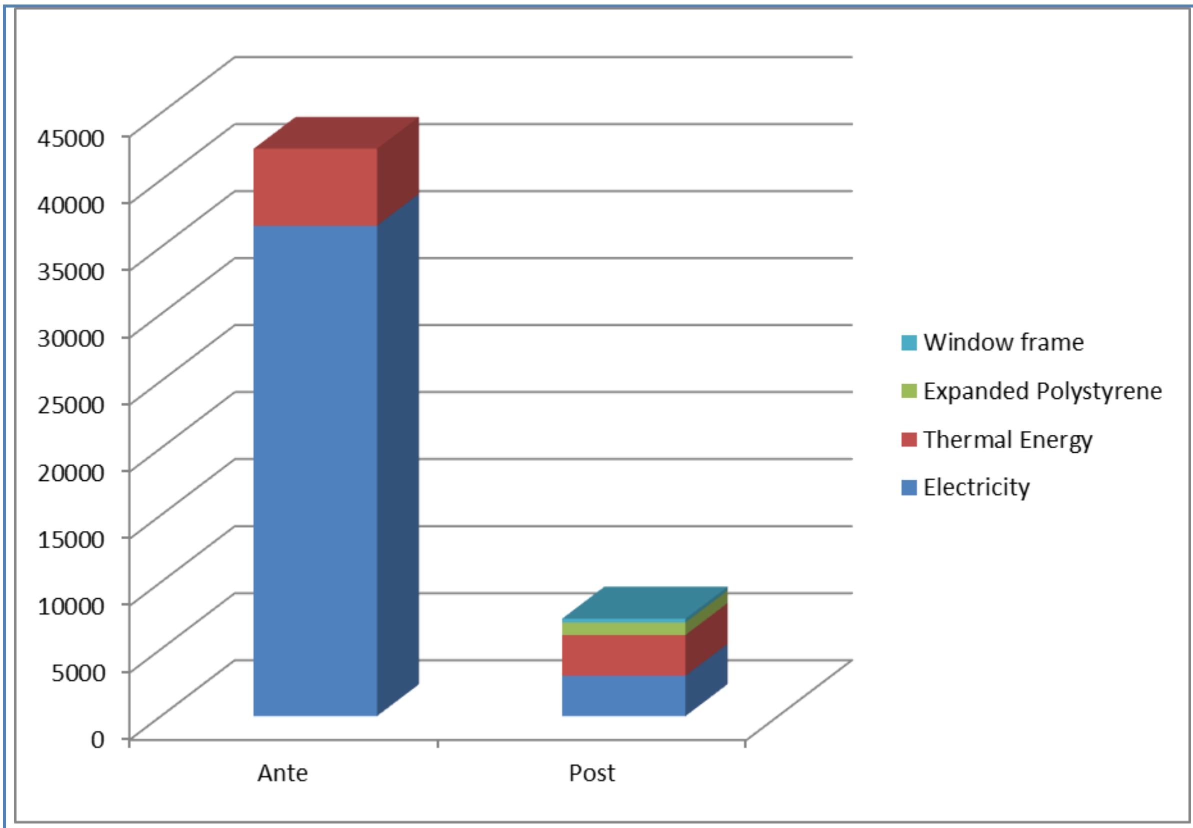
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software


Elementary school Trstenik Split - Ante (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
Elementary school Trstenik Split - Ante (1 year) <u-so>


Elementary school Trstenik Split - Post (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
Elementary school Trstenik Split - Post (1 year) <u-so>

Results



After the proposed renovation, the school overall emissions decreased of around 82% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 17% of the Post intervention emissions.

Elementary school Visoka Split

Description

The school was built in 1988 and the sports hall in 2007. The original building has four parts: a west wing with classrooms, an east wing with classrooms, a central part of the school and an auxiliary part in the north side of the school. The west wing was upgraded with one additional floor in 2009. The school building has an indented triangular shape. The sports hall has a rectangular ground plan, its longer sides oriented to the north and south and connected with the school in south side by the upgraded passage.
The east wing and the central parts of the school were originally built with two storeys high and the west wing was originally built with one storey high. In 2009 west wing was upgraded with one additional floor, so it is also two storeys high as the rest of the school. The auxiliary part of the building with a boiler room on the north side has one floor. The sports hall has one floor height of 10,00 m, and dressing rooms have one floor height of 2,7 m.
The classrooms wings are oriented with longer sides to the north and south, the central part of the school is oriented with longer side to the east and west. The auxiliary part is oriented with longer side to the north and south and the sports hall is oriented with longer side to the north and south too.
The building has been reconstructed several times. Over time, the windows have been replaced and the hydro-insulation on the roof has been renovated. During the reconstruction in 2009, the ground floor of the west wing was thermally insulated.

Initial Energy Requirement

There is one Power Meter in the Main Electrical Box and for the purposes of this report, data on electricity consumption have been collected for the past three years, and the data on consumption and costs are given below:

TABLE 0-17 CONSUMPTION OF ELECTRICITY BY MONTHS

Year	Electricity consumption per month (kWh)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
2015.	7.273	8.332	14.817	6.022	5.205	3.549	1.601	2.752	5.098	7.383	7.855	6.496	**76.383**
2016.	6.868	8.554	7.088	5.726	5.223	3.047	1.797	1.440	5.513	6.524	8.356	6.251	**66.387**
2017.	6.408	7.227	7.199	4.529	4.676	2.819	1.232	1.553	13.283	439	8.579	6.984	**64.928**
Average	**6.850**	**8.038**	**9.701**	**5.426**	**5.035**	**3.138**	**1.543**	**1.915**	**7.965**	**4.782**	**8.263**	**6.577**	**69.233**

The energy source for space heating is fuel oil extra light (FOEL). Consumption data was taken from the Energy Management Information System (EMIS).
The EMIS is a web-based application for supervision and analysis of energy and water consumption in the public buildings. The fuel consumption data (measured data) for the previous three years is listed in the table below:

TABLE 0-18 FOEL CONSUMPTION IN 2015 AND 2016

	2015.			2016.		
	Consumption [l]	Consumption [kWh]	Total cost (VAT included)	Consumption [l]	Consumption [kWh]	Total cost (VAT included)
Month	**[l]**	**[kW]**	**[kn]**	**[l]**	**[kW]**	**[kn]**
1	652	6.650	2.415,00	513	5.233	2.417,00
2	8.592	87.638	45.231,00	8.473	86.425	31.864,00
3	652	6.650	2.415,00	513	5.233	2.417,00
4	631	6.436	2.337,00	496	5.059	2.339,00
5	652	6.650	2.415,00	513	5.233	2.417,00
6	631	6.436	2.337,00	496	5.059	2.339,00
7	652	6.650	2.415,00	513	5.233	2.417,00
8	652	6.650	2.415,00	513	5.233	2.417,00
9	631	6.436	2.337,00	496	5.059	2.339,00
10	652	6.650	2.415,00	496	5.059	2.339,00
11	5.636	57.487	24.871,00	0	0	0,00
12	631	6.436	2.337,00	0	0	0,00
Total	**20.664**	**210.772,80**	**93.940,00**	**13.022**	**132.824,40**	**53.305,00**

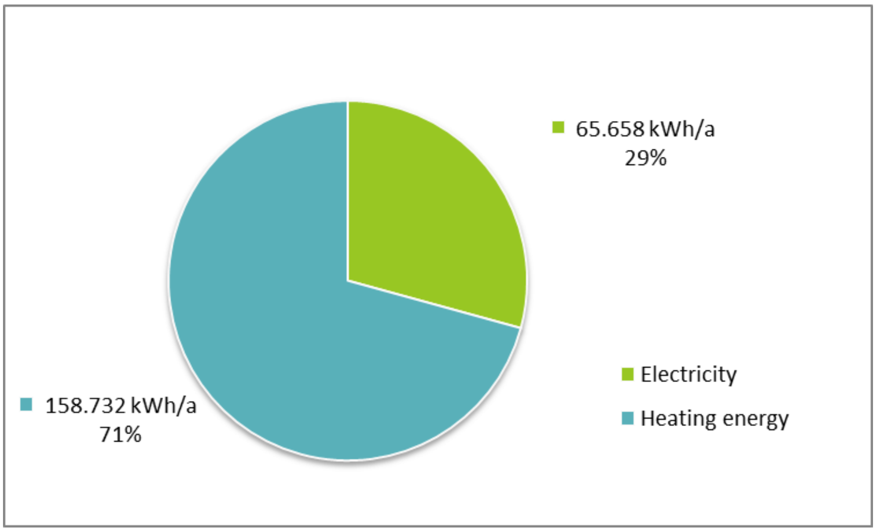
Reference consumption was determined on the basis of average consumption over the previous three years. FOEL reference consumption amounts to 15.562 litres per year, i.e. 158.732 kWh per year. Calculation is done using the lower heating value of H_D=10,2 kWh/l.

Measured consumption represents the actual consumption of energy carriers (electricity and fuel), which is also defined as reference consumption.

TABLE 0-19 MEASURED ENERGY CONSUMPTION AND CO_2 EMISSION

	Energy consumption	CO_2 Emission

Electricity	65.658,00	kWh/a	15.417,15	kg/a
Heating energy - FOEL	158.732,40	kWh/a	47.551,47	kg/a
TOTAL	**224.390,40**	**kWh/a**	**62.968,62**	**kg/a**



PICTURE 0-7 MEASURED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS

Aim of the renovation plan

The aim of the renovation plan is to improve energy efficiency of the school building in a way that the building meets the requirements for Nearly Zero Energy Building (nZEB). Improving the energy performance of the building will ensure savings in energy consumption and energy costs, and will also positively impact the carbon footprint.
Requirements for nZEB standards in Croatia are determined by the following values:
Maximum permitted energy need for heating per square meter of heated space,
Maximum permitted primary energy per square meter of conditioned floor area and
The share of renewable energy use produced on site or nearby.

The full description of the renovation plan is presented in the Energy Audit document.

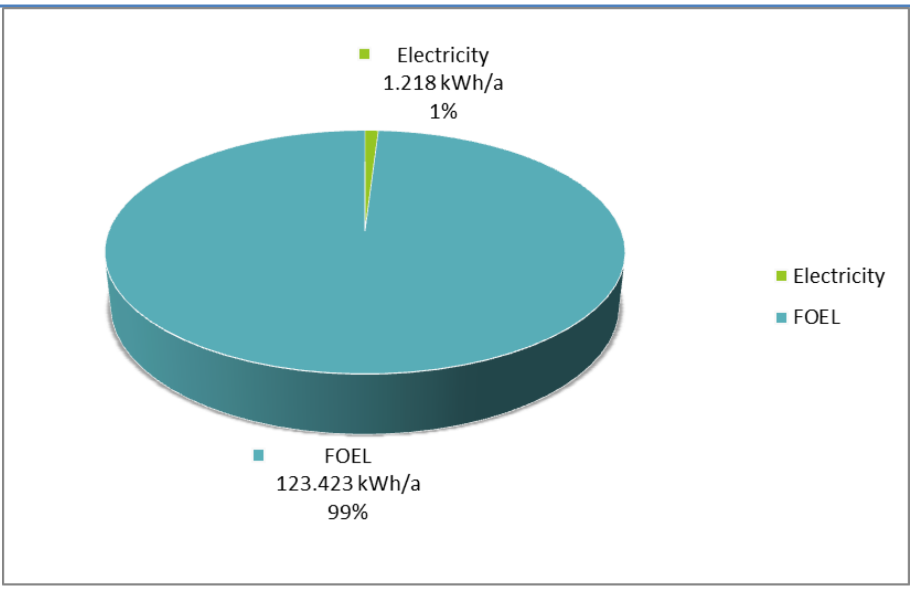
Final Energy Requirement

Estimated final energy consumption and CO_2 emission after recommended improvement actions:

TABLE 0-20 ESTIMATED ENERGY CONSUMPTION AND CO_2 EMISSION AFTER IMPROVEMENT ACTION

Energy carrier	Energy consumption		CO_2 Emission	
Electricity[1]	1.218	kWh/a	286	kg/a
Heating energy - FOEL	123.423	kWh/a	36.974	kg/a
TOTAL	**124.641**	**kWh/a**	**37.260**	**kg/a**

[1] Delivered energy from grid. The on-site produced energy is not shown in the table.



PICTURE 0-8 ESTIMATED ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS AFTER IMPROVEMENT ACTION

ENERGY CONSUMPTION – SHARE OF ENERGY CARRIERS AFTER IMPROVEMENT ACTION

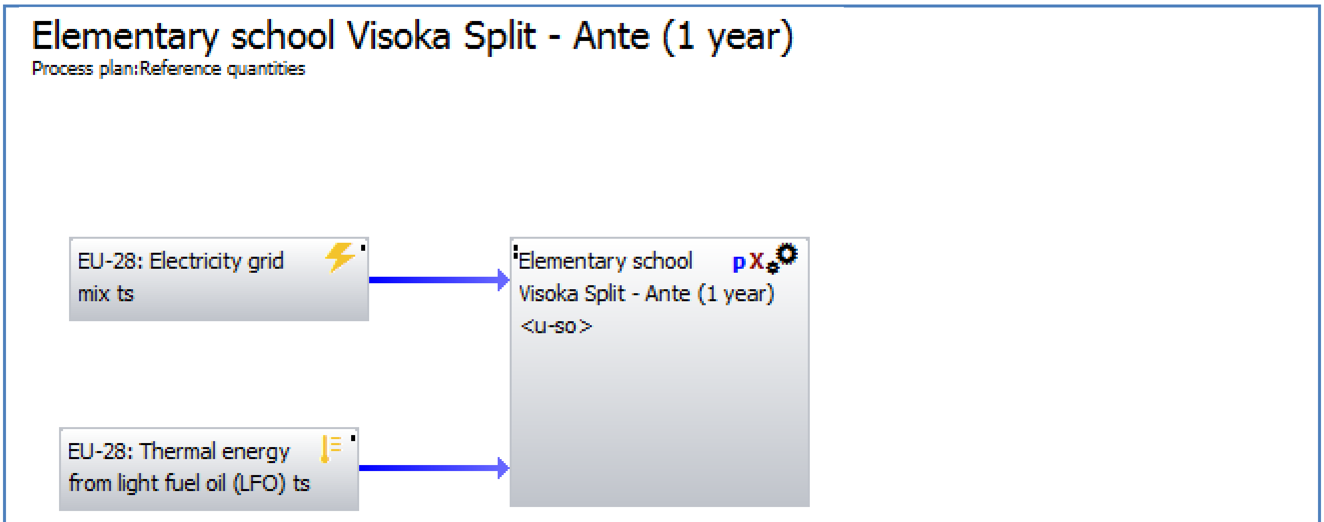
Materials and components

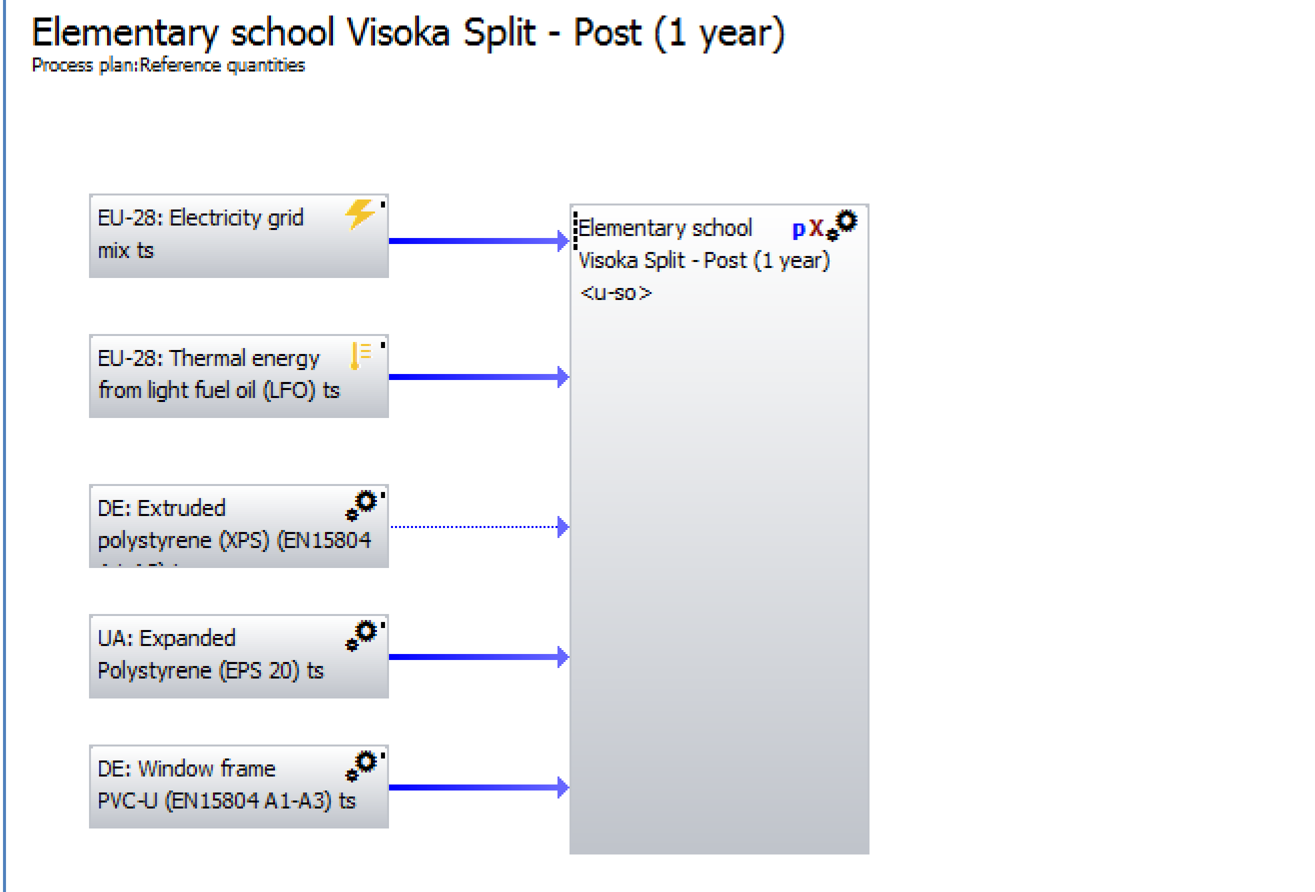
All prices and costs are expressed without VAT.

ACTION	*VOICE*	*U.M.*	*Unit Cost [EUR]*	*Total Cost [EUR]*
Building Envelope	Thermal insulation of external walls	628 m^2	93	58.404
	Windows reconstruction	690 m^2	420	289.800
	Thermal insulation of the flat roof	1.080 m^2	73	78.840
Technical system (Plants)	LED Lighting	468 pcs.	109	51.000
	PV Generation system	33,48 kWp	1.942	65.000
TOTAL				**543.044**

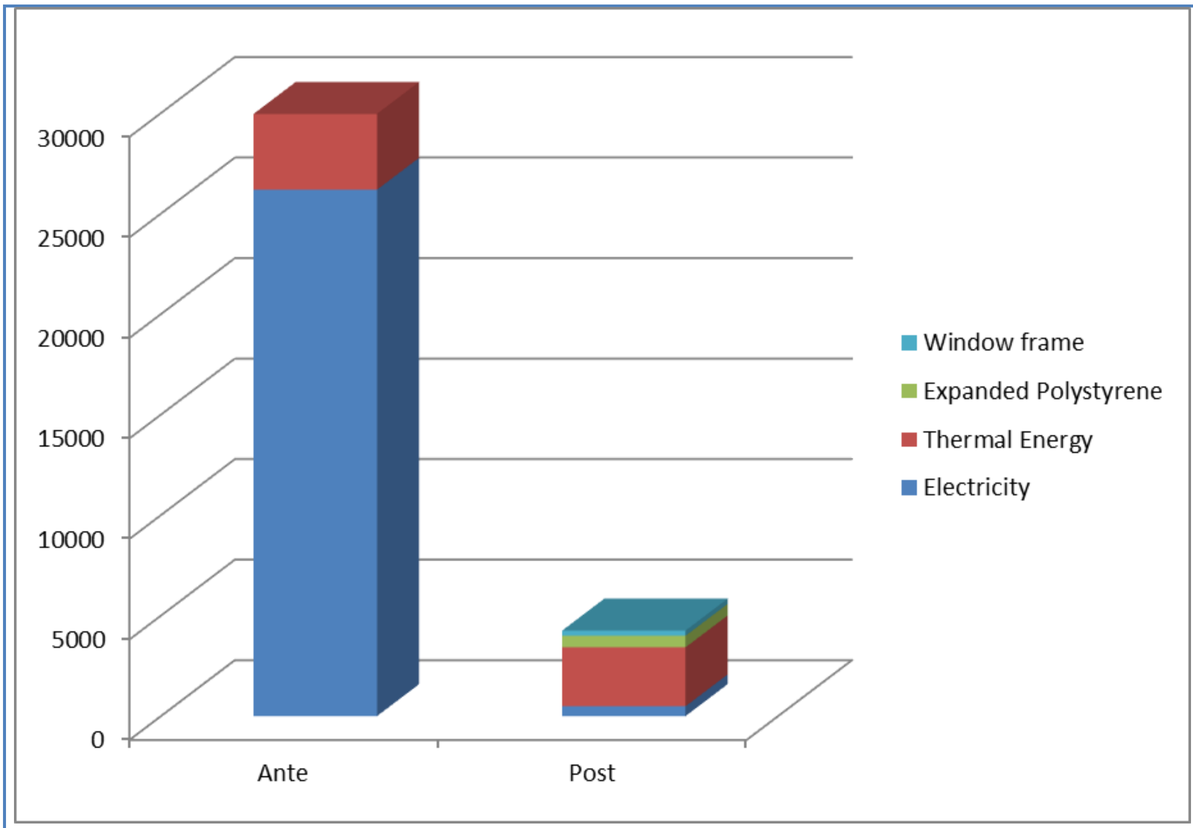
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software


Elementary school Visoka Split - Ante (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
Elementary school Visoka Split - Ante (1 year) <u-so>


Elementary school Visoka Split - Post (1 year)
Process plan:Reference quantities
EU-28: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
Elementary school Visoka Split - Post (1 year) <u-so>

Results



After the proposed renovation, the school overall emissions decreased of around 85% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 19% of the Post intervention emissions.

Cyprus

HADJIGEORGAKIS KORNESIOS PRIMARY SCHOOL IN AGLANTZIA, NICOSIA
Description
The school is located in the municipality of Aglantzia (36 Thessalias Street) in the province of Nicosia, next to the Akadimias Forest Park (coordinates 35.16 °N, 33.38 °E) – Figure 2. The municipality has a population of around 22 000 and is contiguous with Nicosia Municipality. Aglantzia is near the buffer zone and it has an area of about 31 km², of which 14 km² are agricultural land and under occupation. Of the remaining 17 km², 9 km² are national forest parks (Athalassa park: 8.6 km²) and Pedagogical Academy park: 0.4 km²). Aglantzia is Nicosia's highest suburb, since its largest part is built either on hills or on hillsides or at plain level.
Initial Energy Requirement
From the analysis of the collected electricity invoices, it seems that a seasonal profile is not easy to be acquired as the consumption does not range significantly through the various seasons. Even during the period which the school remains close for the students, there is a significant consumption due to the installations, the equipment and external safety lighting (Table 15). However, it can be seen that the lowest consumption is observed during April and May, whereas for the remaining months the consumption is highly connected to the external conditions and the usage of the building (Graph 14). Overall, it remains to the same levels which are highly expected as the use profile remains almost stable at each year (lighting use, equipment use). Moreover, as the school does not use active cooling in the

classrooms and uses oil for heating, the variations due to the climatological data can be seen mainly in terms of primary energy.

TABLE 15: ELECTRICITY CONSUMPTION AND ELECTRICITY COST FOR THE PERIOD OCTOBER 2015 – DECEMBER 2017

Electricity Consumption			
Time Period	Final Consumption (kWh)	Average Cost (€/kWh)	Total Cost (€)
06/10/15 - 03/12/15	2962	0.18	530.08
03/12/15 - 04/02/16	5175	0.16	850.1
04/02/16 - 06/04/16	3447	0.15	514.18
06/04/16 - 03/06/16	3146	0.15	477.93
03/06/16 - 03/08/16	5450	0.17	927.27
03/08/16 - 05/10/16	3789	0.17	658.79
05/10/16 - 05/12/16	4618	0.18	842.41
05/12/16 - 03/02/17	4540	0.21	935.15
03/02/17 - 05/04/17	4432	0.21	914.34
05/04/17 - 06/06/17	3167	0.20	633.67
06/06/17 - 03/08/17	4326	0.19	842.87
03/08/17 - 04/10/17	4267	0.19	817.95
04/10/17 - 05/12/17	4434	0.18	777.77
Annual Average	25395.50	0.18 €	4596.22

The oil refills for each season (academic year), are taking place in early autumn[14] according to the School Board. Over a period of 3 years it seems that the demand for heating remains stable at around 2 600 L (or 26 478.47 kWh) – Table 16. This is justified due to the fact that the operating profile of the heating system and the system itself remained the same over these years, the school premises did not change, and students are more or less the same. Moreover, even if there were differences among the climatological conditions during these years, it seems that it didn't affect the school at a great extent.

TABLE 16: HEATING OIL CONSUMPTION AND COST FOR THE PERIOD OCTOBER 2015 – MARCH 20178

Heating Oil Consumption				
Time Period	Final Consumption (L)	Final Consumption (kWh)	Average Cost (€/L)	Total Cost (€)
09/15 - 03/16	2977	30082.585	0.59	1764.32
09/16 - 03/17	2393	24181.265	0.70	1679.90
10/17 - 03/18	2491	25171.555	0.715	1783.06
Annual Average	2 620.33	26 478.47	1 756.02	1 167.69

Aim of the renovation plan

In this chapter the suggestions for an energy upgrade of the building are examined and analysed. The criteria for the evaluation of the suggested measures are the reduction of the energy consumption, the Net Present Value (NPV) and the achievement of better thermal comfort conditions. It is understood that the energy consumption and energy costs will continue to exist to meet the requirements in lighting, heating and electrical appliances/equipment. The benefit to Present Values, is the comparison between the implementation scenario and the non-implementation of the proposal.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Energy assessment

The energy consumption of the building without any intervention is as follows:

Electricity consumption in the building per year is 26 983 kWh

Oil consumption in the building per year is 25 436 kWh

With the implementation of the NZEB scenario, consumption will be modified as follows:

Electricity consumption in the building per year is 4 209 kWh (Including reduction from the PV production)

Oil consumption in the building per year is 12 050 kWh

Therefore, the resulting savings are as follows:

Electricity Savings in the building: 4 974 kWh (Excluding the savings from the PV system)

Heating oil savings in the building: 13 386 kWh$_{oil}$/year, equivalent to about 1 315 L/year

Materials and components

This scenario concerns the energy upgrade of the School Building to a NZEB as this is defined in the relative law (Regulatory Administrative Act 366/2014 & ANNEX C). In order to be in line with the legislation, the following measures were taken:

Placement of thermal Insulation on the exterior of the walls: Extruded polystyrene 10 cm with, λ=0.032 W/mK – Current Price in the market: around 15-20 € /m$_2$, Total needed: 1 471 m$_2$

Placement of thermal Insulation on the roofs: Extruded polystyrene 10 cm, with λ=0.032 W/mK – Current Price in the market: around 45 € /m$_2$, Total needed: 1 114 m$_2$

Replacement of the doors and windows: Double-glazing windows, aluminium frame with thermal break and shades where necessary - Current Price in the market: around 350 - 400 € /m$_2$, Total needed: 429 m$_2$

Replacement of the existing lights: Installation of 288 new LED lamps (Total Cost: 4351 €, As described in Scenario 2)

Thermal insulation of the distribution pipes of the heating system (Total Cost: 675 €, As described in Scenario 3)

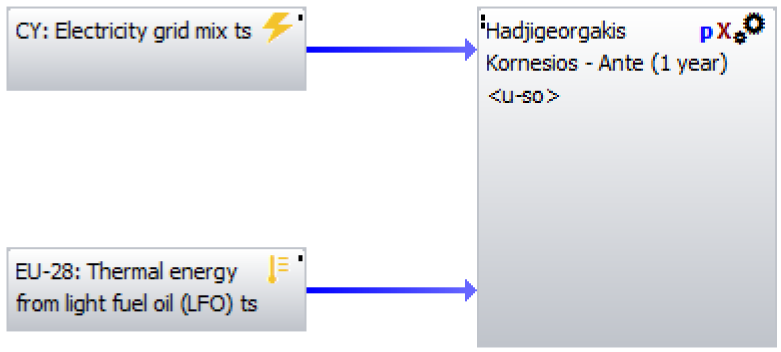
Installation of PV system: 10.4 kW$_p$ with the net-metering method (40 panels – 80 m$_2$ needed)[19] – Cost: 14 830 € including the purchasing and installing the photovoltaic system

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

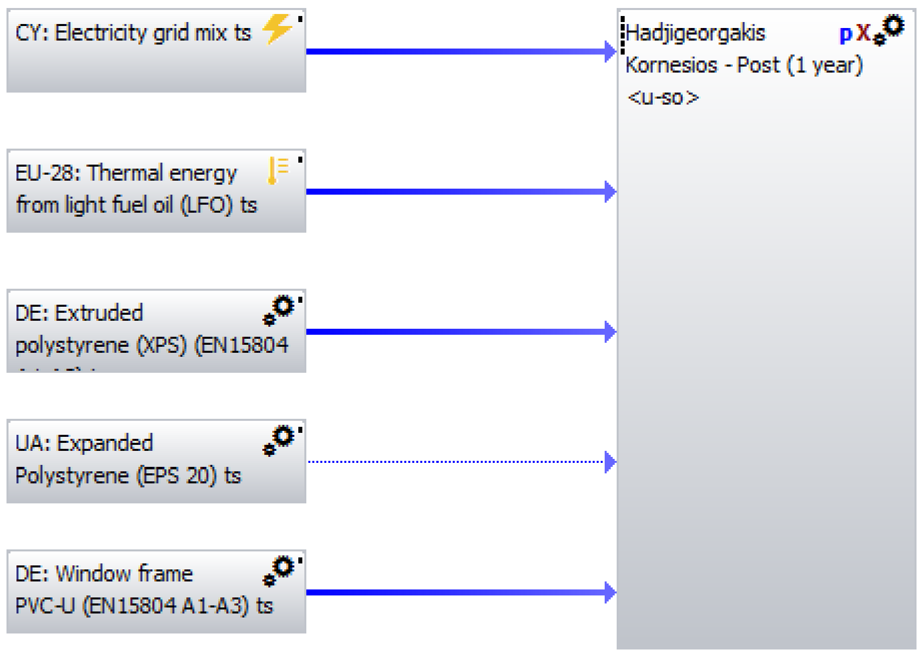
Hadjigeorgakis Kornesios - Ante (1 year)

Process plan:Reference quantities

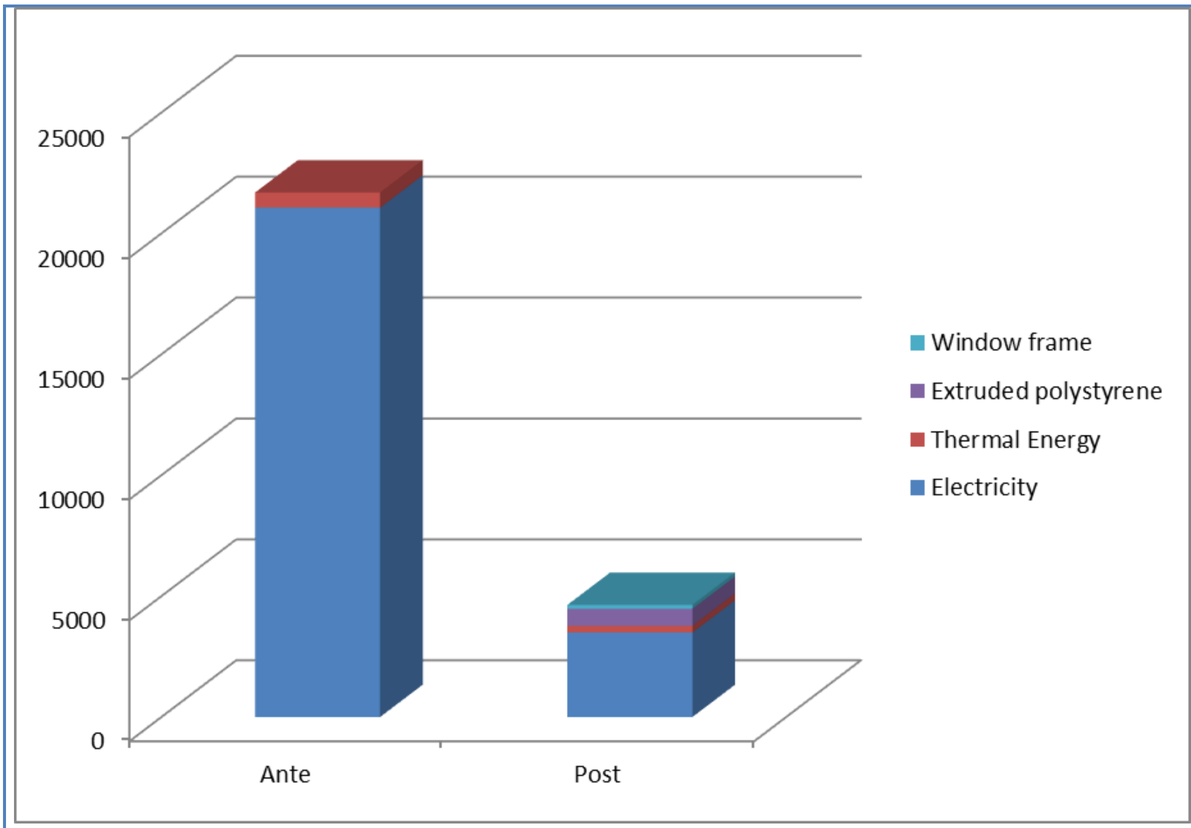


Hadjigeorgakis Kornesios - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 79% respect the initial conditions. The impact due to the materials used for the restoration contributes for an 18% of the Post intervention emissions.

VOROKLINI PRIMARY SCHOOL, LARNACA

Description

The school is located at the community of Oroklini on Pedias Street, about eight kilometres north-east of the city of Larnaca (coordinates: 34°98"N ,33°66"E), as indicated in Figure 2. Oroklini stands upon a barrow at the foot of a low, petal-shaped hill, at an altitude of about 50 m above sea level. Oroklini is connected to the Larnaca -- Ammochostos highway in the south-west, and to the quarries and mines that are located between Oroklini and the villages Troulloi and Avdellero in the north-west. At 3 km on the north-east it connects to the bordering, mixed-population village of Pyla. In the west it connects to the Livadia municipality. According to the last census (2011), it has about 6,134 residences.

Initial Energy Requirement

From the analysis of the collected electricity invoices (Table 7), it seems that a seasonal profile can be acquired as the consumption through all the years of gathered data, follows the same trend (the only exception is the period mid Sep- mid Nov 2016). The lowest consumption is observed during the period mid_July-August, as the school is closed for most of the time. However, the consumption is still significant, as during July some school premises are used for summer school. Between mid-May and mid-July the 2nd lowest consumption is observed, as the school is in reduced operation. It is also noted that the climatological conditions in Cyprus, between April and May, are usually comfortable to warm and the daylight duration is longer, therefore the school is free-running , which justifies the lower consumptions. On the other hand, the highest consumptions are observed during the winter months which are highly connected with the extended

use of artificial lighting (Graph 1). Regarding the periods when the school is closed, the observed consumptions are mainly due to the operating equipment and external safety lighting.
Overall, the consumption is highly connected to the external conditions and the usage of the building (Graph 1). Generally, it follows the same variations over the years which are highly expected as the use profile remains almost stable at each year (lighting use, equipment use). Moreover, as the school does not use active cooling in the classrooms and uses oil for heating, the variations due to the climatological data can be seen mainly in terms of primary energy.

TABLE 21: ELECTRICITY CONSUMPTION AND ELECTRICITY COST FOR THE PERIOD JULY 2014 - MAY 2018

Electricity Consumption			
Time Period	**Final Consumption (kWh)**	**Average Cost (€/kWh)**	**Total Cost (€)**
15/07/14 - 15/09/14	2,581	0.25	641.35
15/09/14 - 17/11/14	4,458	0.25	1,108.75
17/11/14 - 19/01/15	4,468	0.23	1,045.58
19/01/15 – 16/03/15	4,535	0.20	892.59
16/03/15 - 17/05/15	3,722	0.19	712.91
18/05/15 – 15/07/15	2,419	0.20	488.37
15/07/15 – 15/09/15	2,754	0.20	558.03
15/09/15 – 16/11/15	5,784	0.19	1,077.33
16/11/15 – 19/01/16	5,182	0.18	928.18
19/01/16 – 16/03/16	5,238	0.16	846.34
16/03/16 – 18/05/16	3,792	0.16	589.03
18/05/16 – 15/07/16	4,447	0.16	695.69
15/07/16 – 15/09/16	3,216	0.17	555.01
15/09/16 – 15/11/16	2,179	0.28	608.71
15/11/16 – 17/01/17	5,126	0.18	932.29
17/01/17 – 15/03/17	4,995	0.20	1,023.23
15/03/17 – 16/05/17	4,393	0.20	878.78
16/05/18 - 16/07/17	3,281	0.20	656.16
17/07/17 - 15/09/17	3,286	0.19	635.34
15/09/17 - 15/11/17	5,192	0.18	925.07
15/11/17 - 16/01/18	4,806	0.18	866.18
16/01/18 - 19/03/18	5,883	0.19	1,093.51
19/03/18 - 18/05/18	3,744	0.19	717.35
Annual Average	**24,424.93**	**0.20**	**4,812.22**

The oil refills for each season (academic year), are not taking place on regular time periods but they are done when dimmed necessary, usually between December - February, according to the school board. The refills are of fixed quantity and their frequency is differentiated on the basis of the predicted meteorological conditions (Graph 3). Over a period of 4 academic years it seems that the demand varied significantly. This indicates that except the differences among the climatological conditions during these years, the operating profile of the heating system was also differentiated, as the heating system and the school premises did not change significantly. The four new classrooms which were added on 2015, do not seem to be the reason for the increased consumption in 2016-2017, as during the next year, the consumption was reduced. On the following table (8), the annual average consumption, which equals to around 1,875 L (or 18,946 kWh), is indicated along with other indexes.

TABLE 22: HEATING OIL CONSUMPTION AND COST FOR THE PERIOD JANUARY 2015 – JANUARY 2018

Heating Oil Consumption				
Time Period	**Consumption (L)**	**Consumption (kWh)**	**Average Cost (€/L)**	**Total Cost (€)**
09/01/2015	1,000.00	10,105.00	0.81	811.00
25/02/2015	1,000.00	10,105.00	0.85	845.00
21/12/2015	1,000.00	10,105.00	0.73	728.00
09/12/2016	1,000.00	10,105.00	0.75	749.00
17/01/2017	500.00	5,052.50	0.81	404.50
06/02/2017	1,000.00	10,105.00	0.81	809.00
11/12/2017	1,000.00	10,105.00	0.83	827.00
26/01/2018	1,000.00	10,105.00	0.84	844.00
Annual Average	**1,875.00**	**18,946.88**	**0.80**	**1,490.86**

The primary energy consumption and the corresponding CO_2 emissions of the school are presented in Table 9. The school has an average annual final energy consumption of around 43.4 MWh, which translates to 86.8 MWh or 56.58 kWhPR/mHFA2 of primary energy consumption. The total emissions of the school are around 24.4 t CO_2. Both the energy consumption and the emissions of Voroklini Primary school are lower when compared to the average of Cypriot public schools. The lower consumptions are mainly due to the energy saving measures which already have been taken in the school (motion sensors, behavioural change). In addition, as the school's roof is insulated, and the iron-framed windows have been replaced, the internal conditions are more adequate, resulting in less energy use for thermal comfort.

TABLE 23: ANNUAL AVERAGE PRIMARY ENERGY CONSUMPTION AND CO_2 EMISSIONS FOR ELECTRICITY AND OIL

Electricity Consumption		
Time Period	**Primary Energy (kWh)[2]**	**CO_2 Emissions ($kg{\cdot}CO_2/kWh$)**
15/07/14 - 15/09/14	6,968.70	2,049.31
15/09/14 - 17/11/14	12,036.60	3,539.65
17/11/14 - 19/01/15	12,063.60	3,547.59
19/01/15 – 16/03/15	12,244.50	3,600.79
16/03/15 - 17/05/15	10,049.40	2,955.27
18/05/15 – 15/07/15	6,531.30	1,920.69
15/07/15 – 15/09/15	7,435.80	2,186.68
15/09/15 – 16/11/15	15,616.80	4,592.50
16/11/15 – 19/01/16	13,991.40	4,114.51
19/01/16 – 16/03/16	14,142.60	4,158.97
16/03/16 – 18/05/16	10,238.40	3,010.85

[2] Conversion factor for primary energy and CO_2 Emissions for electricity: 2.7 and 0.794 respectively.
Source: Energy Service, Ministry of Energy, Commerce, Industry and Tourism (2015), *Building Energy Performance Calculation Methodology – Part C*, Nicosia, Cyprus.

18/05/16 – 15/07/16	12,006.90	3,530.92
15/07/16 – 15/09/16	8,683.20	2,553.50
15/09/16 – 15/11/16	5,883.30	1,730.13
15/11/16 – 17/01/17	13,840.20	4,070.04
17/01/17 – 15/03/17	13,486.50	3,966.03
15/03/17 – 16/05/17	11,861.10	3,488.04
16/05/18 - 16/07/17	8,858.16	2,604.96
17/07/17 - 15/09/17	8,872.20	2,609.08
15/09/17 - 15/11/17	14,018.40	4,122.45
15/11/17 - 16/01/18	12,976.20	3,815.96
16/01/18 - 19/03/18	15,884.10	4,671.10
19/03/18 - 18/05/18	10,108.80	2,972.74
Oil Consumption		
Time Period	**Primary Energy (kWh)[3]**	**CO_2 Emissions ($kg{\cdot}CO_2/kWh$)**
09/01/2015	11,115.50	2,687.93
25/02/2015	11,115.50	2,687.93
21/12/2015	11,115.50	2,687.93
09/12/2016	11,115.50	2,687.93
17/01/2017	5,557.75	1,343.97
06/02/2017	11,115.50	2,687.93
11/12/2017	11,115.50	2,687.93
26/01/2018	11,115.50	2,687.93
Annual Average	**86,788.88 (43,371.81 Final Energy)**	**24,433.27**

Aim of the renovation plan

In this chapter the suggestions for an energy upgrade of the building are examined and analysed. The criteria for the evaluation of the suggested measures are the reduction of the energy consumption, the Life Cycle Cost (LCC) and the Net Cash Flow (NCF) of each measure, and the achievement of better thermal comfort conditions in a quantify matter. It is understood that the energy consumption and energy costs will continue to exist to meet the requirements in lighting, heating and electrical appliances/equipment.
The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

In the following table the final energy consumption and the associated CO_2 emissions for each intervention scenario are illustrated.

TABLE 24: ANNUAL ENERGY CONSUMPTION AND CO_2 EMISSIONS FOR THE BASELINE SCENARIO AND THE EXAMINED SCENARIOS

Intervention	Electricity consumption [kWh/a]	Oil consumption [kWh/a]	CO_2 Emissions [kg/a]

[3] Conversion factor for primary energy and CO_2 Emissions for Heating Oil: 1.1 and 0.266 respectively. Lower Calorific value of heating oil: 10.11 kWh/L. Source: Energy Service, Ministry of Energy, Commerce, Industry and Tourism (2015), *Building Energy Performance Calculation Methodology – Part C*, Nicosia, Cyprus.

Current situation	24,425	18,947	24,433
SC1. Insulation of the heating distribution pipelines	24,425	15,462	23,506
SC2. Energy efficient lighting (LED Technology)	17,478	18,947	18,917
SC3. Installation of PV system – 5.2 kW_p capacity	10,625	18,947	13,476
SC4. Upgrade to a NZEB	2,214	8,857	4,113

Materials and components

This scenario concerns the energy upgrade of the School Building to a NZEB as this is defined in the relative law (Regulatory Administrative Act 366/2014[4] & ANNEX C). In order to be in line with the legislation, the following measures were taken:

Placement of thermal Insulation on the exterior[5] of the walls: Extruded polystyrene 100 mm with, λ equal to 0.032 W/(m·K) – Current Price in the market: around 45 € /m^2, Total needed: 4,331 m^2

Placement of thermal Insulation on the roofs of Block B-E: Rockwool 50[6] mm, with λ equal to 0.037 W/(m·K) – Current Price in the market: around 30 € /m^2, Total needed: 692 m^2

Placement of thermal Insulation on the false ceiling of Block A roof: Rockwool 100 mm, with λ equal to 0.037 W/(m·K) – Current Price in the market: around 25 € /m^2, Total needed: 275 m^2

Replacement of the doors and windows: Double-glazing windows, aluminium frame with thermal break and shades where necessary – Current Price in the market: 400 €/m^2 (mean average cost depending on the size and extra features), Total needed: 434 m^2

Replacement of the existing lights: Installation of 306 new LED lamps (Total cost: 6,037 €, as described in Scenario 2)

Thermal insulation of the heating distribution pipelines of the heating system (Total cost: 637 €, As described in Scenario 1)

Installation of PV system: 7.8 kW_p with the net-metering method (30 panels – 145 m^2 needed) – Cost: 11,750 € including the purchasing and installing the photovoltaic system

It is noted that Block F is excluded from the calculations for thermal insulation on the roofs and the walls, and for new windows, as it is a new building and it meets most of the minimum requirements.

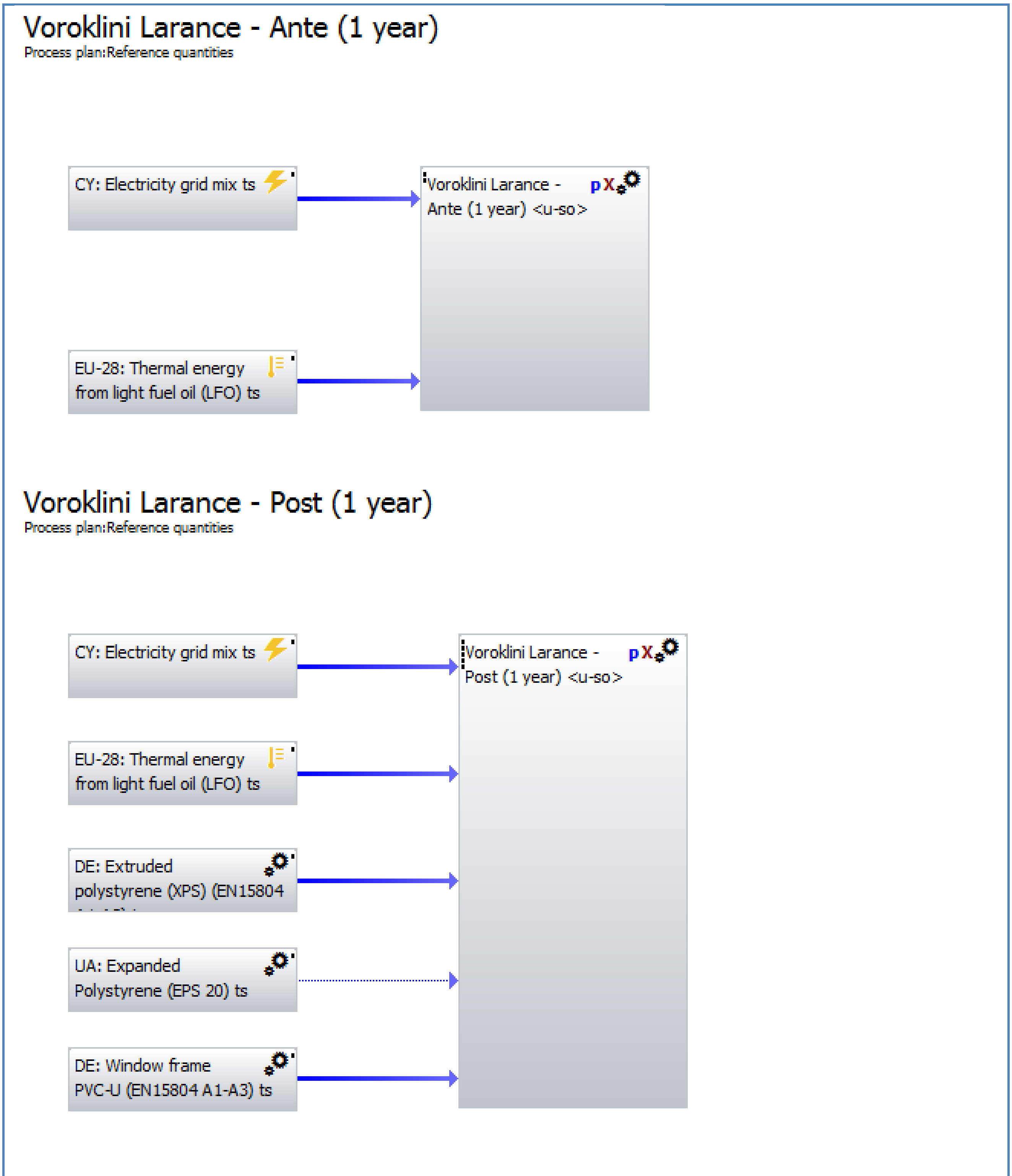
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

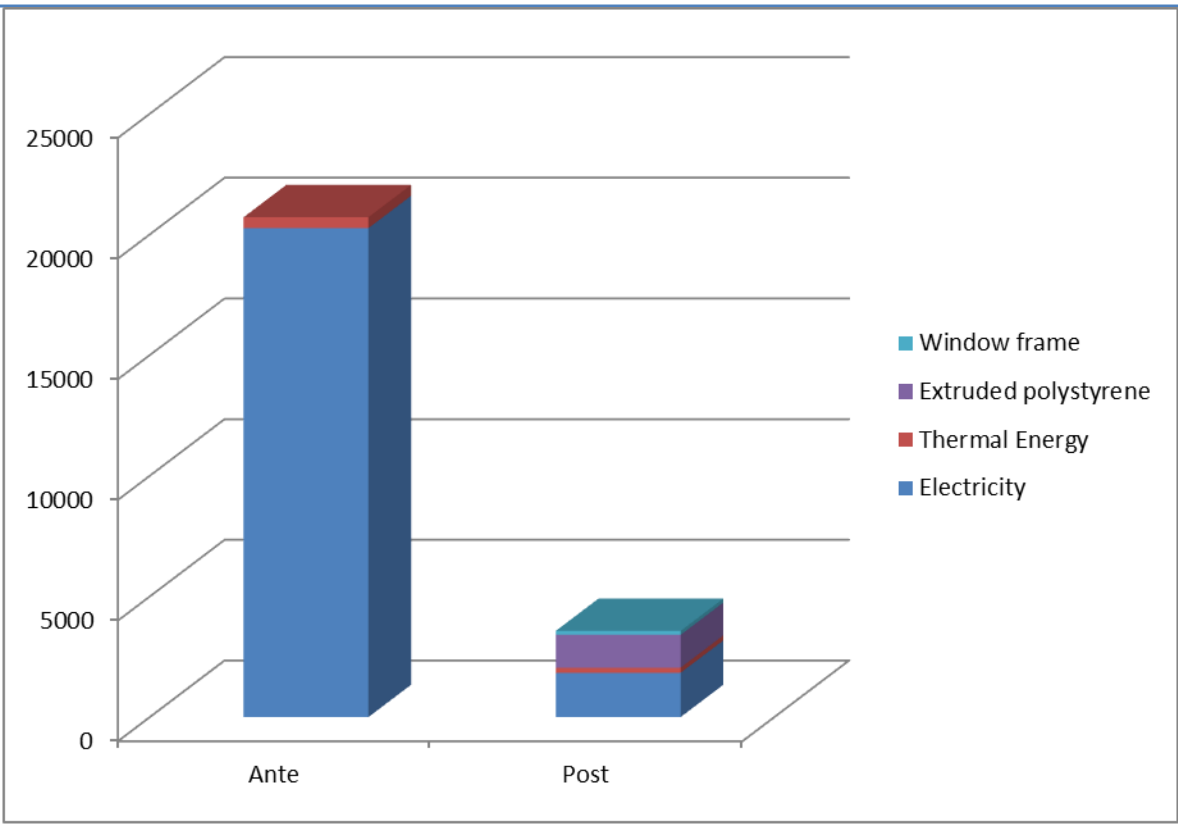
[4] MECIT (2014), "*Requirements and technical characteristics to be met by the Nearly Zero Energy Building - RAA 366/2014*"

[5] It's suggested to place external insulation and not internal, since the latter will cause problems on the interior of the spaces, due to the creation of thermal bridges.

[6] The roofs of Block B, C, D and E are already insulated with 50 mm, therefore another 50 mm are added to meet the minimum requirements.


Voroklini Larance - Ante (1 year)
Process plan:Reference quantities
CY: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
Voroklini Larance - Ante (1 year) <u-so>
Voroklini Larance - Post (1 year)
Process plan:Reference quantities
CY: Electricity grid mix ts
EU-28: Thermal energy from light fuel oil (LFO) ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
Voroklini Larance - Post (1 year) <u-so>

Results



After the proposed renovation, the school overall emissions decreased of around 82% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 42% of the Post intervention emissions.

France

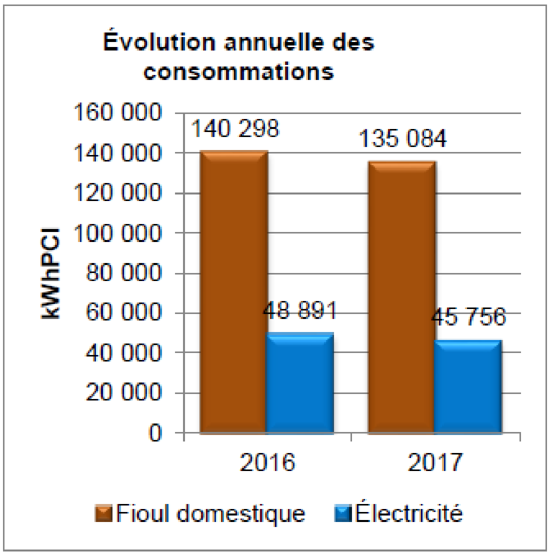
Regional Training Center - AVIGNON DIVISION	
Description	
Regional Training Center - AVIGNON DIVISION - 7 Avenue de l'étang	
Type	Training Centre / Offices.
NUA	2,003 m2
Heated area	1,669 m2
Number of floors	2 (ground floor and 1st floor)
Heating system	Oil-fired boiler
Initial Energy Requirement	

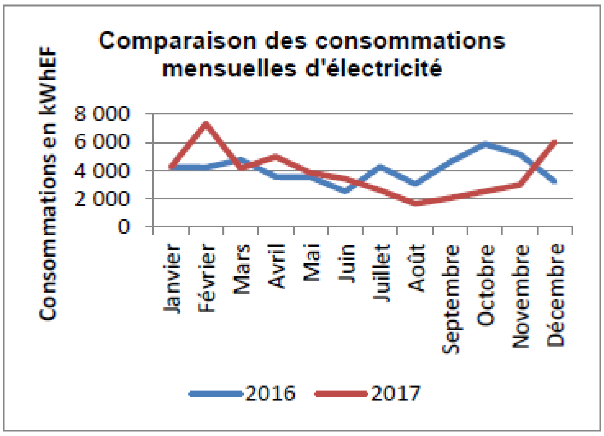
3.1 Consumption history

Actual energy consumption		2016	2017	Average	Ratio/m²NUA
Oil	Consumption (kWhEF)	140,298	135,084	137,691	81.4
	CO2 emissions (Teq-CO2)	42	40	41	
	Expenses (€INC.T)	7,725	10,424	9,074	
	Unit cost (€INC.T/kWh)	0.05	0.07	0.06	
Electricity	Consumption (kWh)	48,891	45,756	41,324	
	CO2 emissions (Teq-CO2)	4	4	4	
	Expenses (€INC.T)	9,277	9,080	9,178	
	Unit cost (€INC.T/kWhPCI)	0.19	0.20	0.19	

The data shown below is taken from energy bills over the last two years (2016 and 2017).

Evolutions des consommations réelles





Aim of the renovation plan

The "Energy optimisation" scenario: this last scenario allows presenting an optimal source of energy savings for the building. The associated costs will be high but inherent to the proposed solutions because the objective is to reduce the site's energy consumption by 62%.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

5.3 Scenario 3: "Energy optimisation"

	Synthesis			
Annual energy saving	169,900	kWhEF	43 kWhEP/m²	51 to 110 B
Share of total consumption	84.3	%		
Financial savings in the first year	12,400	€INC.T		
CO2 emissions prevented	54	tonnes		
Cost of the work	303,300	€EXC.T	5 kgeqCO2/m²	6 to 15 B
Cost per m²NUA	149	€EXC.T/m²		
Gross return time	27	years		
Actualised return time	17	years		
EEC valuation (€0.40c/kWhCUMAC)	26,394	€		

List of interventions performed

Actions	Cost	Cost / m²
Replacement of circulation pumps	3 500 €TTC	1,7 €TTC/m²
Replacement of fan coil units	15 000 €TTC	7,4 €TTC/ m²
LED relamping	16 000 €TTC	7,4 €TTC/m²
Reinforcement of the roof insulation	48 600 €TTC	48,5 €TTC/m²
Installation of an air/water heat pump	46 900 €TTC	23 €TTC/m²
Insulation of the walls on the north side	80 500 €TTC	40 €TTC/m²
Replacement of inefficient openings	42 500 €TTC	21 €TTC/m²
Cost of the work	**303 000 €TTC**	**149 €TTC/ m²**

Changes in consumption

Changes in the energy class (kWh_{EP}/m^2_{SHON})	114	111 à 210 C	▶	43	< 51 A
Changes in the climate class ($kg\ CO_2/m^2_{SHON}$)	28	11 to 30 C	▶	5	< 6 A

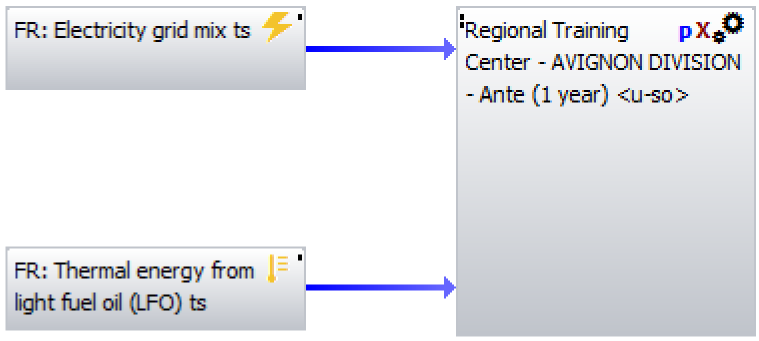
Materials and components

Information about materials used can be find in the energy audit

Model on GaBi software

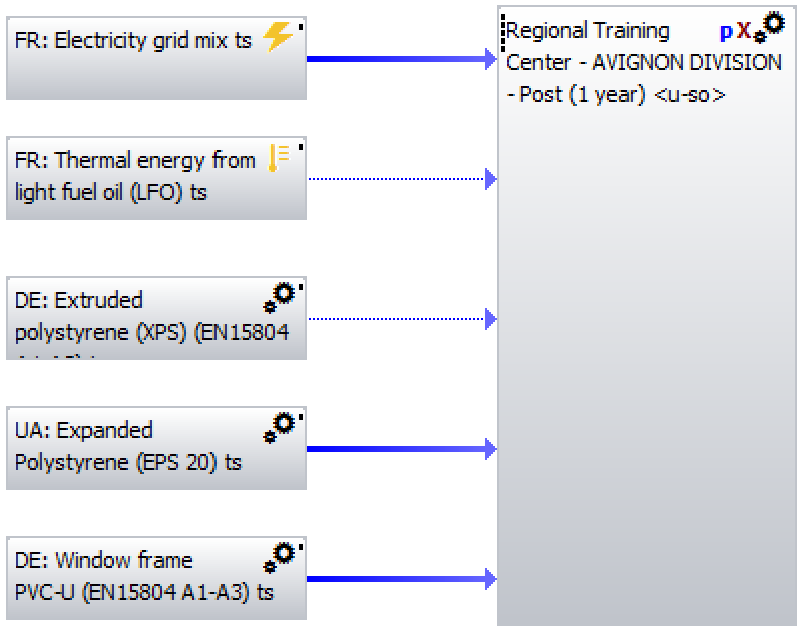
Regional Training Center - AVIGNON DIVISION - Ante (1 year)

Process plan:Reference quantities

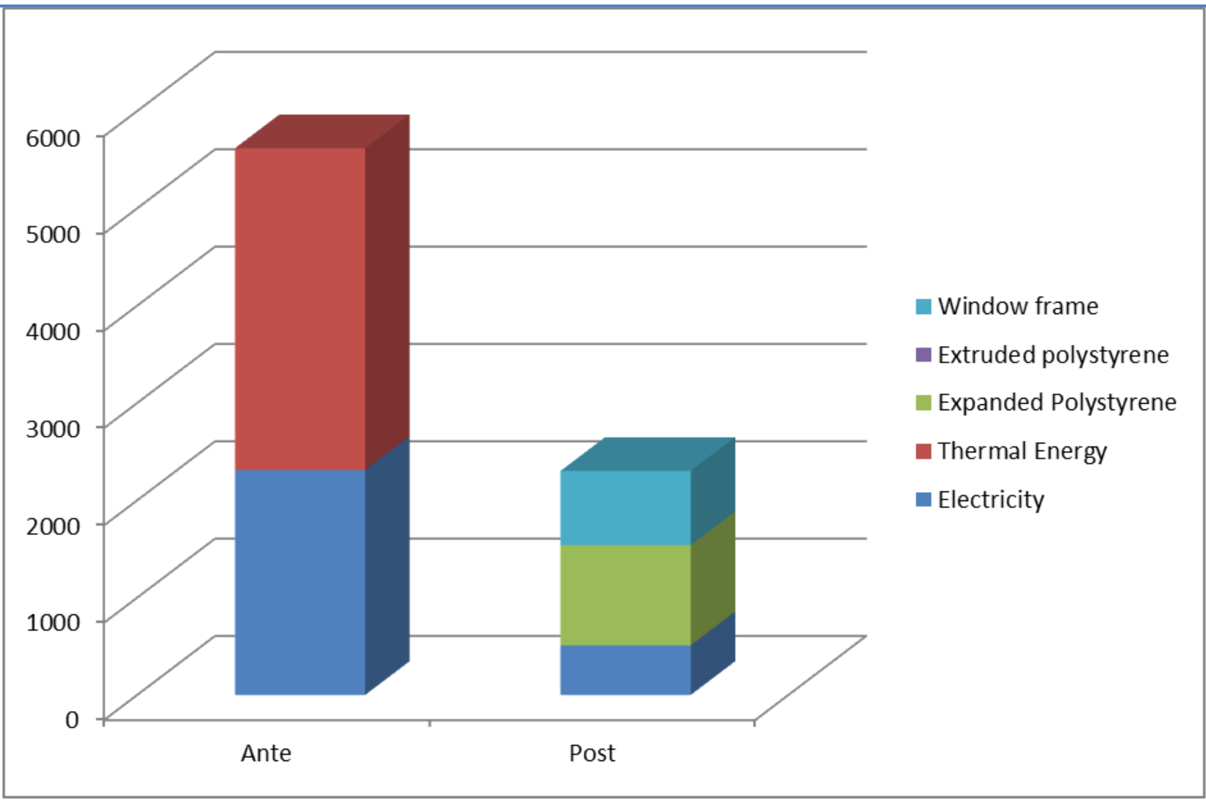


Regional Training Center - AVIGNON DIVISION - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 59% respect the initial conditions. The impact due to the materials used for the restoration is the 78% of the Post intervention emissions.

Regional Training Centre - Dignes les Bains

Description

Regional Training Centre - Dignes les Bains Campus - 15 Rue Maldonat 04000 Digne-les-Bains
Construction period 1977
Type Training Centre / Offices.
NUA 8,117 m2
Heated area 7,379 m2
Number of floors 3 (ground floor, 1st floor and 2nd floor)
Heating system Gas boilers, convectors, radiant panels
Ventilation system Single flow natural and mechanical ventilation.

Initial Energy Requirement

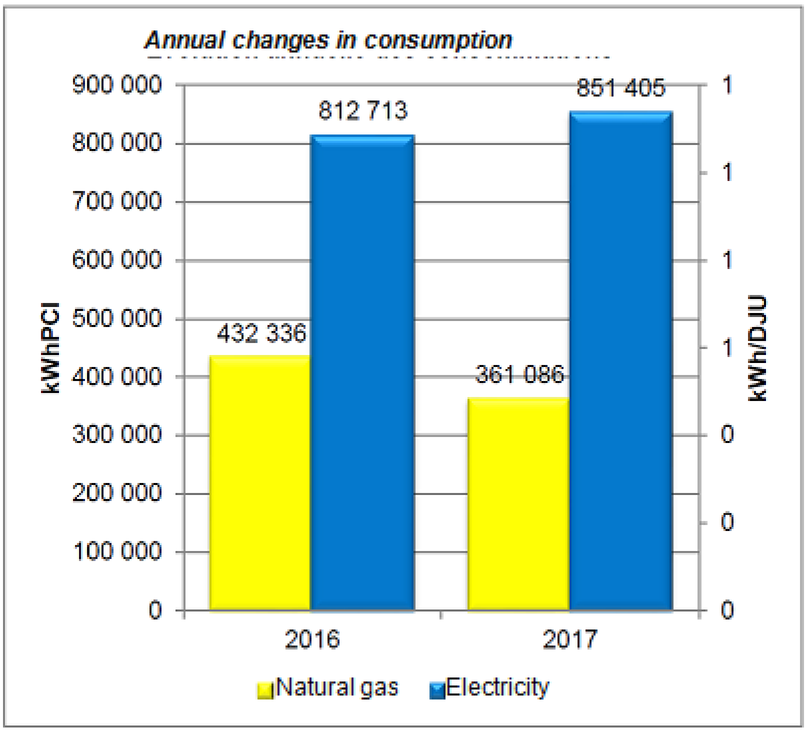
The analysis of energy consumption makes it possible to monitor heating consumption according to climatic severity and the changes in electricity consumption in order to note any deviations. Moreover, this analysis makes it possible to control the price of energies and their evolutions.

Electricity consumption is stable over 2016, 2017.
Consumption of natural gas increases by 16% between 2016 and 2017, this is due to climatic severity, stronger in 2017 compared to 2016.

Actual energy consumption		2016	2017	Average	Ratio/m²NUA
Gas	Consumption (kWhEF)	432 336	361 086	396 711	54
	CO_2 emissions (Teq-CO_2)	101	84	92	
	Expenses (€INC.T)	33 072	19 742	26 407	
	Unit cost (€INC.T/kWh)	7	5	6	
Electricity	Consumption (kWh)	812 713	851 405	832 059	113
	CO_2 emissions (Teq-CO_2)	68	72	70	
	Expenses (€INC.T)	96 807	93 546	95 176	
	Unit cost (€INC.T/kWhPCI)	10	9	10	

The data shown below is taken from energy bills over the last two years (2016 and 2017).

Changes in actual consumption



Aim of the renovation plan

The "Energy optimisation" scenario: this last scenario allows presenting an optimal source of energy savings for the building. The associated costs will be high but inherent to the proposed solutions because the objective is to reduce the site's energy consumption by 47%.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

5.3 Scenario 3: "Energy optimisation"

	Synthesis			
Annual energy saving	602100	kWhEF	177 kWhEP/m²	111 t 210 C
Share of total consumption	47	%		
Financial savings in the first year	53900	€INC.T		
CO2 emissions prevented	85	tonnes		
Cost of the work	855300	€EXC.T	11 kgeqCO2/m²	6 t 15 B
Cost per m²NUA	231	€EXC.T/m²		
Gross return time	>30	years		
Actualised return time	30	years		
EEC valuation (€0.40c/kWhCUMAC)	30719	€		

List of interventions performed				
Actions	**Cost**		**Cost / m²**	
Setting up a clock to control the ventilation	6000	€INC.T	1.6	€INC.T/m²
Installation of thermostatic valves	700	€INC.T	0.1	€TTC/m²
Replacement of circulation pumps	6600	€INC.T	1.7	€INC.T/m²
Replacement of convectors	175000	€INC.T	47	€INC.T/m²
Decentralisation of domestic hot water production	45500	€INC.T	12	€INC.T/m²
Replacement of boilers	50100	€INC.T	14	€INC.T/m²
Repair of poorly insulated high floors	29700	€INC.T	8	€INC.T/m²
Insulation of the walls from the inside	240000	€INC.T	65	€INC.T/m²
Replacement of inefficient openings	177500	€INC.T	48	€INC.T/m²
LED relamping	124200	€INC.T	34	€INC.T/m²
Cost of the work	**855300**	**€INC.T**	**231**	**€INC.T/m²**

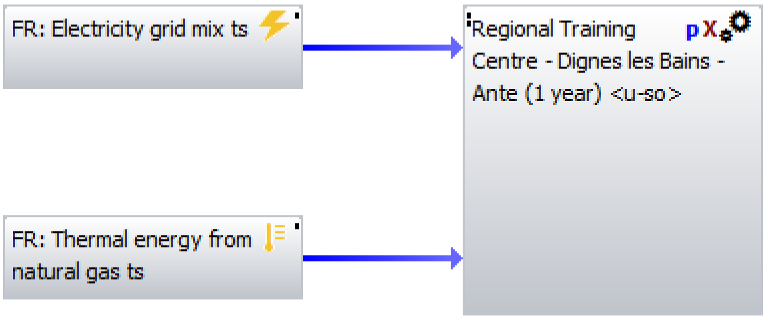
Materials and components

Information about materials used can be find in the energy audit

Model on GaBi software

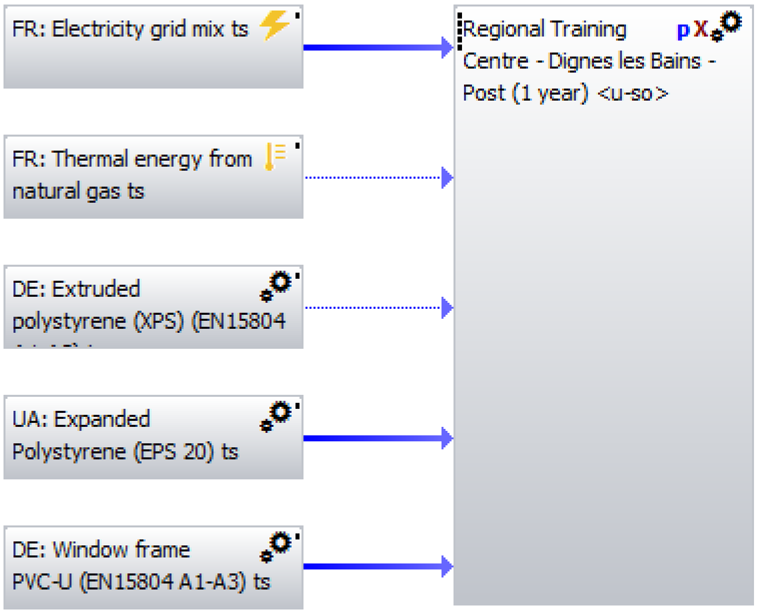
Regional Training Centre - Dignes les Bains - Ante (1 year)

Process plan:Reference quantities

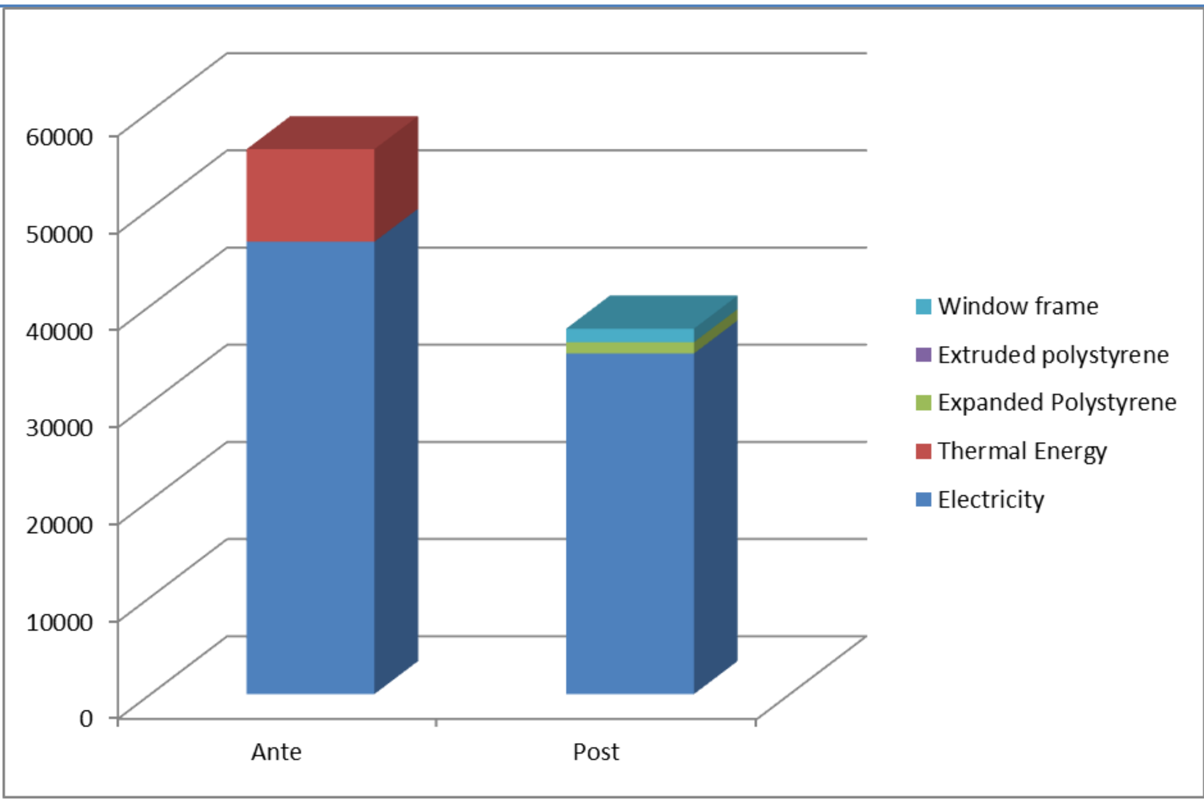


Regional Training Centre - Dignes les Bains - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 33% respect the initial conditions. The impact due to the materials used for the restoration contributes for the 7% of the Post intervention emissions.

Regional Training Center - Gap

Description

Regional Training Center - Gap Campus 10 Route de Graffinel 05000 Gap

Construction period 1992
Type Training Centre / Offices.
NUA 4,402 m2
Heated area 4,002 m2
Number of floors 2 (ground floor and 1st floor)
Heating system Gas-fired boilers
Ventilation system Single flow natural and mechanical ventilation.

Initial Energy Requirement

The analysis of energy consumption makes it possible to monitor heating consumption according to climatic severity and the changes in electricity consumption in order to note any deviations. Moreover, this analysis makes it possible to control the price of energies and their evolutions.

The electricity consumption for 2017 is not complete, the month of December was not provided to us; an estimate, in relation to previous years, was thus prepared for the simulation.
Consumption of natural gas follows climatic severity; nevertheless, it increases by 14% between 2015 and 2016. It should also be noted that the price per kWh of natural gas drops significantly in 2017.

Electricity consumption is stable at 5% for the 2015-2017 period.

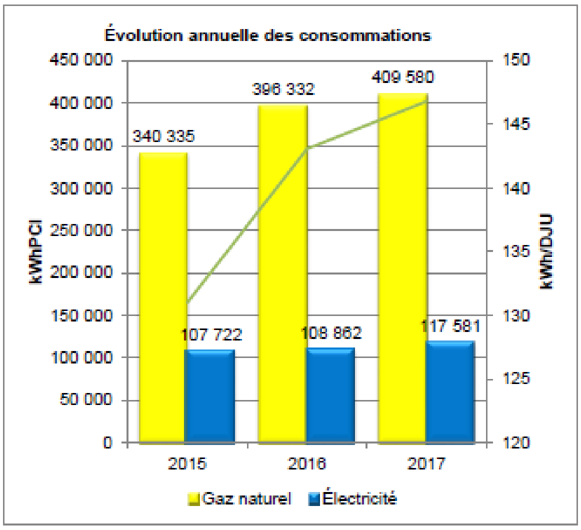
The monthly electricity consumption profiles also make it possible to display an estimated consumption of 1000 kWh/month (observable in July and August).

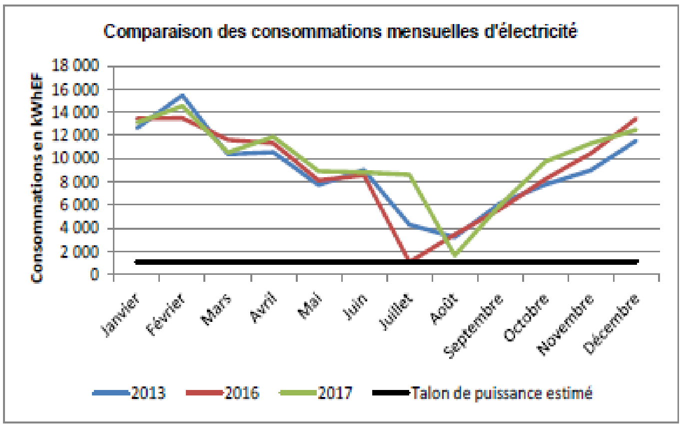
3.1 Consumption history

Actual energy consumption		2015	2016	2017	Average	Ratio/m²NUA
Gas	Consumption (kWhEF)	340,335	397,332	409,580	382,082	**95.5**
	CO2 emissions (Teq-CO2)	79.6	92.7	95.8	89.4	
	Expenses (€INC.T)	18,944	21,552	12,184	17,560	
	Unit cost (€INC.T/kWh)	**0.05**	**0.05**	**0.02**	**0.04**	
Electricity	Consumption (kWh)	107,722	108,862	117,581	111,388	**27.8**
	CO2 emissions (Teq-CO2)	9.04	9.14	9.88	9.36	
	Expenses (€INC.T)	17,559	15,741	17,931	17,077	
	Unit cost (€INC.T/kWhPCI)	**0.16**	**0.17**	**0.15**	**0.15**	

The data shown below is taken from energy bills over the last three years (2015, 2016 and 2017).

Evolutions des consommations réelles





Aim of the renovation plan

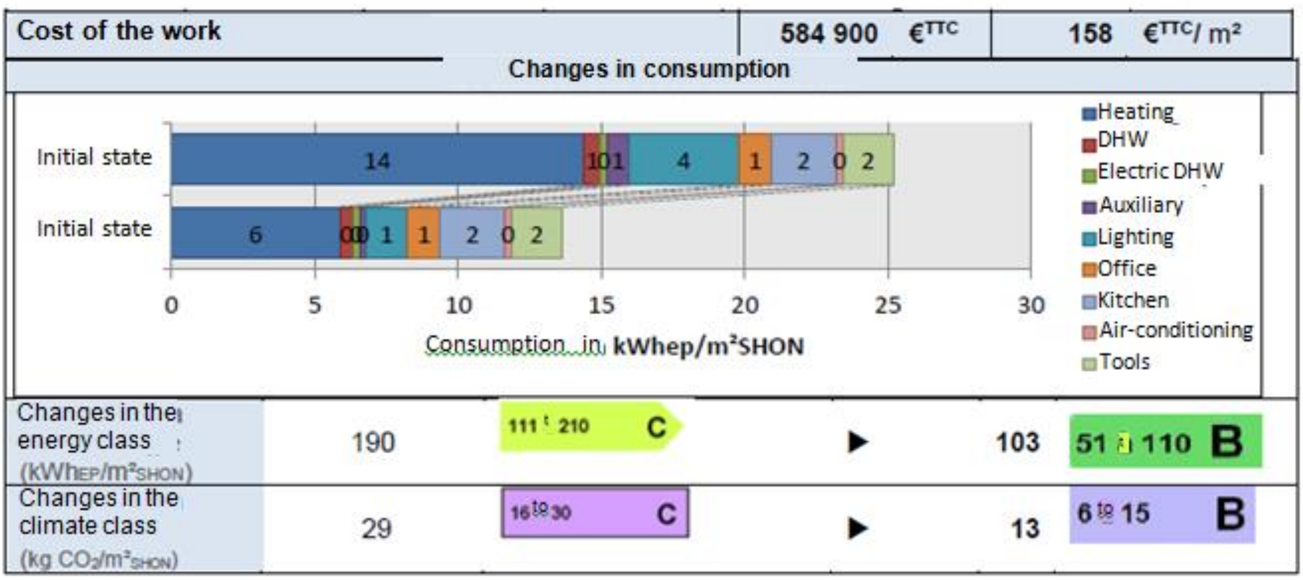
The "Energy optimisation" scenario: this last scenario allows presenting an optimal source of energy savings for the building. The associated costs will be high but inherent to the proposed solutions because the objective is to reduce the site's energy consumption by 62%.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	Synthesis		
Annual energy saving	272,100	kWh_{EF}	103 kWhEP/m²
Share of total consumption	51.6	%	51 to 110 B
Financial savings in the first year	13,400	€$^{INC.T}$	
CO_2 emissions prevented	59	tonnes	
Cost of the work	584,900	€$^{EXC.T}$	5 kgeqCO_2/m²
Cost per m²NUA	158	€$^{EXC.T}$/m²	
Gross return time	>30	years	6 t 15 B
Actualised return time	26	years	
EEC valuation (€0.40c/kWhCUMAC)	44,333	€	

List of interventions performed		
Actions	**Cost**	**Cost / m ²**
Optimisation of the regulation parameters	€100$^{INC.T}$	<1 €$^{INC.T}$/m^2
Installation of thermostatic valves	€3,100$^{INC.T}$	<1 €$^{INC.T}$/m^2
Insulation of heat distribution networks	€1,600$^{INC.T}$	<1 €$^{INC.T}$/m^2
Replacement of circulation pumps	€18,000$^{INC.T}$	€5$^{INC.T}$/m^2
LED relamping	€126,900$^{INC.T}$	€34$^{INC.T}$/m^2
Thermal insulation from the outside	€247,800$^{INC.T}$	€67$^{INC.T}$/m^2
Replacement of inefficient openings	€132,000$^{INC.T}$	€36$^{INC.T}$/m^2
Replacement of boilers	€55,000$^{INC.T}$	€15$^{INC.T}$/m^2



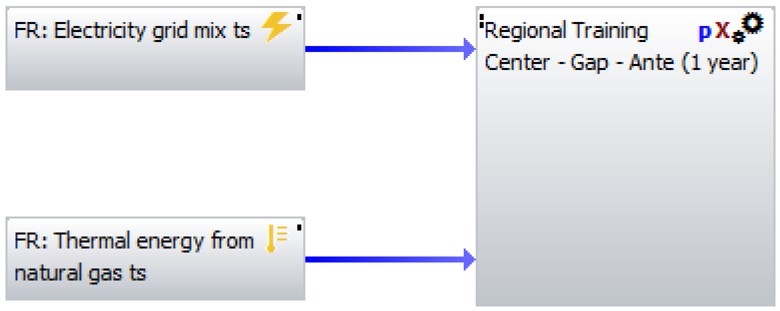
Materials and components

Information about materials used can be find in the energy audit

Model on GaBi software

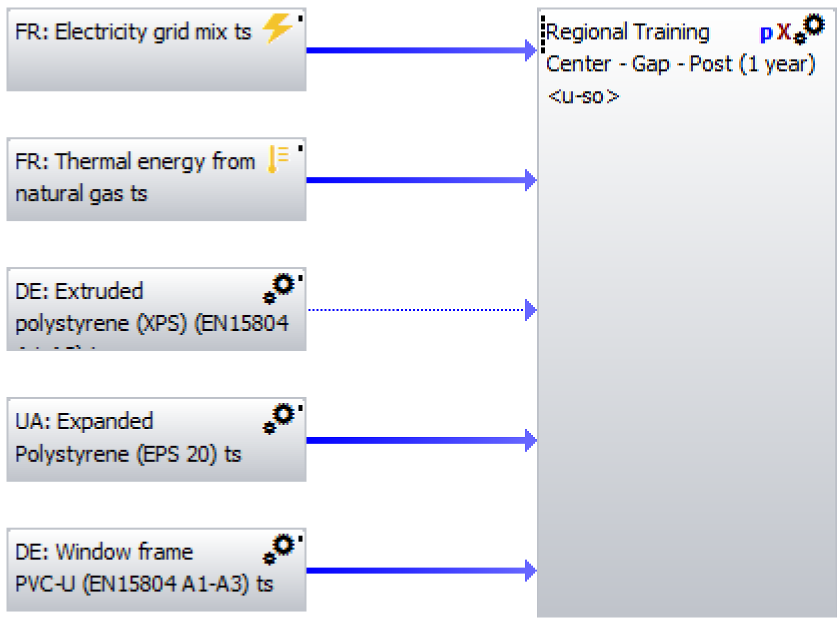
Regional Training Center - Gap - Ante (1 year)

Process plan:Reference quantities

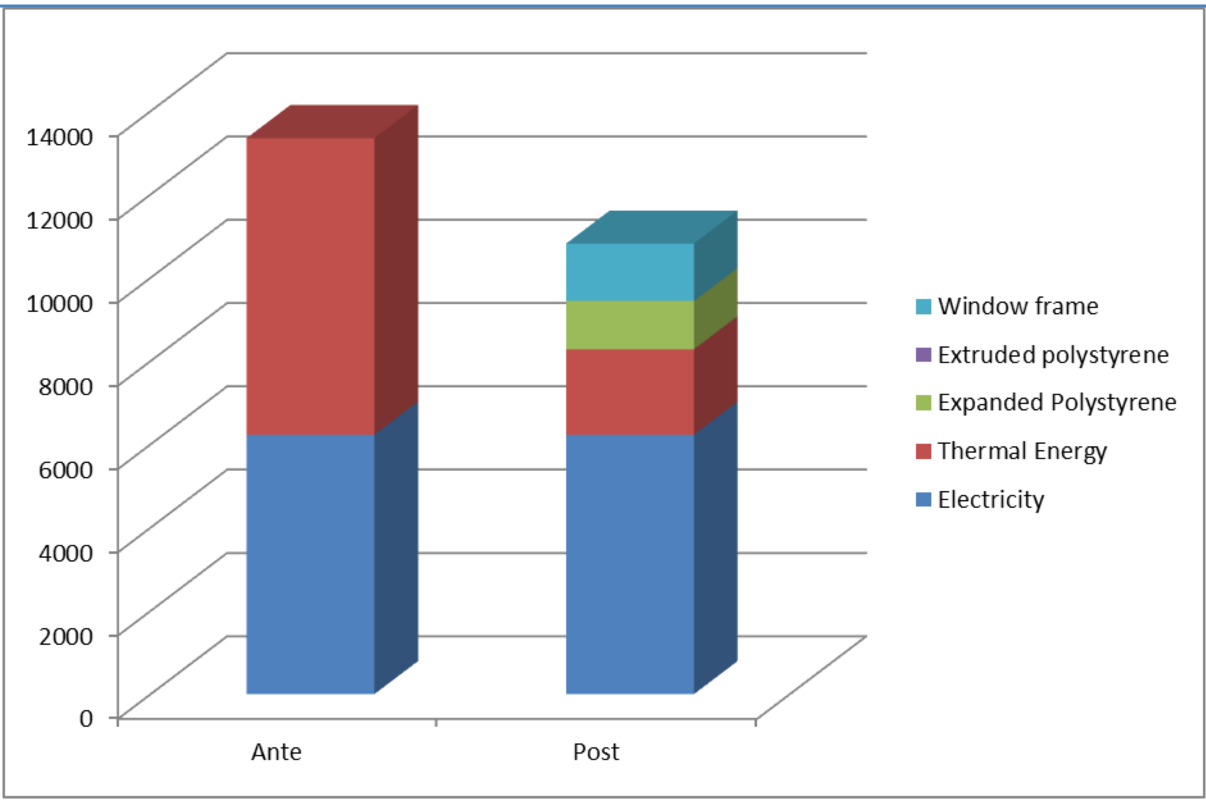


Regional Training Center - Gap - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 19% respect the initial conditions. The impact due to the materials used for the restoration contributes for the 23% of the Post intervention emissions.

Regional Training Center - Les Arcs

Description

Regional Training Center - Les Arcs Campus Chemin de Gueringuier 83460 Les Arcs
Construction period 1974 (A,B,C,D,E,G,H), 1998 (Bld. F), 2014 (modular)
Type Training Centre / Offices.
NUA 4,403m2
Heated area 3,369m2
Number of floors 2 (ground floor and 1st floor)
Heating system Gas boilers, convectors, radiant panels
Ventilation system Single flow natural and mechanical ventilation.

Initial Energy Requirement

The analysis of energy consumption makes it possible to know the heating consumption according to climatic severity and the changes in electricity consumption in order to note any deviations. Moreover, this analysis makes it possible to control the price of energies and their evolutions.

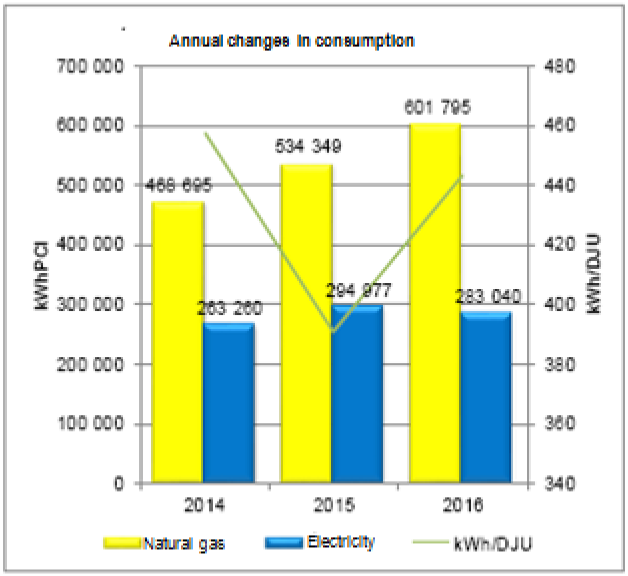
Consumption of natural gas does not follow the climatic severity; nevertheless, it increases by 14% between 2014 and 2015, and by 11% between 2015 and 2016. It should also be noted that the price per kWh of natural gas increases significantly in 2014 and 2016.
In order to control natural gas consumption, it is recommended to set up monthly energy monitoring.

Electricity consumption is stable at 8% for the 2014-2016 period.
In order to control energy consumption, it is recommended to set up monthly monitoring.

	Actual energy consumption	2014	2015	2016	Average	Ratio/m^2_{NUA}
Gas	Consumption (kWhEF)	468,695	534,349	409,580	470,875	**121.5**
	CO_2 emissions (Teq-CO_2)	99	113	126	112	
	Expenses (€$^{INC.T}$)	7,458	14,597	37,748	19,934	
	Unit cost (€$^{INC.T}$/kWh)	**0.02**	**0.03**	**0.07**	**0.04**	
Electricity	Consumption (kWh)	263,260	294,977	284,040	280,426	**63.7**
	CO_2 emissions (Teq-CO_2)	22	25	24	24	
	Expenses (€INC.T)	37,915	44,299	39,329	40,515	
	Unit cost (€$^{INC.T}$/kWh$_{PCI}$)	**0.14**	**0.15**	**0.14**	**0.14**	

The data shown below is taken from energy bills over the last three years (2014, 2015 and 2016).

Changes in actual consumption



Aim of the renovation plan

The "Energy optimisation" scenario: this last scenario allows presenting an optimal source of energy savings for the building. The associated costs will be high but inherent to the proposed solutions because the objective is to reduce the site's energy consumption by 56%.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

5.2 Scenario 2: "Energy efficiency"

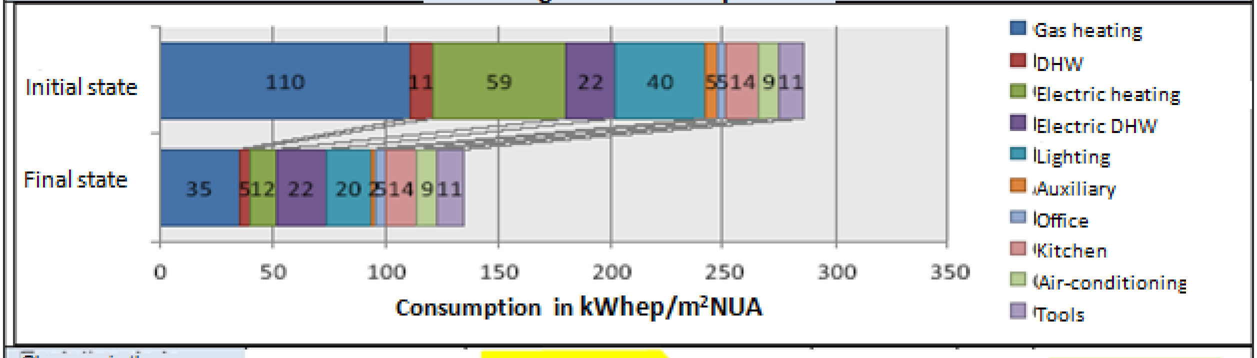
	Synthesis

Annual energy saving	477500	kWhEF	64 kWhEP/m²
Share of total consumption	58.7	%	111 to 210 C
Financial savings in the first year	31100	€INC.T	
CO2 emissions prevented	93.7	tonnes	
Cost of the work	483000	€EXC.T	15 kgeqCO2/m²
Cost per m²NUA	110	€EXC.T/m²	
Gross return time	16	years	6 to 15 B
Actualised return time	12	years	
EEC valuation (€0.40c/kWhCUMAC)	26609	€	

List of interventions performed

Actions	Cost		Cost / m²	
Insulation of DWH distribution networks	5 400	€TTC	1,2	€TTC/m²
Installation of radiant panels with inertia	8 000	€TTC	1,8	€TTC/ m²
Replacement of circulators	4 500	€TTC	1,0	€TTC/m²
Installation of condensing gas boilers	53 600	€TTC	47,1	€TTC/m²
Thermal insulation from the outside	205 200	€TTC	23	€TTC/m²
Installation of a ventilation clock	2 500	€TTC	1	€TTC/m²
LED relamping	55 600	€TTC	13	€TTC/m²
Cost of the work	**446 100**	**€TTC**	**100**	**€TTC/ m²**

Changes in consumption



Changes in the energy class (KWhEP/m²SHON)	286	211 to 360 D	▶	134	111 to 210 C
Changes in the climate class (kg CO_2/m²SHON)	34	31 to 60 D	▶	12	6 to 15 B

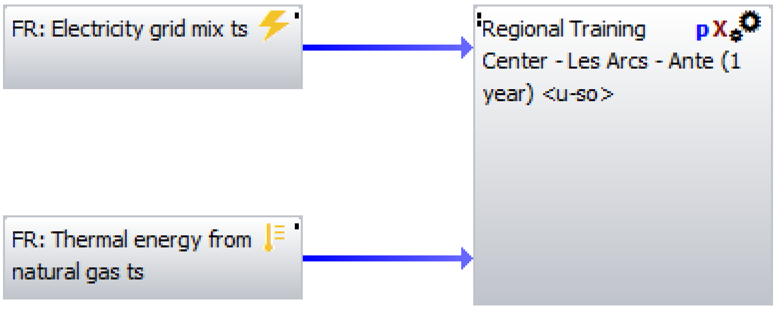
Materials and components

Information about materials used can be find in the energy audit

Model on GaBi software

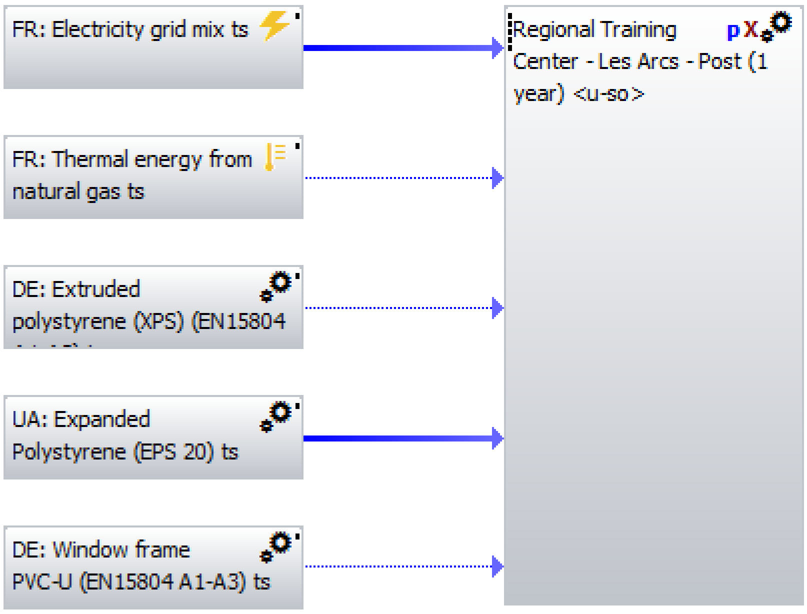
Regional Training Center - Les Arcs - Ante (1 year)

Process plan:Reference quantities

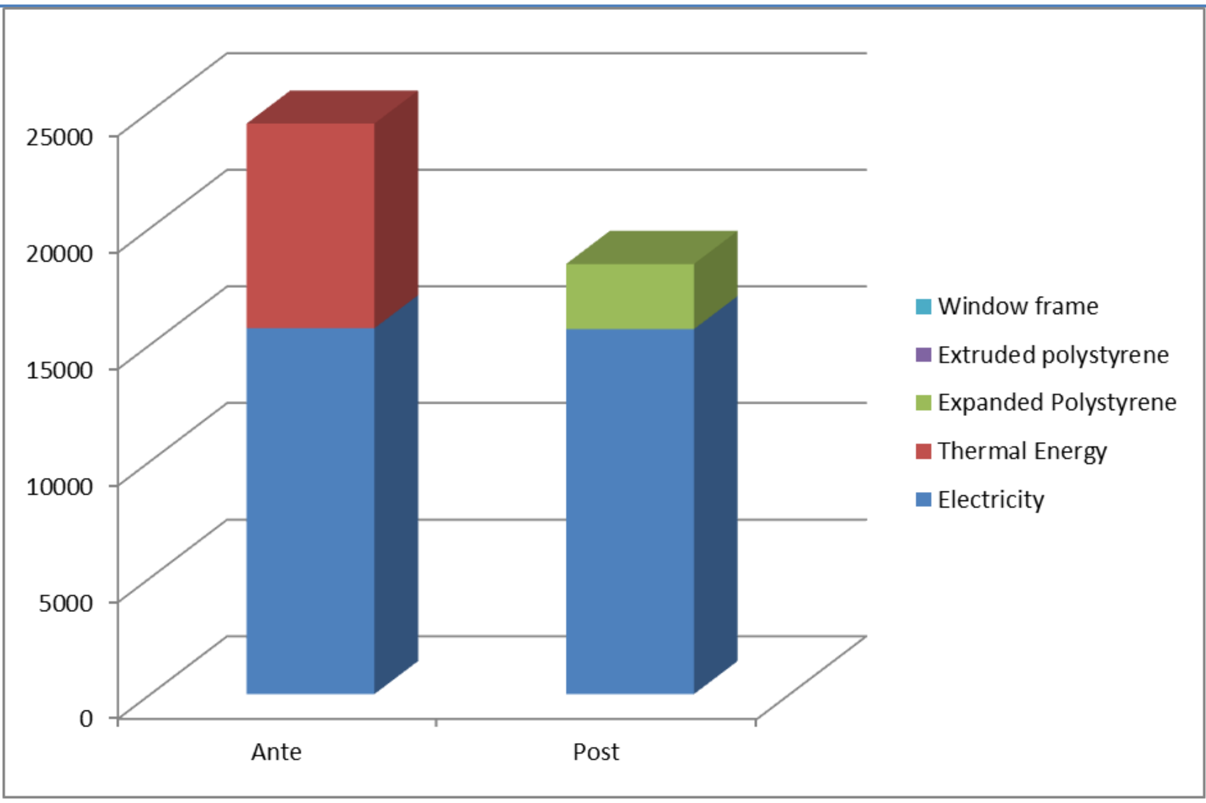


Regional Training Center - Les Arcs - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 25% respect the initial conditions. The impact due to the materials used for the restoration contributes for the 15% of the Post intervention emissions.

Regional Training Center - Le Beausset Campus

Description

Regional Training Center - Le Beausset Campus - 138 Allée des Primevères 83330 Le Beausset Type Training Centre / Offices.
Construction period 1974
Type Training Centre / Offices.
NUA 3,916 m2
Heated area 3,263 m2
Number of floors 2 (ground floor and 1st floor)
Heating system Gas boilers, convectors, radiant panels
Ventilation system Natural ventilation and single flow extraction

Initial Energy Requirement

The analysis of energy consumption makes it possible to monitor heating consumption according to climatic severity and the changes in electricity consumption in order to note any deviations. Moreover, this analysis makes it possible to control the price of energies and their evolutions.

Consumption of natural gas decreases between 2014 and 2015 by 19%, then increases significantly by 56%, this increase follows climatic severity (DD).

The price of KWH gas is stable over 2014, 2015, 2016, however it is advisable to review the natural gas supply contract (high KWh price).

Electricity consumption increases by 14% between 2014 and 2015 and by 7% between 2015 and 2016, this is due to the installation of the new heat pump in Building A.

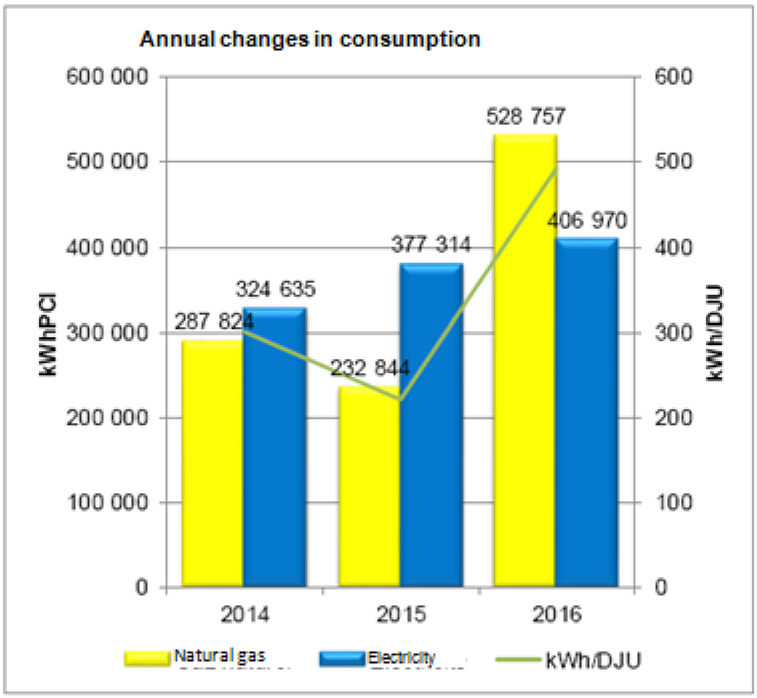
In order to control consumption of the site, it is recommended to set up energy monitoring.

3.1 Consumption history

Actual energy consumption		2014	2015	2016	Average	Ratio/m²NUA
Gas	Consumption (kWhEF)	287 824	232 844	528 757	349 808	89
	CO2 emissions (Teq-CO2)	61	49	111	74	
	Expenses (€INC.T)	20 026	16 058	31 012	22 365	
	Unit cost (€INC.T/kWh)	7	7	6	6	
Electricity	Consumption (kWh)	324 635	377 314	406 970	369 640	94
	CO2 emissions (Teq-CO2)	27	31	34	31	
	Expenses (€INC.T)	40 028	48 076	46 875	44 993	
	Unit cost (€INC.T/kWh)	10	11	8	9	

The data shown below is taken from energy bills over the last three years (2014, 2015 and 2016).

Changes in actual consumption



Aim of the renovation plan

The “Energy optimisation” scenario: this last scenario allows presenting an optimal source of energy savings for the building. The associated costs will be high but inherent to the proposed solutions because the objective is to reduce the site's energy consumption by 47%.

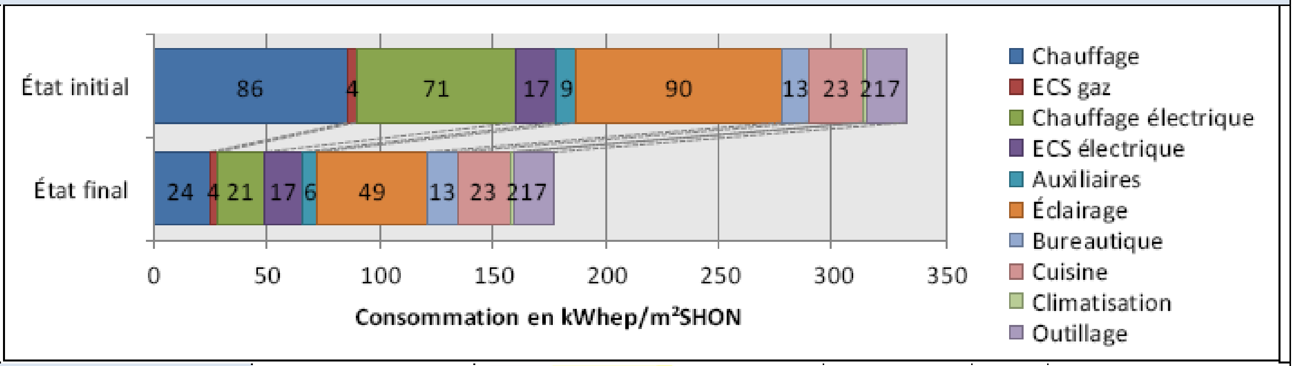
The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

Synthesis			
Annual energy saving	384,600	kWhEF	**177 kWhEP/m²** 111 to 210 C
Share of total consumption	53	%	
Financial savings in the first year	31700	€INC.T	
CO_2 emissions prevented	68.5	tonnes	
Cost of the work	475300	€EXC.T	5 kgeqCO_2/m² 6 to 15 B
Cost per m²NUA	121	€EXC.T/m²	
Gross return time	28	years	
Actualised return time	25	years	
EEC valuation (€0.40c/kWh$_{CUMAC}$)	51805	€	

Liste des interventions réalisées				
Actions	**Coût**		**Coût / m²**	
Mise en place de robinets thermostatiques	1 700	€TTC	0,4	€TTC/m²
Relamping LED	36 700	€TTC	9,3	€TTC/ m²
Remplacement des circulateurs	9 000	€TTC	2,3	€TTC/m²
Remplacement des chaudières	56 800	€TTC	14	€TTC/m²
Mise en place d'une ITE	111 200	€TTC	28	€TTC/m²
Reprise d'isolation des planchers hauts peu isolées	153 400	€TTC	39	€TTC/m²
Remplacement des ouvrants peu performants	67 800	€TTC	17	€TTC/m²
Mise en place d'une pompe à chaleur air/eau bât G et F	38 700	€TTC	10	€TTC/m²
Coût des travaux	**475 300**	**€TTC**	**121**	**€TTC/ m²**

Evolution des consommations



Evolution de la classe énergie (kWhEP/m²SHON)	**333**	211 à 350 **D**	▶	**177**	111 à 210 **C**
Evolution de la classe climat (kg CO_2/m²SHON)	**29**	31 à 60 **D**	▶	**11**	6 à 15 **B**

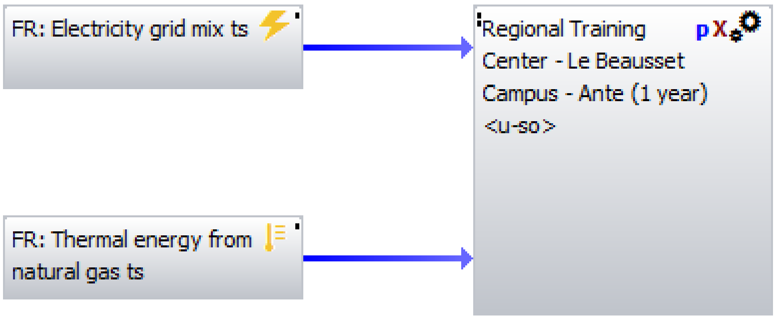
Materials and components

Information about materials used can be find in the energy audit

Model on GaBi software

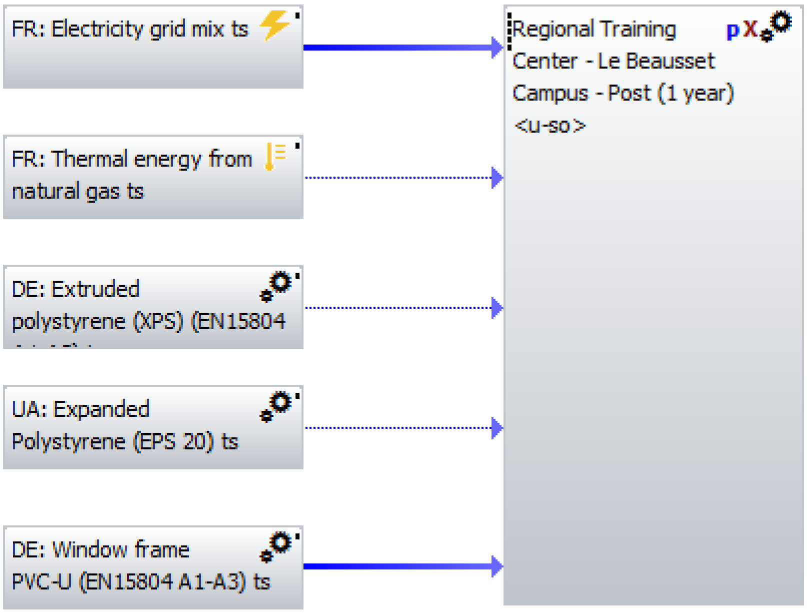
Regional Training Center - Le Beausset Campus - Ante (1 year)

Process plan:Reference quantities

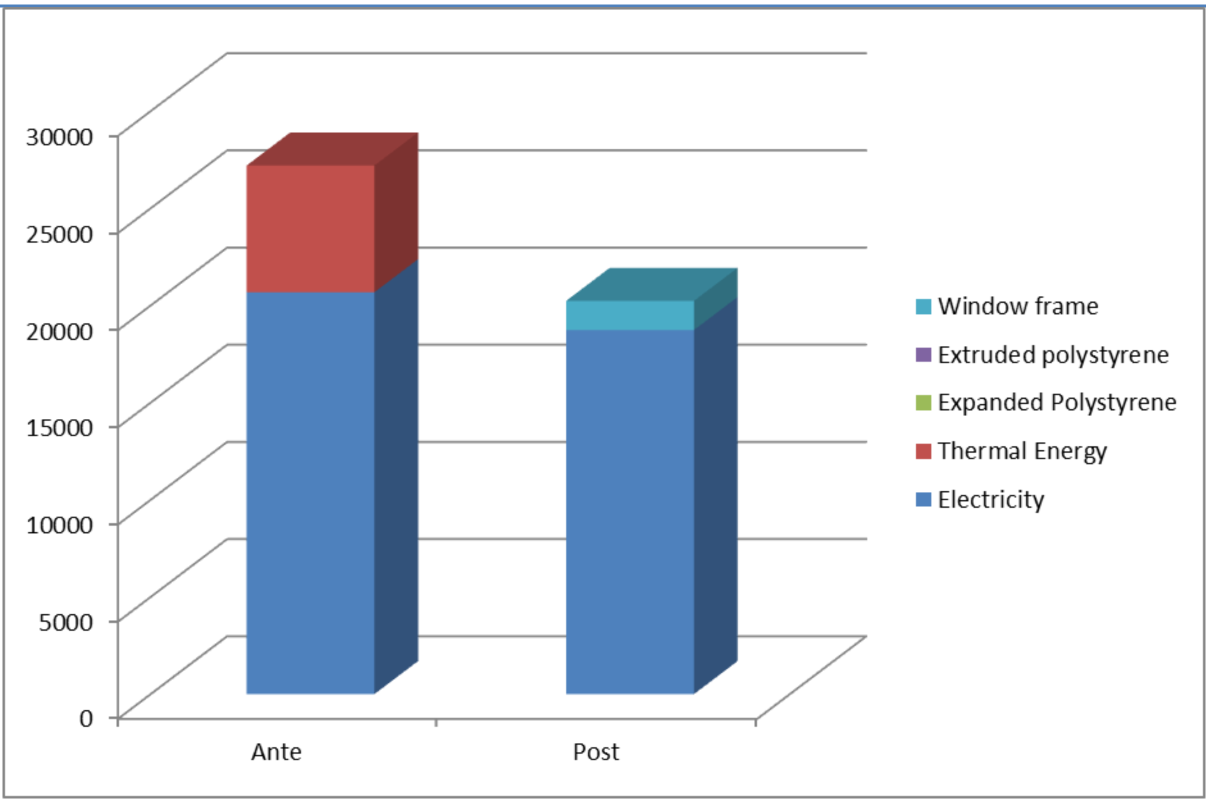


Regional Training Center - Le Beausset Campus - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 25% respect the initial conditions. The impact due to the materials used for the restoration contributes for the 7% of the Post intervention emissions.

Greece

1st Junior High School of Voula
Description
The 1st Junior High School of Voula is located in the municipality of VVV and belongs to a bigger complex of school buildings and sports facilities. More Specifically the building is at 18 Xenofontos Str, near the Centre of Voula area. It is around 500 m northeast of the seaside and also 500 m southwest of the main avenue (Vouliagmenis) that connects southern suburbs with Athens. The area around the school is urban, but not very densely built with either 3 to 4 floors high multifamily houses or 2 floor single family houses.
Initial Energy Requirement
Monthly electricity consumption data were not available. One full annual and one two full year measurements of the electricity consumption were found and estimation has been done for the average

yearly electricity consumption of the school building. These data are presented in the following table.

Table 0.25 ***Estimation of the average yearly electricity consumption of the school building***

Period	Measured [kWh]	Annual Average Measured Consumption [kWh]
March 2014 – February 2015	13,474	13,474
March 2015 – February 2017	22,647	11,324
Average annual consumption		12,400

The 1st Junior High School of Voula uses oil for covering its heating demand during winter. The oil tank of the school building is around 3.5 m^3 of volume and is refuelled usually 2 or 3 times per year. From the amount of oil purchased during the last 3 heating seasons an estimation of the average yearly consumption was made, which is 2,400 lt that is equivalent to 24,365 kWh using the Net Calorific Value of diesel to make the conversion.

Table 0.26 ***Total Energy Consumption and CO_2 Emissions of 1st Junior High School of Voula***

Energy carrier	**Final Annual Energy Consumption Annually [kWh]**	**Primary Energy Consumption Annually [kWh]**	**Annual CO_2 Emissions [kg]**
Electricity	12,400	35,960	12,263
Fuel Oil - Diesel	24,364	26,801	6,432
Total	**36,764**	**62,761**	**18,696**

Aim of the renovation plan

The renovation plan for the 1st Junior High School of Voula will be oriented in both reducing the energy demand and improving the efficiency of its energy systems. The reason for the first is that the building shell has almost no thermal insulation as it was built before the first Thermal Insulation Regulation of Buildings, issued in 1979. Therefore, adding insulation to the building elements will be the first proposed renovation measure which will also have a positive effect to thermal comfort in both winter and warm periods. On the other hand heating and lighting systems are using old technologies and can be essentially improved and enhanced with automated control systems in order to consume less energy. Finally, on site energy generation will ensure that the energy performance of the building after renovation will be within NZEB benchmarks.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

The change in electricity mix as far as the school is concerned is that after all the ECMs applied the electricity consumption of the school will be totally covered by the PV system generation in a yearly basis. So, it will be 100% solar energy generated on-site but connected to the grid with Net Metering method.

Table 0.27 ***New Electricity Mix***

	Type of Energy Source	Percentage	Generation	Annual Generation/Consumption
Electricity Mix after ECMs	Solar	100%	On site – Net Metering	9,000 kWh

The combination of all the energy conservation measures had a result in a total final energy consumption reduction of almost 70%. In this reduction it is included the contribution of the PV system generation of electricity. The results are summed in Table 3.22 and for better understanding electricity consumption is presented both with and without PV contribution.

Table 0.28 Final Energy Consumption after improvement actions

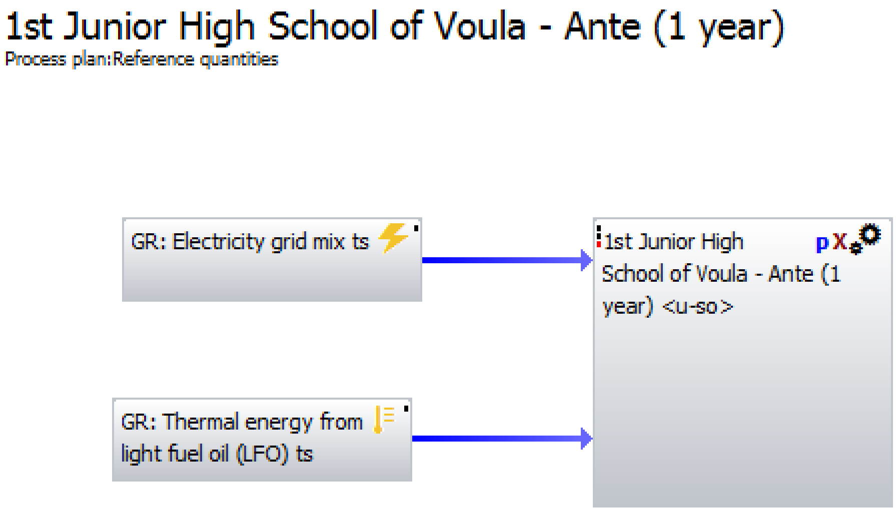
Type of energy carrier	Final Energy Consumption Before Renovation [kWh]	Final Energy Consumption After Renovation [kWh]	Final Energy Consumption Reduction
Electricity	12,400	7,197	42.0 %
Electricity Net		0	100 %
Fuel Oil	24,364	11,188	54.1 %
Total	36,764	18,385	50.0 %
Total Net		11,188	69.6 %

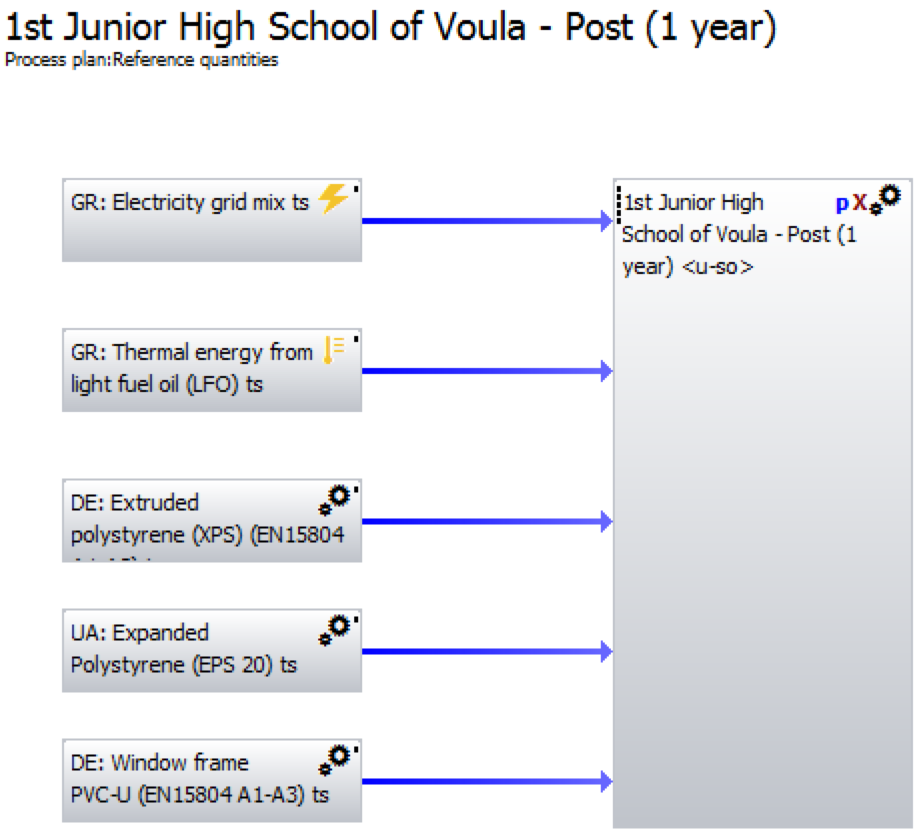
Materials and components

Table 0.29 *Summary of ECMs cost*

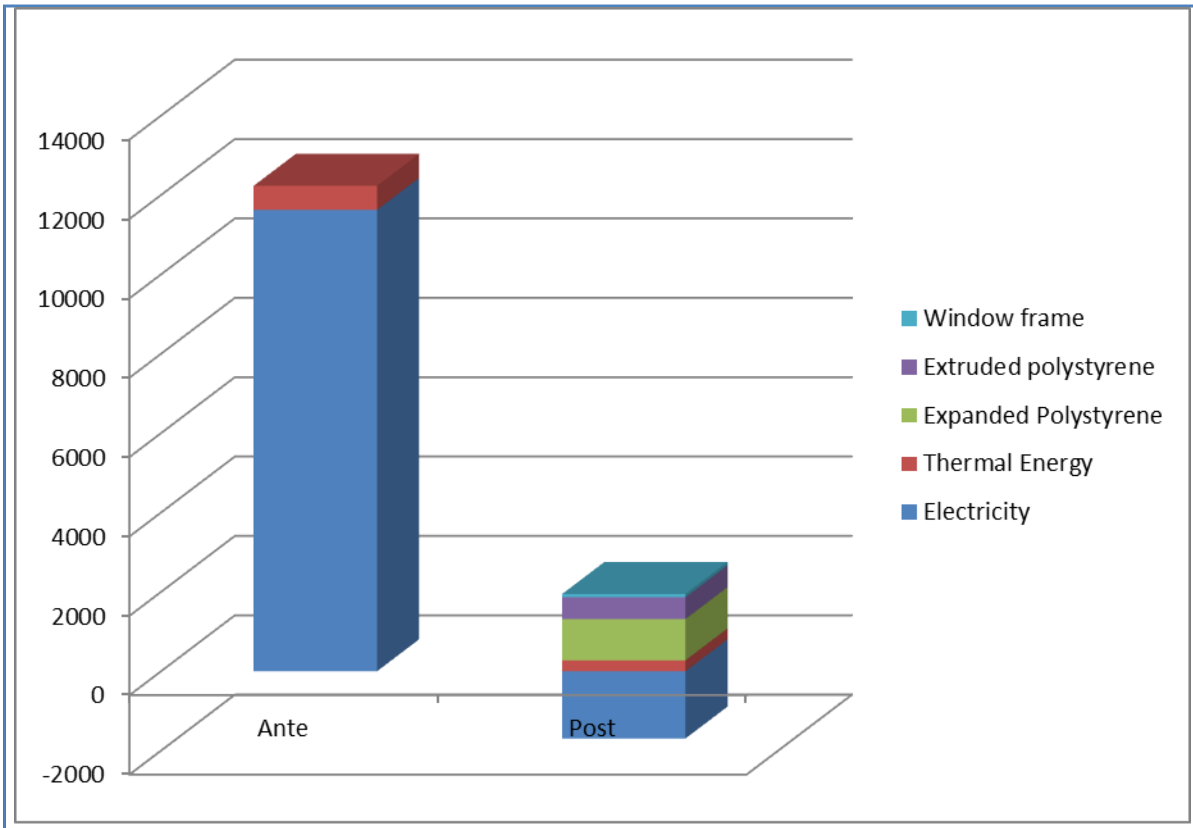
ECMs	*ACTION*	*VOICE*	*U.M.*	*Unit Cost*	*Total Cost*
ECM 1	*Building Envelope*	*Wall External Insulation*	730.5 m^2	45.9 €/m^2	33,515
		Flat Roof Insulation	420.8	39.7 €/m^2	16,699
		Pitched Roof Insulation	72	24.8 €/m^2	1,786
		Windows Replacement	219.72	235 €/m^2	51,634
TOTAL					**103,634**
ECM 2	*Energy Systems Upgrade*	*LED panels for lighting*	157	60 €/panel	9,420
	Lighting Automated Control	*Light Sensors*	18	120 €/sensor	2,160
TOTAL	…				**11,580**
ECM 3	*Energy Systems*	*Condensing Oil Boiler 160 kW*	1		15,000
	Systems Automations	*Thermostatic Valves*	25		7,000
TOTAL					**22,000**
PV	*RES*	*PV panels*	8.75 kWp	1,488/kW	**13,020**
TOTAL					**150,234**
TOTAL	***COMBINED****				**144,014**

Quantities of materials employed are gathered from the economic renovation evaluation
Model on GaBi software





Results



After the proposed renovation, the school overall emissions decreased to a carbon neutrality considering the avoided impacts of the electricity produced. As the solar panels produce more energy than the required to the school needs, the impacts in the Post intervention are due to the materials used for the restoration.

1st Primary School of Voula
Description
The 1st Primary School of Voula is right next to the centre of Voula which is the first to meet when coming from the north and belongs to the broader Vari Voula Vouliagmeni Municipality. It is located just 200 meters from Vouliagmenis Avenue and less than 700 meters from the seaside. It is also 1km to the southeast of 1st Junior High of Voula that was described in the previous chapter. Therefore, the surrounding area is similar, with urban characteristics, but not densely built with single family houses or multifamily houses up to 4 floors high.
Initial Energy Requirement
From the available data it is derived that the yearly average electricity consumption of these 2 years is 29,025 kWh which corresponds to a specific electricity consumption of 15.6 kWh/m^2 of total floor area. The fuel oil consumption for the small part of the school was estimated by the data given from the municipality about the amount of fuel that was added to the fuel tank and the dates refuelling took place. According to data of two heating seasons the oil consumption was 200 lt of fuel oil (diesel). This corresponds to a final energy consumption for heating of 2,030 kWh. **Table 0.30 Total *Energy Consumption and CO_2 Emissions of 1st Primary School of Voula***

Energy carrier	Final Annual Energy Consumption Annually [kWh]	Primary Energy Consumption Annually [kWh]	Annual CO_2 Emissions [kg]
Electricity	29,025	84,174	28,552
Gas	17,879	18,773	3,504
Fuel Oil	1,424	1,566	376
Total	**48,328**	**104,513**	**32,432**

Aim of the renovation plan

The aim of the renovation plan is to significantly reduce the final energy use of the school buildings both by reducing the energy demand and by increasing the efficiency of its systems. The general strategy for renovation of the 1st Primary School building complex includes intervention proposals that are based on the age of each building part and of each system. Whole building A and half of building B for example are old without any thermal insulation while the other half of building B is adequately insulated. Despite the fact that the main heating system gas boiler is relatively new, it should be replaced with a smaller one after reducing the heating demand due to insulation in order not to have over sizing losses. Lighting system is old and consumes almost 40% of the total energy of the school and it should be replaced.
Another factor considered will be the thermal comfort of its users. Winter comfort according to a survey of the school's teachers is adequate while the most complaints are for overheating problems in the end and the beginning of the school year.
Finally, the ultimate goal is for the school building complex to reach NZEB levels. To achieve that on-site energy generation by RES has to be considered.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

The change in electricity mix as far as the school is concerned is that after all the ECMs applied the electricity consumption of the school will be totally covered by the PV system generation in a yearly basis. So, it will be 100% solar energy generated on-site but connected to the grid with Net Metering method.

Table 0.31 ***New Electricity Mix***

Electricity Mix after ECMs	Type of Energy Source	Percentage	Generation	Annual Generation/Consumption
	Solar	100%	On site – Net Metering	18,000 kWh

In terms of final energy the school building consumes only natural gas and fuel oil for heating as it covers all the electricity demand with the PV system generation. In Table 4.20 the total energy consumption is presented as wells as final energy consumption reduction compared to the existing situation. Electricity consumption is shown both without PV and with PV contribution in order to be clear that it is reduced anyway.

Table 0.32 ***Final Energy Consumption after improvement actions***

Type of energy carrier	Final Energy Consumption Before Renovation [kWh]	Final Energy Consumption After Renovation [kWh]	Final Energy Consumption Reduction
Electricity	29,025	14,970	40.5 %
Electricity Net		0	100 %
Gas & Fuel Oil	19,303	12,096	54.1 %

Total	47,914	30,420	45.9 %
Total Net		15,450	81.7 %

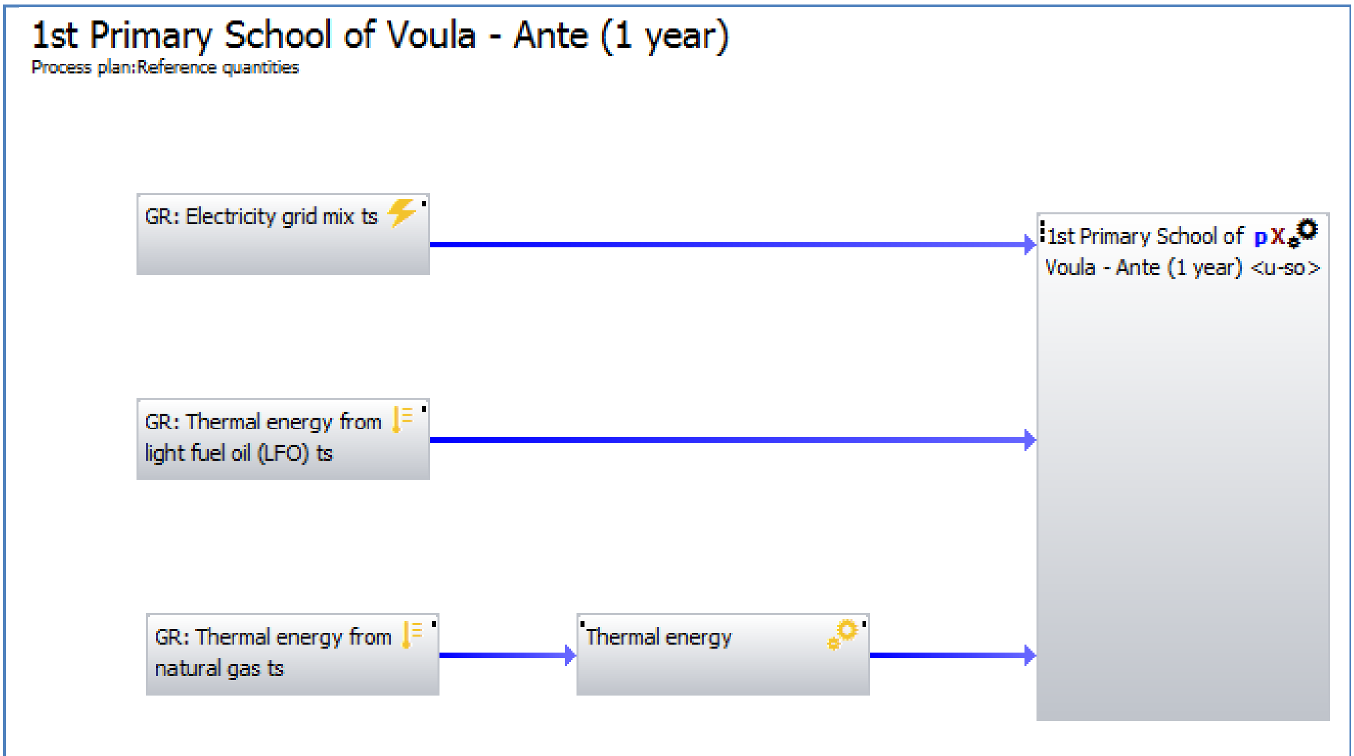
Materials and components

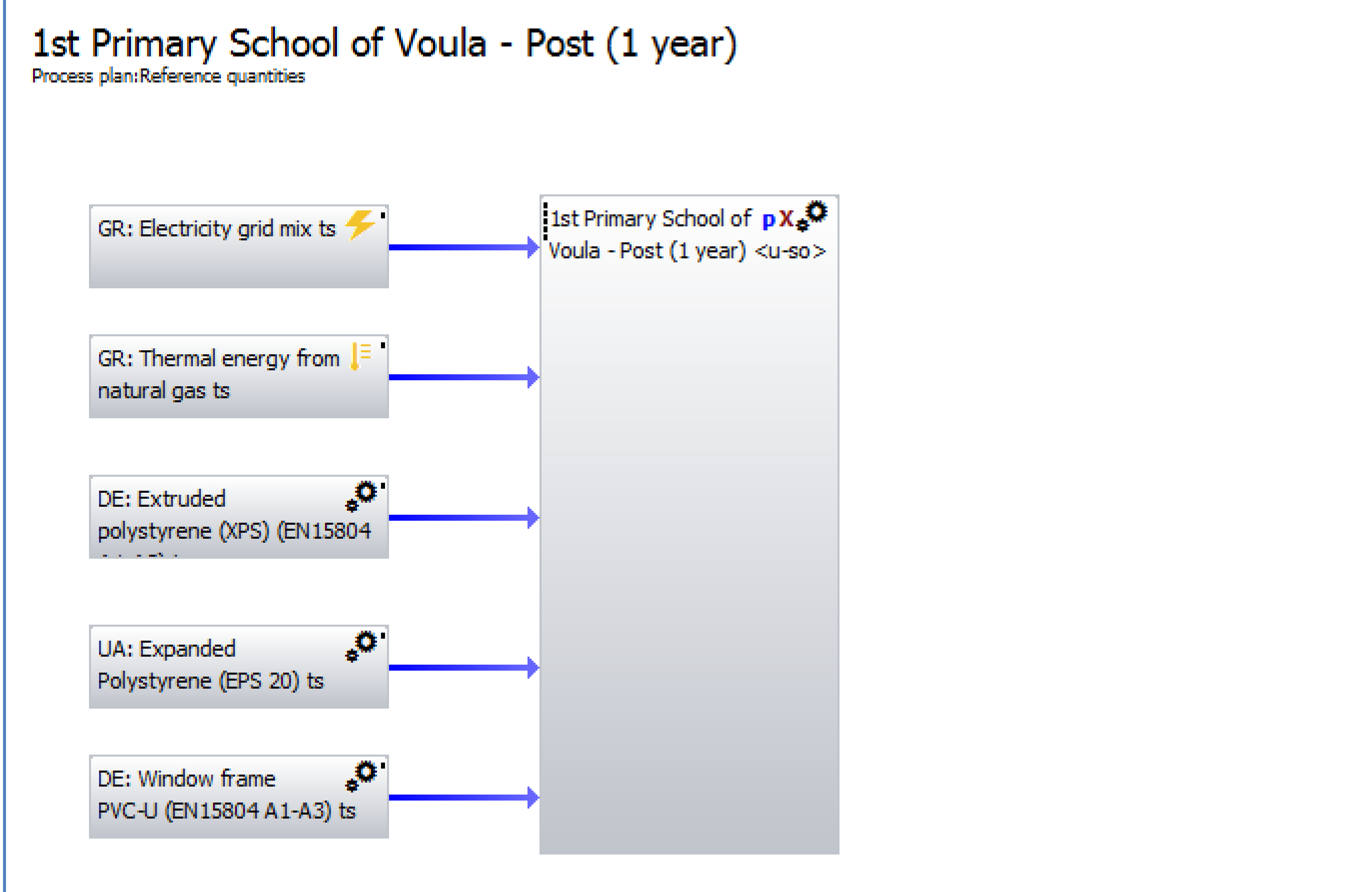
Table 0.33 *Summary of ECMs cost*

ECMs	ACTION	VOICE	U.M.	Unit Cost	Total Cost
ECM 1	*Building Envelope*	*Wall External Insulation*	665 m^2	45.9 €/m^2	30,510
		Flat Roof Insulation	325 m^2	39.7 €/m	12,896
		Pitched Roof Internal Insulation	94 m^2	19 €/m	1,786
		Windows Replacement	158 m^2	235 €/m^2	37,130
TOTAL					**82,322**
ECM 2	*Energy Systems Upgrade*	*LED panels for lighting*	204	60 €/panel	12,240
		LED spotlights for external lighting	3	135 €	405
	Lighting Automated Control	*Light Sensors*	22	120 €/sensor	2,640
TOTAL	…				**15,285**
ECM 3	*Energy Systems*	*Condensing Gas Boiler 200 kW*	1	17,000 €	17,000
		Condensing Oil Boiler 15 kW	1	2,900 €	2,900
	Systems Automations	*Thermostatic Valves*	20		7,000
TOTAL					**26,900**
PV	*RES*	*PV panels*	20 kWp	1,488/kW	**29,760**
TOTAL					**154,267**
TOTAL	***COMBINED****				**138,363**

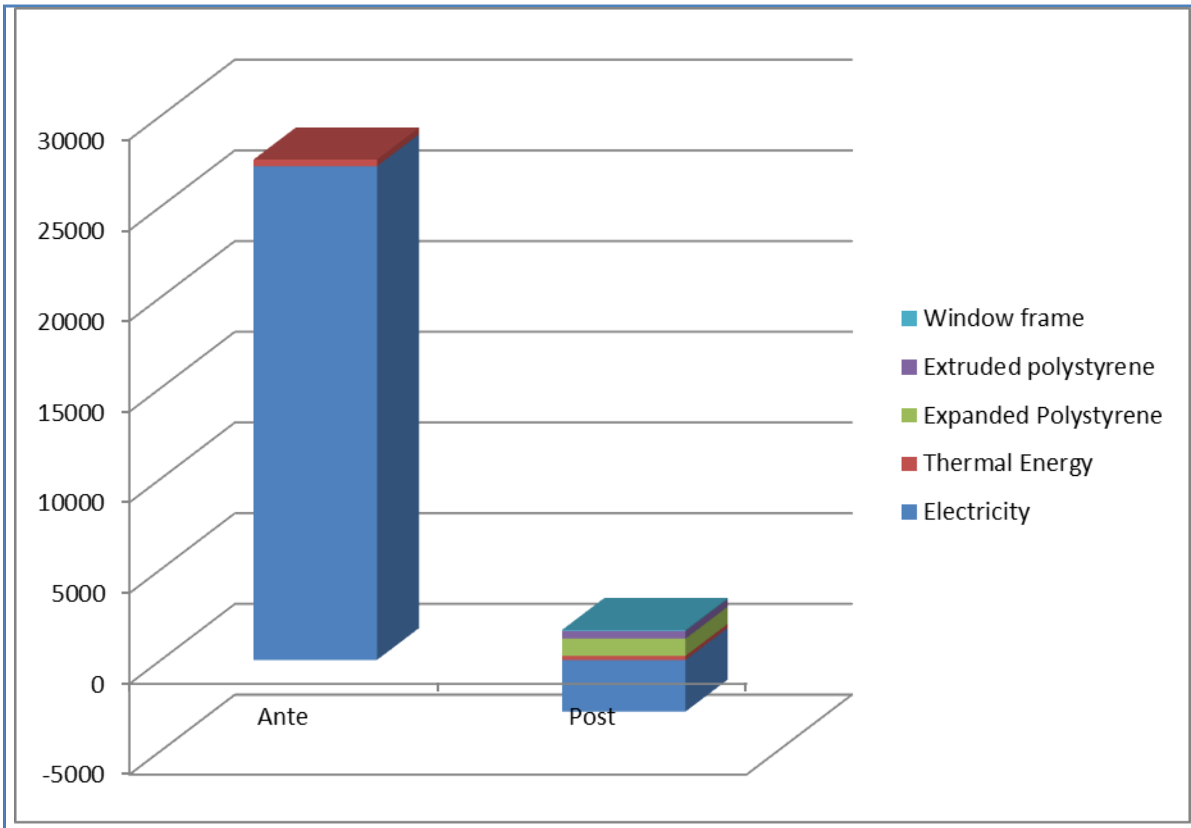
Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software


1st Primary School of Voula - Ante (1 year)
Process plan:Reference quantities
GR: Electricity grid mix ts
GR: Thermal energy from light fuel oil (LFO) ts
GR: Thermal energy from natural gas ts
Thermal energy
1st Primary School of Voula - Ante (1 year) <u-so>


1st Primary School of Voula - Post (1 year)
Process plan:Reference quantities
GR: Electricity grid mix ts
GR: Thermal energy from natural gas ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
1st Primary School of Voula - Post (1 year) <u-so>

Results



After the proposed renovation, the school overall emissions decreased to a carbon neutrality considering the avoided impacts of the electricity produced. As the solar panels produce more energy than the required to the school needs, the impacts in the Post intervention are due to the materials used for the restoration.

2nd Junior High School of Vari

Description

The 2nd Junior High School of Vari is located in the south east part of the municipality of VVV in the former municipality of Vari, at Varis Avenue and Zakinthou Street. It is around 600 m from the centre of Vari area and around 3 km from the sea. The surrounding area is mostly built around Varis Avenue with various retail stores and warehouses and in the south of the school buildings there is a hill. The broader area includes some clusters of single family houses scattered around the hills. The location of the school is just on the south tip of mountain Ymittos foot but with low altitude at around 40 m above sea level.

Initial Energy Requirement

From the available data it is derived that the yearly average electricity consumption of these 2 years is 22,300 kWh which corresponds to a specific electricity consumption of 10.37 kWh/m2 of floor area.

The school building complex of the 2nd Junior High School of Vari has only one type of fuel consumption for covering its basic heating needs. Oil fuel (diesel) real consumption was provided also by the municipality that handles the refuelling. Due to the type of the system and the capacity of the oil tank that feeds the boiler refuelling takes place around once or twice per year and usually right before the heating season starts. According to the information given by the records of the school principal Table 2.10 was filled that includes the dates and the amount of fuel that was inside the oil tank and the amount of fuel purchased and put in the oil tank.

Table 0.34 *Oil consumption data of 2nd Junior High School of Vari for heating seasons 2015-2016 & 2016-2017*

Date	Oil left in tank [lt]	Oil added [lt]
14-Dec-2015	1248	2000
12-Dec-2016	1220	2000
26-Oct-2017	940	2350

According to these data it is estimated that the average oil consumption of the two heating seasons was 2,300 lt of fuel oil (diesel). This volume of fuel is converted to kWh using the Net Calorific Value of diesel which is 10.6 kWh/lt. According to this conversion the average final energy heating consumption is 24,380 kWh.

Table 0.35 Total *Energy Consumption and CO_2 Emissions of 2nd Junior High School of Vari*

Energy carrier	**Final Annual Energy Consumption Annually [kWh]**	**Primary Energy Consumption Annually [kWh]**	**Annual CO_2 Emissions [kg]**
Electricity	22,300	64,670	22,055
Fuel Oil - Diesel	25,614	28,175	6,762
Total	**47,914**	**92,845**	**28,817**

Aim of the renovation plan

The renovation strategy of the 2nd Junior High School building complex is planned having as basic axis the improvement of the efficiency of its systems. The reason for this is that the building is not very old compared with the average Greek school building and in terms of thermal insulation it fulfils more than enough the minimum requirement of the period it was constructed while it is not very far from the present requirements of National Building Performance Regulation (KENAK). However, the final state of renovation will be planned in order to reach NZEB standards which means that envelope interventions including windows may be necessary. In heating and lighting system technology breakthroughs have introduced better control which leads to a significant efficiency improvement. Another factor considered will be the thermal comfort of its users. Winter comfort according to a survey of the school's teachers is adequate while the most complaints are for overheating problems in the end and the beginning of the school year. Finally, to reach NZEB levels on-site energy generation by RES has to be considered.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

The change in electricity mix as far as the school is concerned is that after all the ECMs applied the electricity consumption of the school will be totally covered by the PV system generation in a yearly basis. So, it will be 100% solar energy generated on-site but connected to the grid with Net Metering method.

Table 0.36 *New Electricity Mix*

Electricity Mix after ECMs	Type of Energy Source	Percentage	Generation	Annual Generation/Consumption
	Solar	100%	On site – Net Metering	15,000 kWh

In terms of final energy the school building consumes only fuel oil for heating as it covers all the electricity demand with the PV system generation. In Table 2.20 the total energy consumption is presented as wells as final energy consumption reduction compared to the existing situation. Electricity consumption is shown both without PV and with PV contribution in order to be clear that it is reduced anyway.

Table 0.37 *Final Energy Consumption after improvement actions*

Type of energy carrier	Final Energy Consumption Before Renovation [kWh]	Final Energy Consumption After Renovation [kWh]	Final Energy Consumption Reduction
Electricity	22,300	14,970	32.9 %
Electricity Net		0	100 %
Fuel Oil	25,614	15,450	39.7 %
Total	47,914	30,420	36.5 %
Total Net		15,450	67.8 %

Materials and components

Table 0.38 *Summary of ECMs cost*

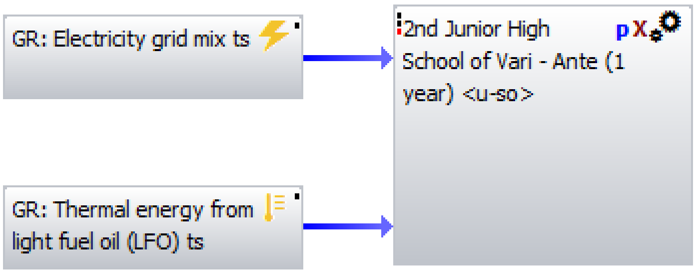
ECMs	ACTION	VOICE	U.M.	Unit Cost	Total Cost
ECM 1	*Building Envelope*	*Windows Replacement*	269.2	235 €/m^2	63,215
TOTAL					**63,215**
ECM 2	*Energy Systems Upgrade*	*LED panels for lighting*	176	60 €/panel	10,560
	Lighting Automated Control	*Light Sensors*	18	120 €/sensor	1,800
TOTAL					**12,360**
ECM 3	*Energy Systems*	*Condensing Oil Boiler 140 kW*	1		14,000
	Systems Automations	*Thermostatic Valves*	25		7,000
TOTAL					**21,000**
PV	*RES*	*PV panels*	15 kWp	1,488/kW	**22,320**
TOTAL					**118,895**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

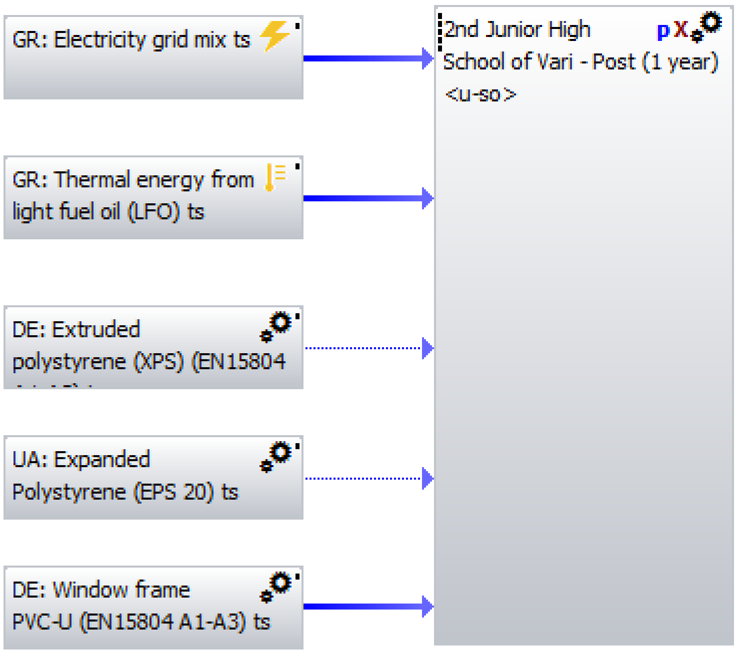
2nd Junior High School of Vari - Ante (1 year)

Process plan:Reference quantities

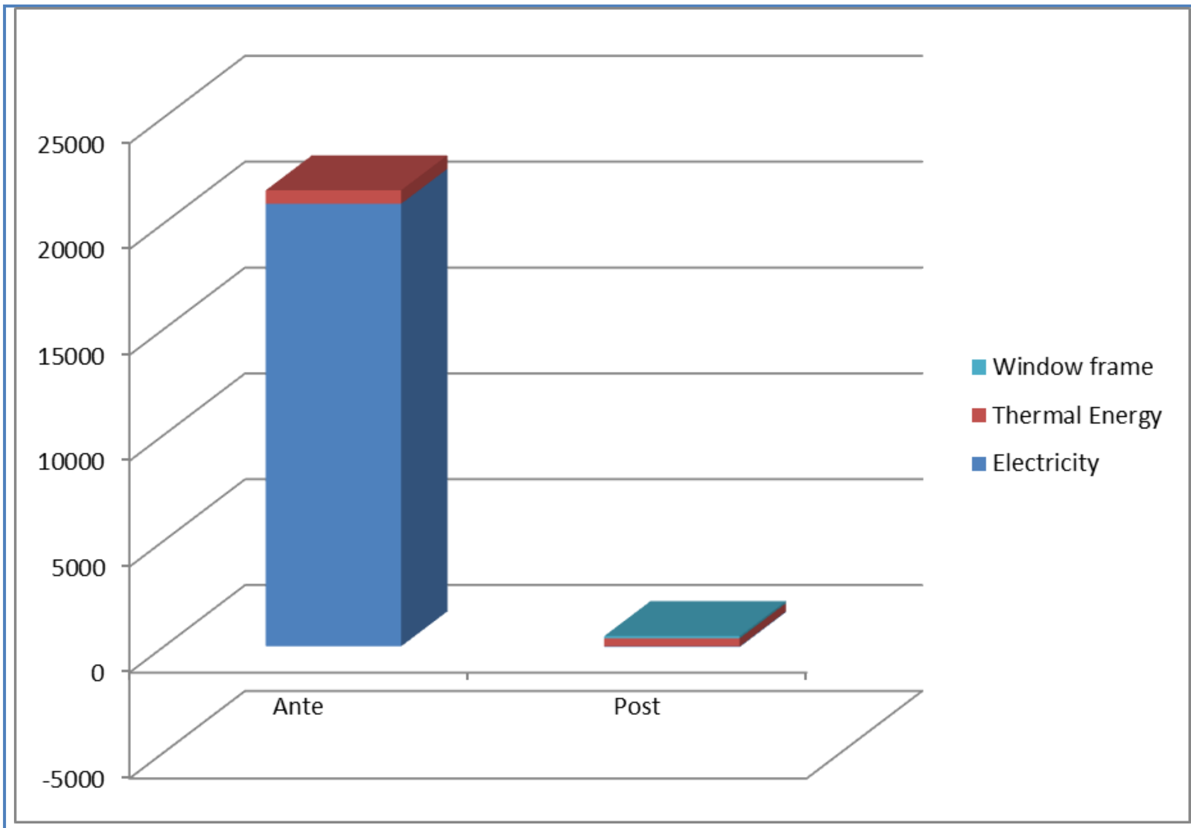


2nd Junior High School of Vari - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased to carbon neutrality considering the avoided impacts of the electricity produced. As the solar panels cover the energy need of the school, the impacts in the Post intervention are due to the materials used for the restoration.

Primary School of Varkiza

Description

Varkiza region is between Vari and Vouliagmeni and lies at the south-southeast part of Vari Voula Vouliagmeni Municipality area. The Primary School of Varkiza is located 600 m west of the main seaside of Varkiza and Poseidonos Avenue, on a small hill. It is built at the limit of the urban area of Varkiza that has mostly 4 floor high multifamily houses and some 2 floor single family houses. Right at the west of the school there are no buildings, just the hill with some trees.

Initial Energy Requirement

From the available data it is derived that the yearly average electricity consumption of these 2 years is 17,100 kWh which corresponds to a specific electricity consumption of 16.5 kWh/m^2 of total floor area.

The school building complex of the Primary School of Varkiza consumes oil fuel (diesel) for covering its heating demand. The fuel oil consumption of the school was estimated by the data given from the municipality and the school's principal about the amount of fuel that was added in the fuel tanks and the dates refuelling took place. According to data of two heating seasons the average oil consumption was 3,600 lt of fuel oil (diesel). This corresponds to final energy consumption for heating of 36,550 kWh.

Table 0.39 Total *Energy Consumption and CO_2 Emissions of Primary School of Varkiza*

Energy carrier	Final Annual Energy Consumption Annually [kWh]	Primary Energy Consumption Annually [kWh]	Annual CO_2 Emissions [kg]
Electricity	17,100	49,590	16,912
Fuel Oil	36,275	39,902	9,577
Total	**53,375**	**89,492**	**26,488**

Aim of the renovation plan

The aim of the renovation plan is to significantly reduce the final energy use of the school buildings both by reducing the energy demand and by increasing the efficiency of its systems. The general strategy for renovation of the Primary School of Varkiza buildings is based firstly on building enveloper insulation and secondly on replacing lighting and heating systems. The main building has no insulation at all at its building elements. The same stands for the prefabricated buildings. Another factor considered will be the thermal comfort of its users. Finally, the ultimate goal is for the school building complex to reach NZEB levels. To achieve that on-site energy generation by RES has to be considered.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

The change in electricity mix as far as the school is concerned is that after all the ECMs applied the electricity consumption of the school will be totally covered by the PV system generation in a yearly basis. So, it will be 100% solar energy generated on-site but connected to the grid with Net Metering method.

Table 0.40 ***New Electricity Mix***

Electricity Mix after ECMs	Type of Energy Source	Percentage	Generation	Annual Generation/Consumption
	Solar	100%	On site – Net Metering	11,700 kWh

In terms of final energy the school building consumes only natural gas and fuel oil for heating as it covers all the electricity demand with the PV system generation. In Table 5.22 the total energy consumption is presented as wells as final energy consumption reduction compared to the existing situation. Electricity consumption is shown both without PV and with PV contribution in order to be clear that it is reduced anyway.

Table 0.41 ***Final Energy Consumption after improvement actions***

Type of energy carrier	Final Energy Consumption Before Renovation [kWh]	Final Energy Consumption After Renovation [kWh]	Final Energy Consumption Reduction
Electricity	17,100	10,950	36.0 %
Electricity Net		0	100 %
Gas & Fuel Oil	19,303	12,096	65.1 %
Total	47,914	23,619	55.8 %
Total Net		12,676	87.4 %

Materials and components

Table 0.42 *Summary of ECMs cost*

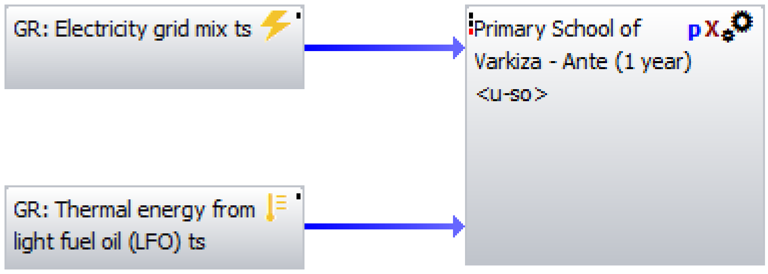
ECMs	ACTION	VOICE	U.M.	Unit Cost	Total Cost
ECM 1	Building Envelope	Wall External Insulation	654 m^2	45.9 €/m^2	30,009
		Pitched Roof Ext. Insulation	385 m^2	39.5 €/m	15,205
		Pitched Roof Internal Insulation	268.1 m^2	19 €/m	5,095
		Windows Replacement	33.25 m^2	235 €/m^2	7,813
TOTAL					**58,122**
ECM 2	Energy Systems Upgrade	LED panels for lighting	130	60 €/panel	7,800
		LED spotlights for external lighting	4	135 €	540
	Lighting Automated Control	Light Sensors	22	120 €/sensor	2,640
TOTAL	…				**10,980**
ECM 3	Energy Systems	Condensing Oil Boiler 85 kW	1	12,000 €	12,000
		Condensing Oil Boiler 70 kW	1	12,000 €	12,000
	Systems Automations	Thermostatic Valves	20		7,000
TOTAL					**31,000**
PV	RES	PV panels	13.5 kWp	1,488/kW	**20,088**
TOTAL					**120,190**
TOTAL	**COMBINED***				**109,494**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

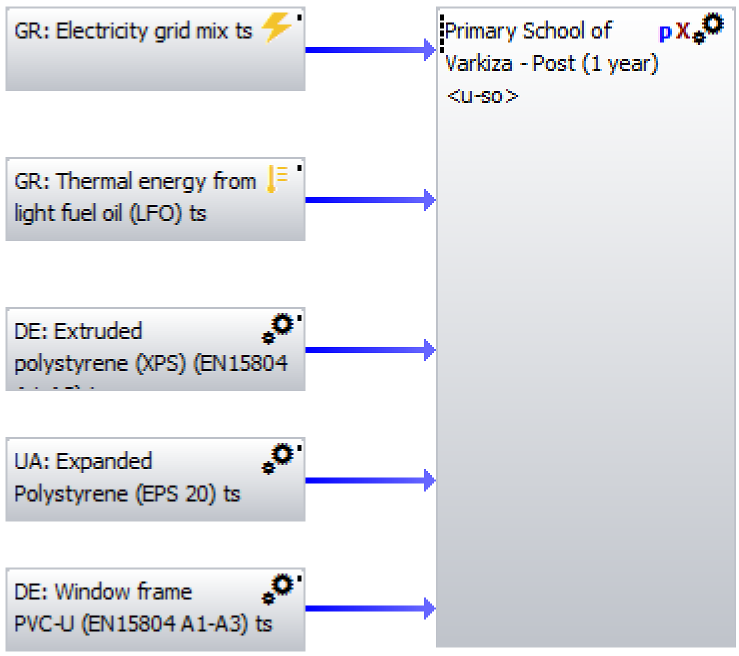
Primary School of Varkiza - Ante (1 year)

Process plan:Reference quantities

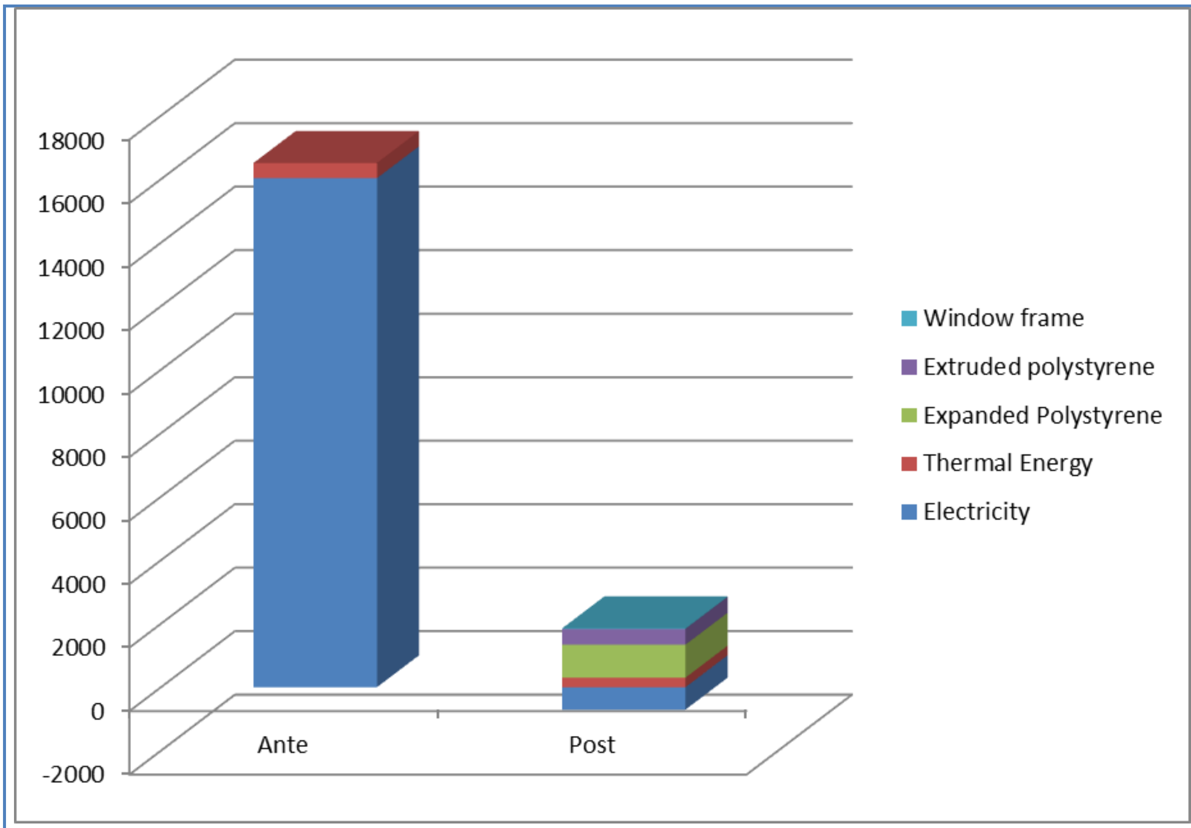


Primary School of Varkiza - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 93% respect the initial conditions considering the avoided impacts of the electricity produced. As the solar panels produce more energy than the required to the school needs, the impacts in the Post intervention are due to the materials used for the restoration.

Primary School of Vouliagmeni

Description

Vouliagmeni region is at the south part of Vari Voula Vouliagmeni Municipality area. The Primary School of Vouliagmeni is located less than 500 m north of the main beach of Vouliagmeni and the commercial and recreational area. It is built at the foot of a small hill separating Vouliagmeni from Varkiza. The school is at the border of the urban area of Vouliagmeni that has mostly multifamily houses and some 4 floor high residential buildings.

Initial Energy Requirement

From the available data it is derived that the average annual electricity consumption is 17,000 kWh which corresponds to a specific electricity consumption of 6.35 kWh/m2 of total floor area.

The school building complex of the Primary School of Vouliagmeni consumes oil fuel (diesel) for covering its heating demand. The fuel oil consumption of the school was estimated by the data given from the municipality and the school’s principal about the amount of fuel that was added in the fuel tanks and the dates refuelling took place. According to data of two heating seasons the average oil consumption was 3,750 lt of fuel oil (diesel). This corresponds to final energy consumption for heating of approximately

38,000 kWh.

Table 0.43 Total *Energy Consumption and CO_2 Emissions of Primary School of Vouliagmeni*

Energy carrier	**Final Annual Energy Consumption Annually [kWh]**	**Primary Energy Consumption Annually [kWh]**	**Annual CO_2 Emissions [kg]**
Electricity	16,938	49,122	16,752
Fuel Oil	37,783	41,561	9,975
Total	**54,721**	**90,683**	**26,727**

Aim of the renovation plan

The aim of the renovation plan is the essential reduction of final energy use of the school buildings both by reducing the energy demand and by increasing the efficiency of its systems. The general strategy for renovation of the Primary School of Vouliagmeni buildings is based both on building envelope insulation and on replacing lighting and heating systems. Special attention is given at the main building because the two sectors have totally different thermal insulation. Only the uninsulated opaque building elements will be proposed for being insulated. Another factor considered will be the thermal comfort of its users. The final goal of the renovation is for the school building to be characterized as NZEB. To achieve that on-site energy generation by RES has to be considered.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

The change in electricity mix as far as the school is concerned is that after all the ECMs applied the electricity consumption of the school will be totally covered by the PV system generation in a yearly basis. So, it will be 100% solar energy generated on-site but connected to the grid with Net Metering method.

Table 0.44 ***New Electricity Mix***

Electricity Mix after ECMs	Type of Energy Source	Percentage	Generation	Annual Generation/Consumption
	Solar	100%	On site – Net Metering	12,000 kWh

In terms of final energy the school building consumes only fuel oil for heating as it covers all the electricity demand with the PV system generation. In Table 6.21 the total energy consumption is presented as wells as final energy consumption reduction compared to the existing situation. Electricity consumption is shown both without PV and with PV contribution in order to be clear that it is reduced anyway.

Table 0.45 ***Final Energy Consumption after improvement actions***

Type of energy carrier	**Final Energy Consumption Before Renovation [kWh]**	**Final Energy Consumption After Renovation [kWh]**	**Final Energy Consumption Reduction**
Electricity	16,938	12,008	29.1 %
Electricity Net		0	100 %
Gas & Fuel Oil	37,783	17,471	53.8 %
Total	54,721	29,479	46.1 %
Total Net		17,471	68.1 %

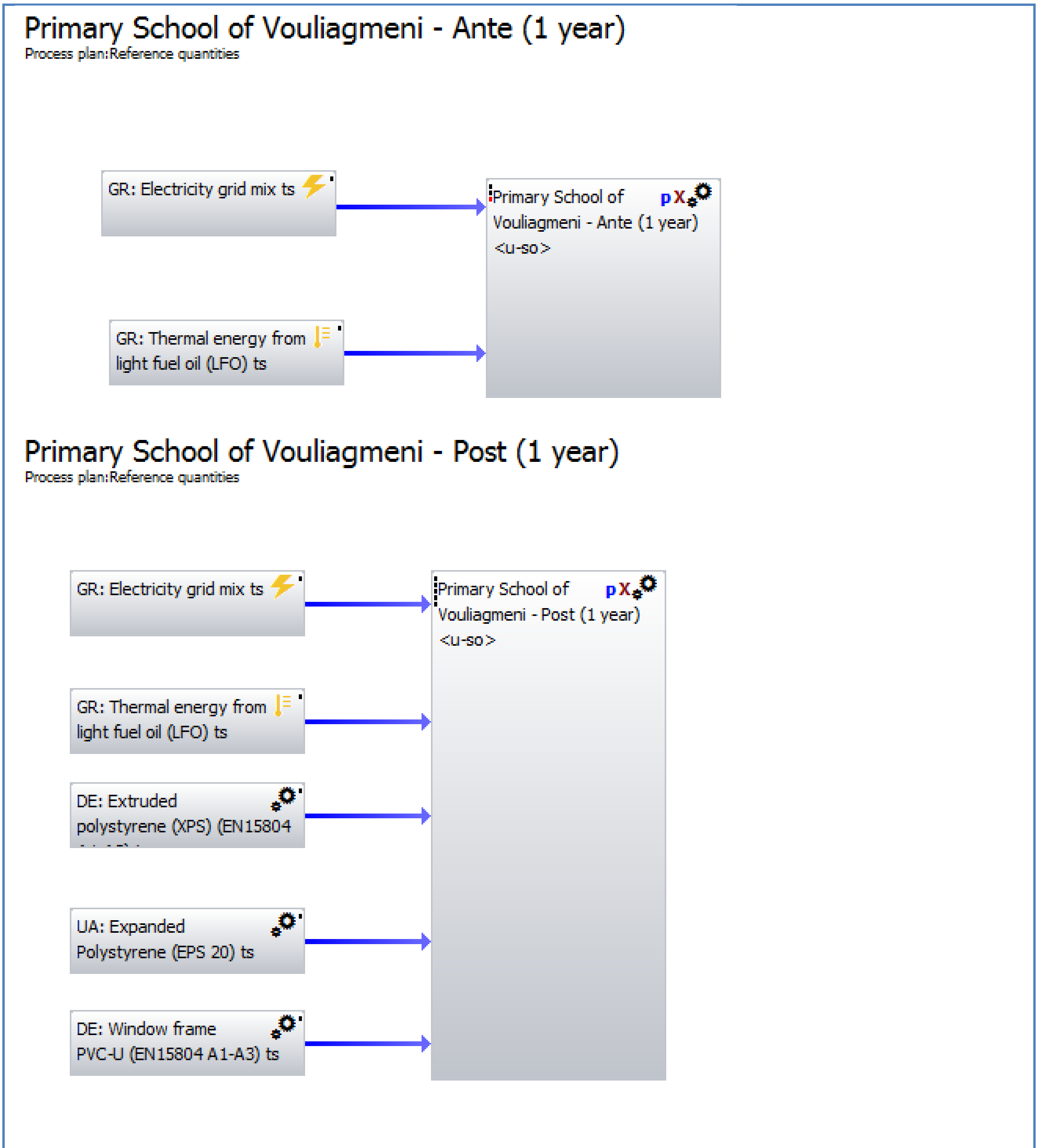
Materials and components

Table 0.46 ***Summary of ECMs cost***

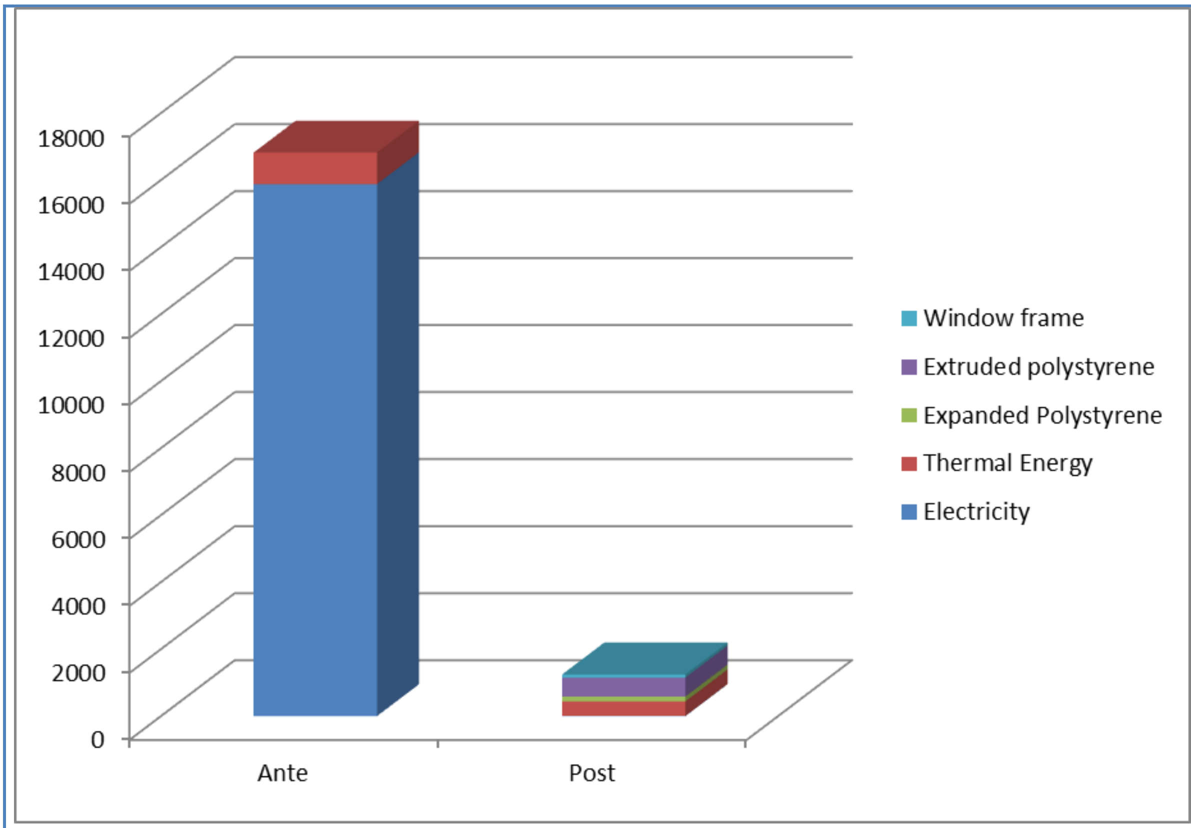
ECMs	*ACTION*	*VOICE*	*U.M.*	*Unit Cost*	*Total Cost*
ECM 1	*Building Envelope*	*Wall External Insulation*	259 m^2	45.9 €/m^2	11,883
		Pitched Roof Internal Insulation	436 m^2	19 €/m	8,290
		Windows Replacement	240 m^2	235 €/m^2	56,400
TOTAL					**76,573**
ECM 2	*Energy Systems Upgrade*	*LED panels for lighting*	205	60 €/panel	12,300
		LED spotlights for external lighting	4	135 €	540
	Lighting Automated Control	*Light Sensors*	21	120 €/sensor	2,520
TOTAL	…				**10,980**
ECM 3	*Energy Systems*	*Condensing Oil Boiler 80 kW*	1	12,000 €	12,000
		Condensing Oil Boiler 70 kW	1	12,000 €	12,000
	Systems Automations	*Thermostatic Valves*	20		7,000
TOTAL					**31,000**
PV	*RES*	*PV panels*	12 kWp	1,488/kW	**17,856**
TOTAL					**140,789**
TOTAL	***COMBINED****				**125,325**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software


Primary School of Vouliagmeni - Ante (1 year)
Process plan:Reference quantities
GR: Electricity grid mix ts
GR: Thermal energy from light fuel oil (LFO) ts
Primary School of Vouliagmeni - Ante (1 year) <u-so>
Primary School of Vouliagmeni - Post (1 year)
Process plan:Reference quantities
GR: Electricity grid mix ts
GR: Thermal energy from light fuel oil (LFO) ts
DE: Extruded polystyrene (XPS) (EN15804
UA: Expanded Polystyrene (EPS 20) ts
DE: Window frame PVC-U (EN15804 A1-A3) ts
Primary School of Vouliagmeni - Post (1 year) <u-so>

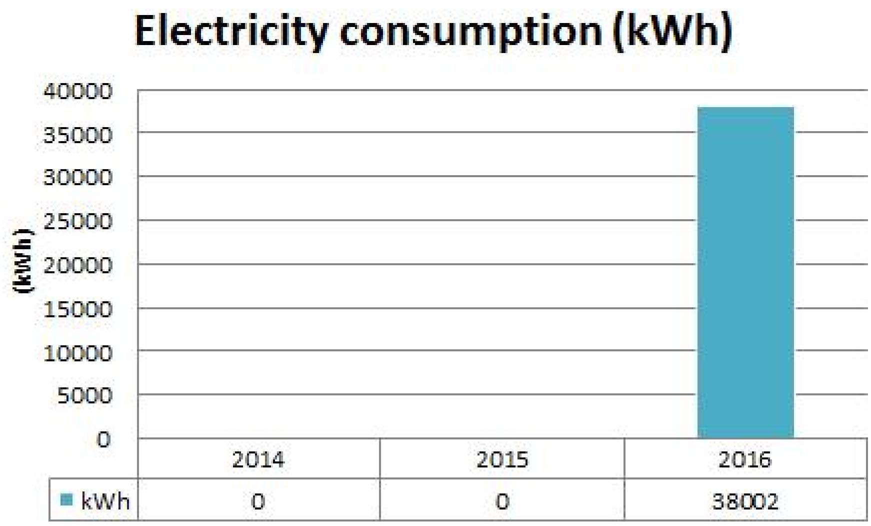
Results



After the proposed renovation, the school overall emissions decreased of around 92% respect the initial conditions. As the solar panels produce almost the energy required to the school needs, the impacts in the Post intervention are due to the materials used for the restoration

Italy

Alberghetti high school in Castel San Pietro Terme
Description
The Alberghetti is a high school, located in Castel San Pietro Terme, in the Metropolitan City of Bologna. It is a district with several building inside: school building, gym, canteen and multifunctional classrooms. The school building has 2 floors. The structure is reinforced concrete and there is not insulation in walls and roof. The roof is made up of sloping pitches and tiles. Also the basement is not insulated and it is realized with reinforced concrete and hollow bricks.
Initial Energy Requirement



Aim of the renovation plan

After collecting the preliminary data it is clear that the school building does not meet the minimum requirements of current Italian legislation. It is therefore necessary to conduct a thorough analysis to verify which improvement actions are applicable to achieve the minimum legal requirements or even to reach the nZEB class.

The description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	ANTE IMPROVEMENT ACTIONS (kWh)	POST IMPROVEMENT ACTIONS (kWhp)
Heating	146.979,89	14.460,64
Cooling	0	0
Lighting	20.505,42	7.476,65
Domestic Hot Water Production	306,98	306,98
Ventilation	0	0

Post improvement actions are expressed in terms of primary energy, the final electricity consumption is estimated to be 10526,86 kWh.

The installation of a photovoltaic solar system with monocrystalline silicon panels was hypothesized too. The peak power is of 15 kW (South exposure). The inclination of the panels is about 15° and the annual production is expected to be around 15.155 kWh.

Materials and components

Envelope

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)

External walls insulation	extruded polystyrene foam	12 cm	0,193	0,260
Roof insulation	Extruded polystyrene foam	12 cm	0,166	0,220
Basement insulation	expanded polystyrene	6 cm	0,289	0,260

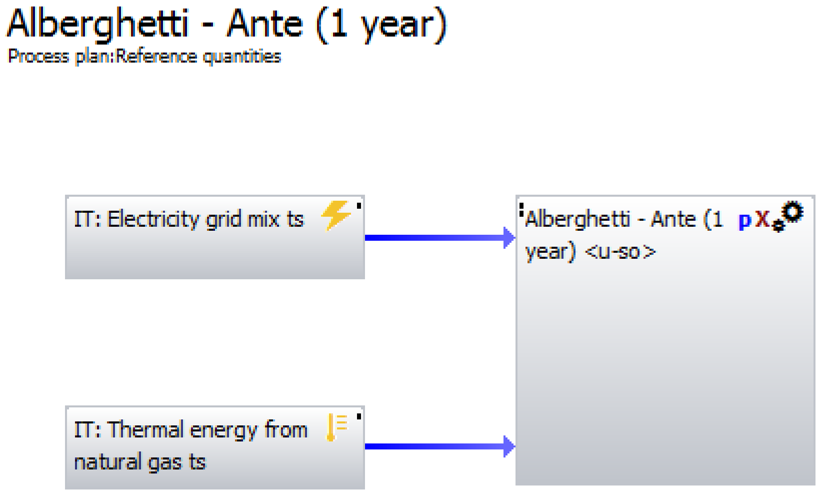
Windows and Shading

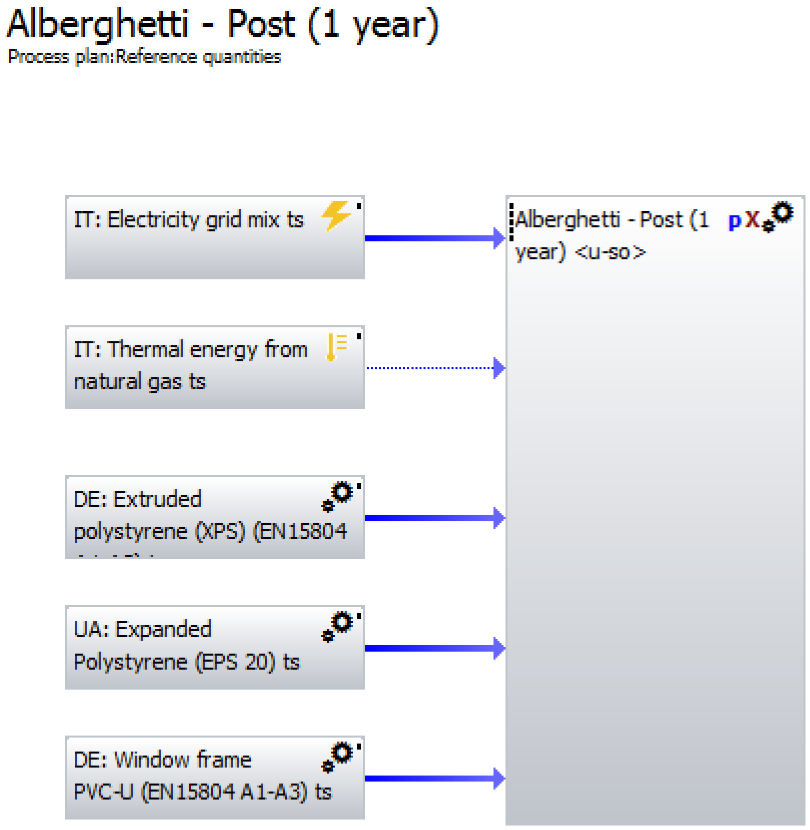
IMPROVEMENT ACTION	**Material**	**Thickness**	**U_{value} (W/m^2*K)**	**$U_{limitvalue}$ (W/m^2*K)**
Insulated windows	double glazed glass filled with argon and low-emission treatment	4/18/4 mm	0,842-0,879	1,80
Insulated rolling-shutter box	extruded polystyrene foam	-	0,674	-
High performances shading system	-	-	0,777	-

ACTION	***VOICE***	***U.M.***	***Unit Cost €/m^2***	***Total Cost €***
Building envelope	*External Walls Insulation*	m^2	65	40.000
Building envelope	*Basement Insulation*	m^2	73	30.000
Building envelope	*Roof Insulation and Roof Ventilation*	m^2	97,50	40.000
Building envelope	*Windows Insulation + Rolling Shutter box Insulation + Shading System*	m^2	850	100.300
Lighting System	*Relamping*	w	-	15.000
Heating System	*Geothermal Heat Pump + Insulated Distribution System + Radiant Floor System*	-	-	80.000
Heating System and Domestic Hot Water Production	*Thermal Solar System*	-	-	98.250

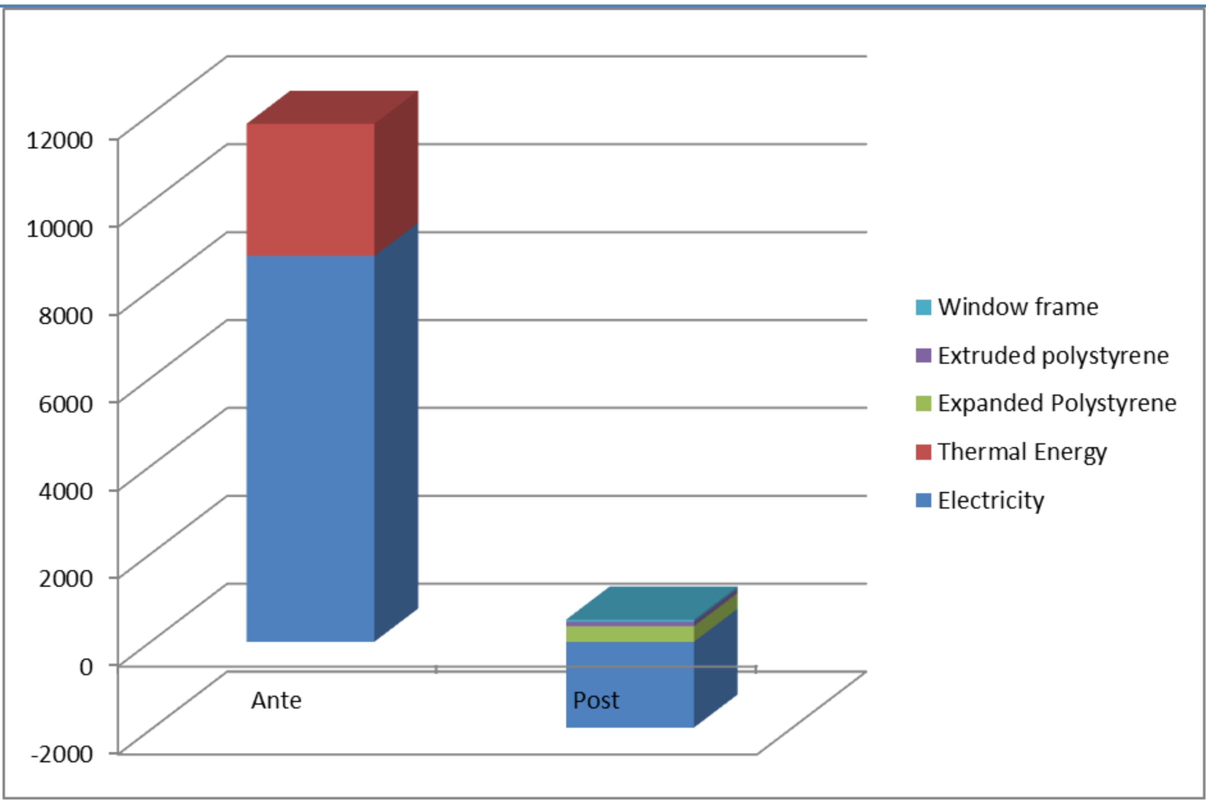
Renewable System	*Photovoltaic*	m^2	2.000	30.000
TOTAL				**409.000**

Model on GaBi software





Results



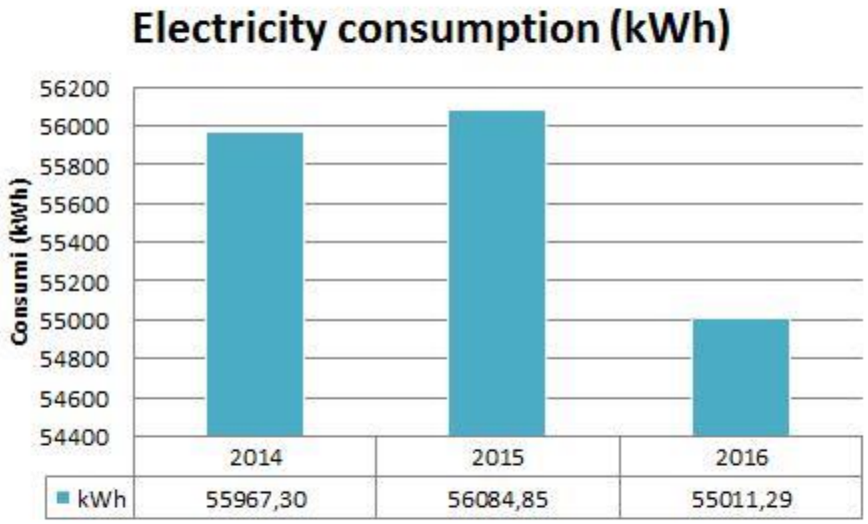
After the proposed renovation, the school overall emissions decreased to a carbon neutrality considering the avoided impacts of the electricity produced. As the solar panels produce more energy than the required to the school needs, the impacts in the Post intervention are due to the materials used for the restoration.

Albertazzi – Pizzighotti primary school, located in Poggio Grande of Castel San Pietro Terme

Description

The Albertazzi – Pizzighotti is a primary school, located in Poggio Grande of Castel San Pietro Terme, in the Metropolitan City of Bologna. It was built in 1950 and it is located in country, it is the smallest among the pilot of TEESCHOOLS project. This school is made up of a principal building with two storeys (old building) and a new part recently built, five classrooms, a small computer laboratory, a room for teachers, a refectory, a small kitchen and hygienic services. In 2003 the school was refurbished and it was built a small gym.

Initial Energy Requirement



Aim of the renovation plan

After collecting the preliminary data it is clear that the school building does not meet the minimum requirements of current Italian legislation. It is therefore necessary to conduct a thorough analysis to verify which improvement actions are applicable to achieve the minimum legal requirements or even to reach the nZEB class.

The description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	ANTE IMPROVEMENT ACTIONS (kWh)	POST IMPROVEMENT ACTIONS (kWhp)
Heating	80.309,05	103.308,56
Cooling	0	0
Lighting	368.687,97	149.632,68
Domestic Hot Water Production	1.215,42	1.215,42
Ventilation	0	0

Post improvement actions are expressed in terms of primary energy, the final electricity consumption is estimated to be 120.276,68 kWh.

The installation of a photovoltaic solar system with monocrystalline silicon panels was hypothesized too. The peak power is of 40 kW (South exposure). The inclination of the panels is about 15° and the annual production is expected to be around 41.170 kWh.

Materials and components

Envelope

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)

External walls insulation	extruded polystyrene foam	10 cm	0,196	0,260
Roof insulation	Extruded polystyrene foam	12cm	0,105	0,220
Basement insulation	expanded polystyrene + polyurethane	3 cm + 7,2 cm	0,211	0,260

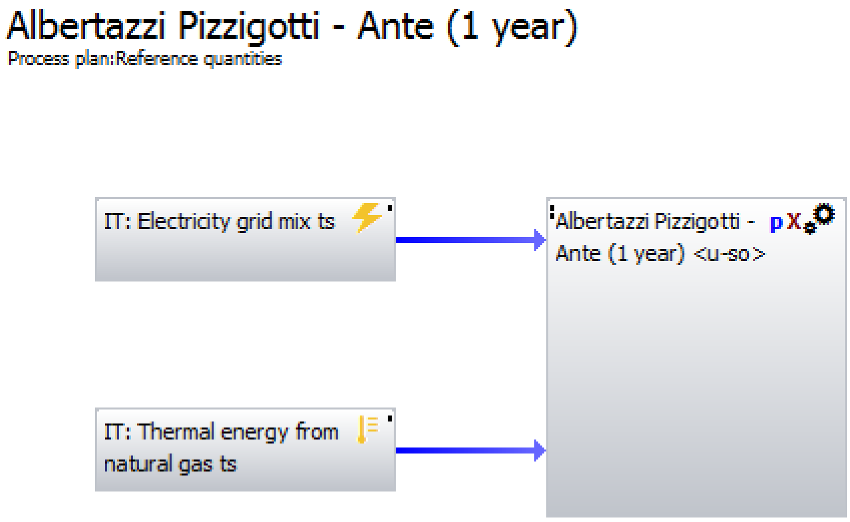
Windows And Shading

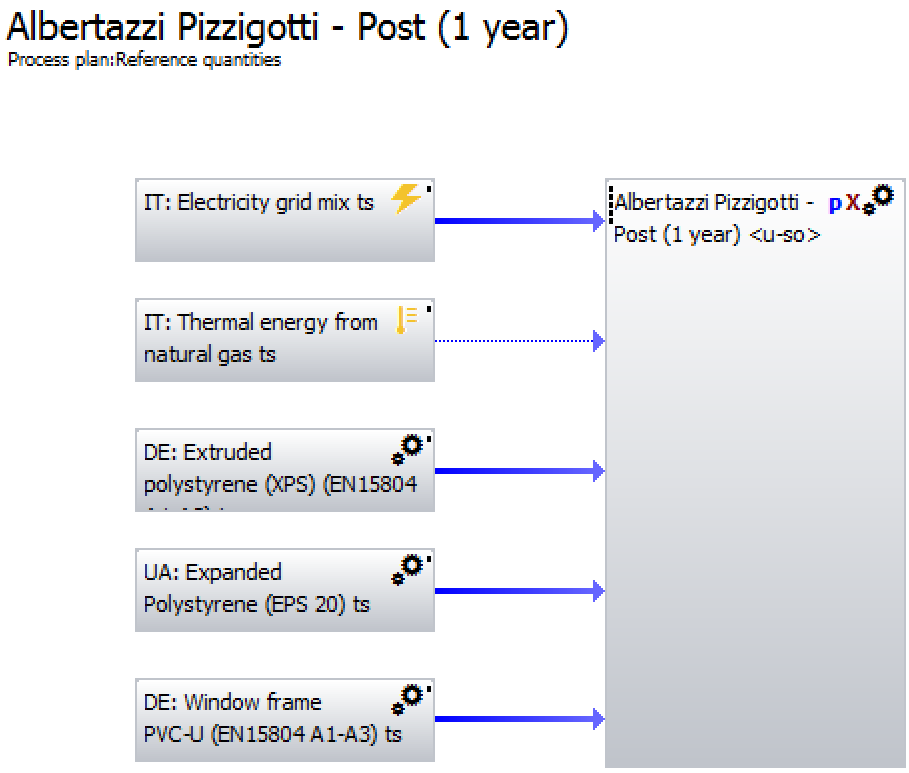
IMPROVEMENT ACTION	**Material**	**Thickness**	**U_{value} (W/m^2*K)**	**$U_{limitvalue}$ (W/m^2*K)**
Insulated windows	double glazed glass filled with argon and low-emission treatment	4/18/4 mm	0,847-0,948	1,80
Insulated rolling-shutter box	extruded polystyrene foam	-	0,674	-
High performances shading system	-	-	0,777	-

ACTION	*VOICE*	*U.M.*	*Unit Cost €/m^2*	*Total Cost €*
Building envelope	*External Walls Insulation*	m^2	70	245.000
Building envelope	*Basement Insulation*	m^2	65	130.000
Building envelope	*Roof Insulation and Roof Ventilation*	m^2	60	120.000
Building envelope	*Windows Insulation + Rolling Shutter box Insulation + Shading System*	m^2	850	650.000
Lighting System	*Relamping*	w	-	40.000
Heating System	*Geothermal Heat Pump + Insulated Distribution System + New Emission System*	-	-	100.000
Heating System and Domestic Hot	*Thermal Solar System*	-	-	90.000

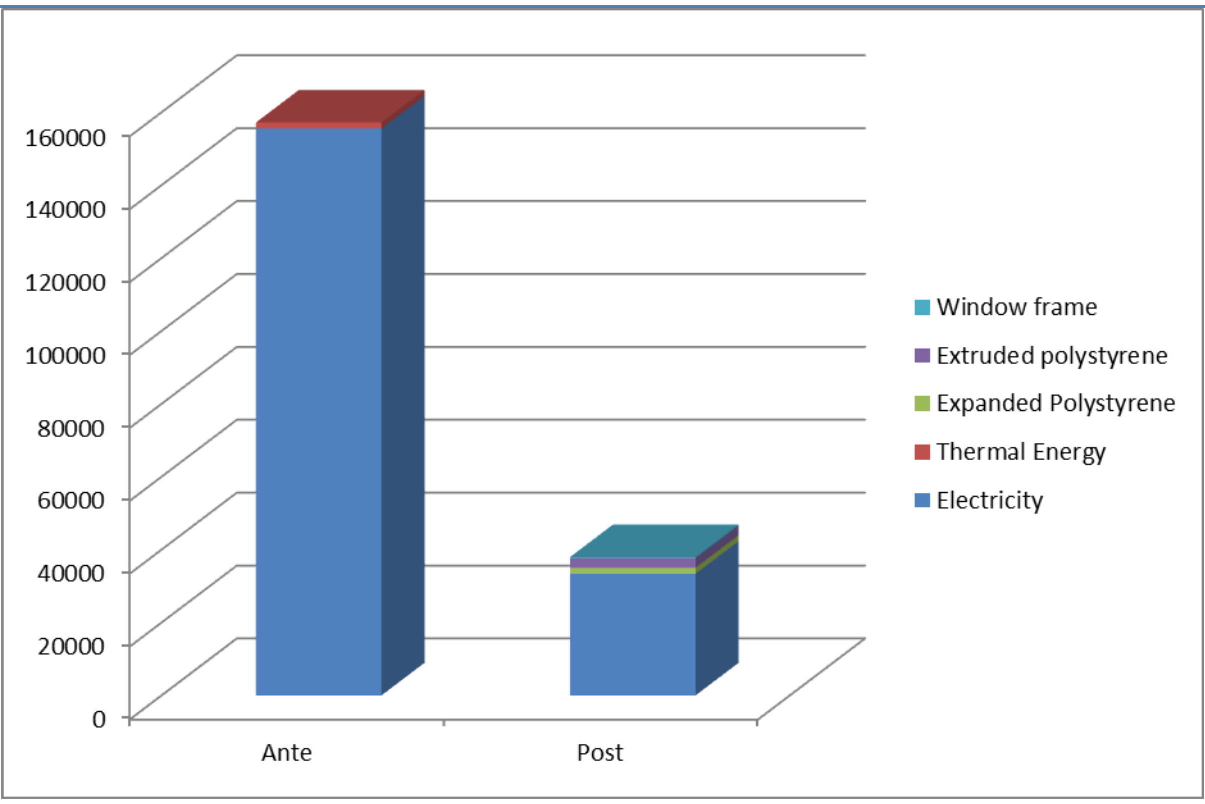
Water Production				
Renewable System	*Photovoltaic*	m^2	2.000	80.000
TOTAL				**1.455.000**

Model on GaBi software





Results



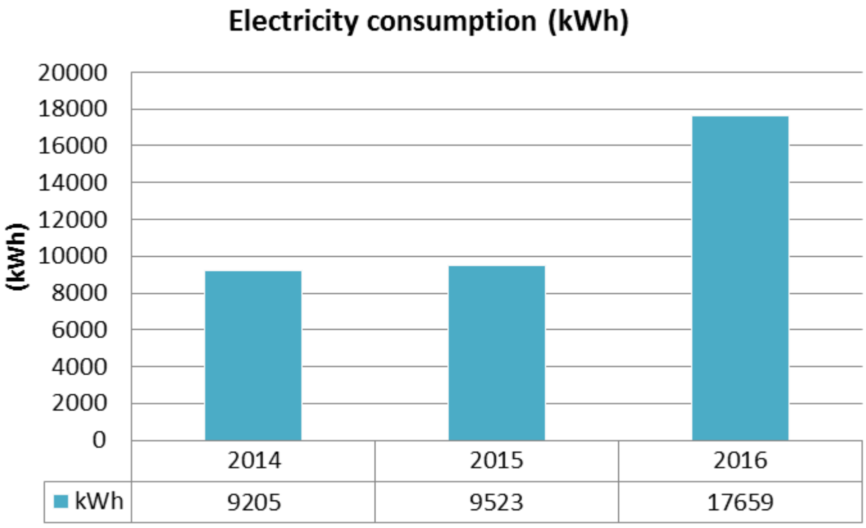
After the proposed renovation, the school overall emissions decreased of around 75% respect the initial conditions considering the avoided impacts of the electricity produced. The impact due to the materials used for the restoration contributes for a 12% of the Post intervention emissions.

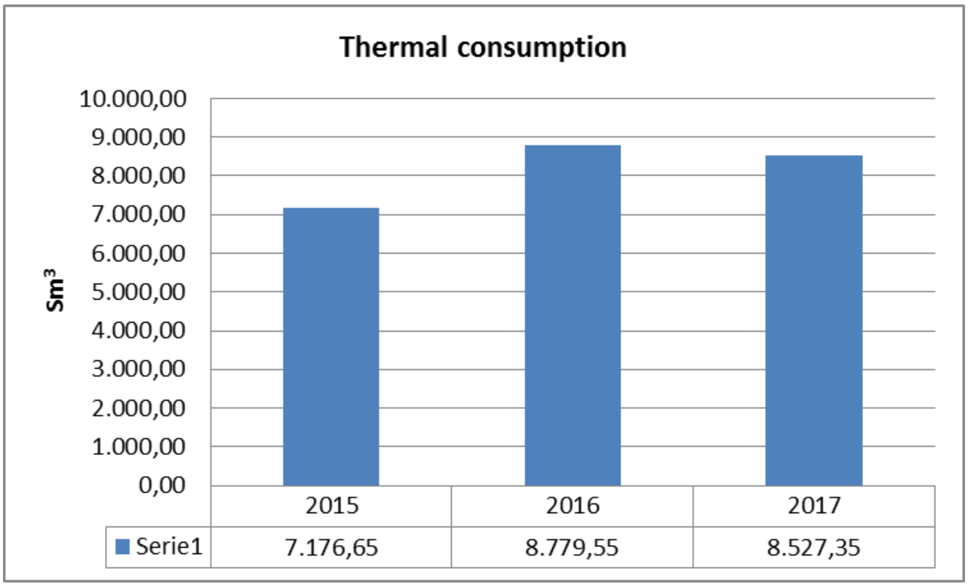
Don Lorenzo Milani primary school, in Poggio Grande of Castel San Pietro Terme

Description

The Don Lorenzo Milani is a primary school, located in Poggio Grande of Castel San Pietro Terme, in the Metropolitan City of Bologna. It was built in 1950 and it is located in countryside; it is the smallest among the pilot of TEESCHOOLS project. This school is made up of a principal building with two storeys (old building) and a new part recently built, five classrooms, a small computer laboratory, a room for teachers, a refectory, a small kitchen and hygienic services. In 2003 the school was refurbished and it was built a small gym.

Initial Energy Requirement





Aim of the renovation plan

After collecting the preliminary data it is clear that the school building does not meet the minimum requirements of current Italian legislation. It is therefore necessary to conduct a thorough analysis to verify which improvement actions are applicable to achieve the minimum legal requirements or even to reach the nZEB class.

The description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	ANTE IMPROVEMENT ACTIONS (kWh)	POST IMPROVEMENT ACTIONS (kWhp)
Heating	119.694,95	25.720,83
Cooling	0	0
Lighting	29.438,96	12.302,34
Domestic Hot Water	122,79	122,79

Production		
Ventilation	0	0

Post improvement actions are expressed in terms of primary energy, the final electricity consumption is estimated to be 18.052,13 kWh.

The installation of a photovoltaic solar system with monocrystalline silicon panels was hypothesized too. Two strings have been designed: the first one with a peak power of 1.5 kW (East exposure) and the second one with a peak power of 7.425 kW (South exposure). The inclination of the panels is about 20° and the annual production is expected to be around 8.600 kWh.

Materials and components

Envelope

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)
External walls insulation	extruded polystyrene foam	10 cm	0,202	0,260
Ventilation and roof insulation	Extruded polystyrene foam + air	14 cm + 10 cm	0,211	0,220
Basement insulation	expanded polystyrene + polyurethane	3 cm + 7,2 cm	0,238	0,220

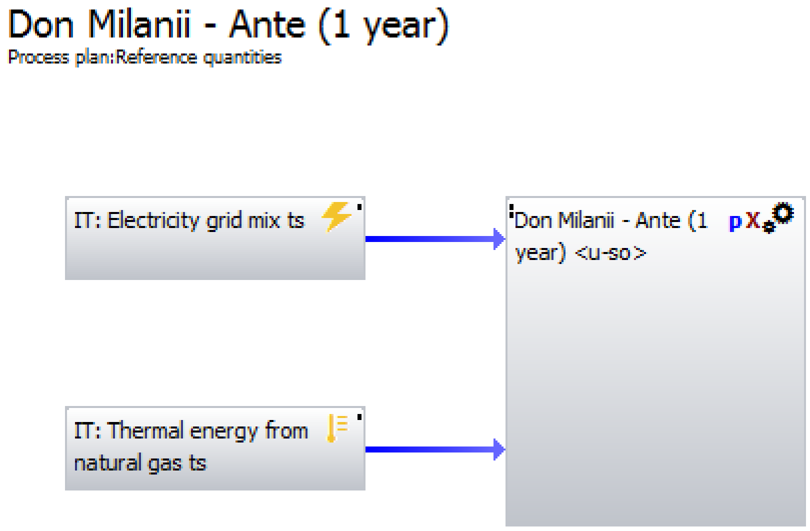
Windows and Shading

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)
Insulated windows	double glazed glass filled with argon and low-emission treatment	4/18/4 mm	0,711-0,819	1,40
Insulated rolling-shutter box	extruded polystyrene foam	-	0,674	-
High performances shading system	-	-	0,777	-

ACTION	*VOICE*	*U.M.*	*Unit Cost €/m^2*	*Total Cost €*
Building envelope	*External Walls Insulation*	m^2	61	41.000
Building envelope	*Basement Insulation*	m^2	380	20.000

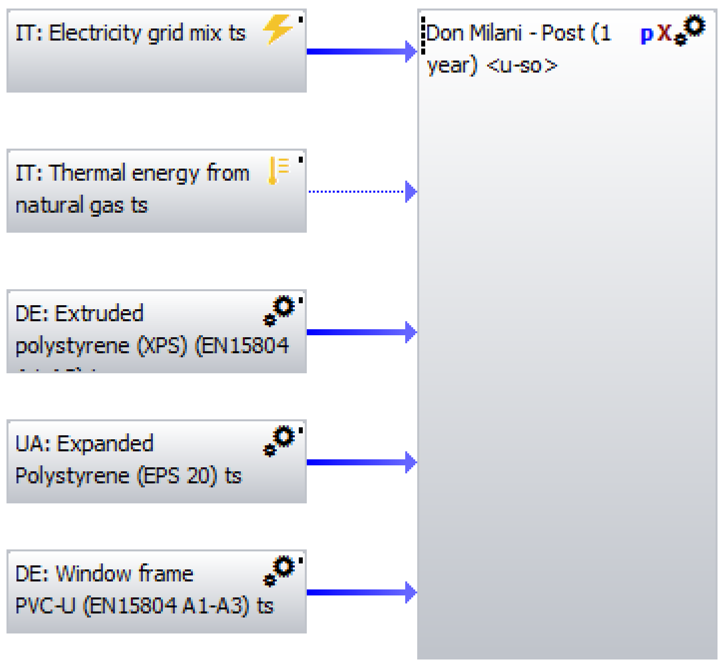
Building envelope	*Roof Insulation and Roof Ventilation*	m^2	470	80.000
Building envelope	*Windows Insulation + Rolling Shutter box Insulation + Shading System*	m^2	130	110.000
Lighting System	*Relamping*	w	-	20.000
Heating System	*Geothermal Heat Pump + Insulated Distribution System + Radiant Floor System*	-	-	100.000
Heating System and Domestic Hot Water Production	*Thermal Solar System*	-	-	20.000
Renewable System	*Photovoltaic*	m^2	59,50	18.000
TOTAL				**409.000**

Model on GaBi software

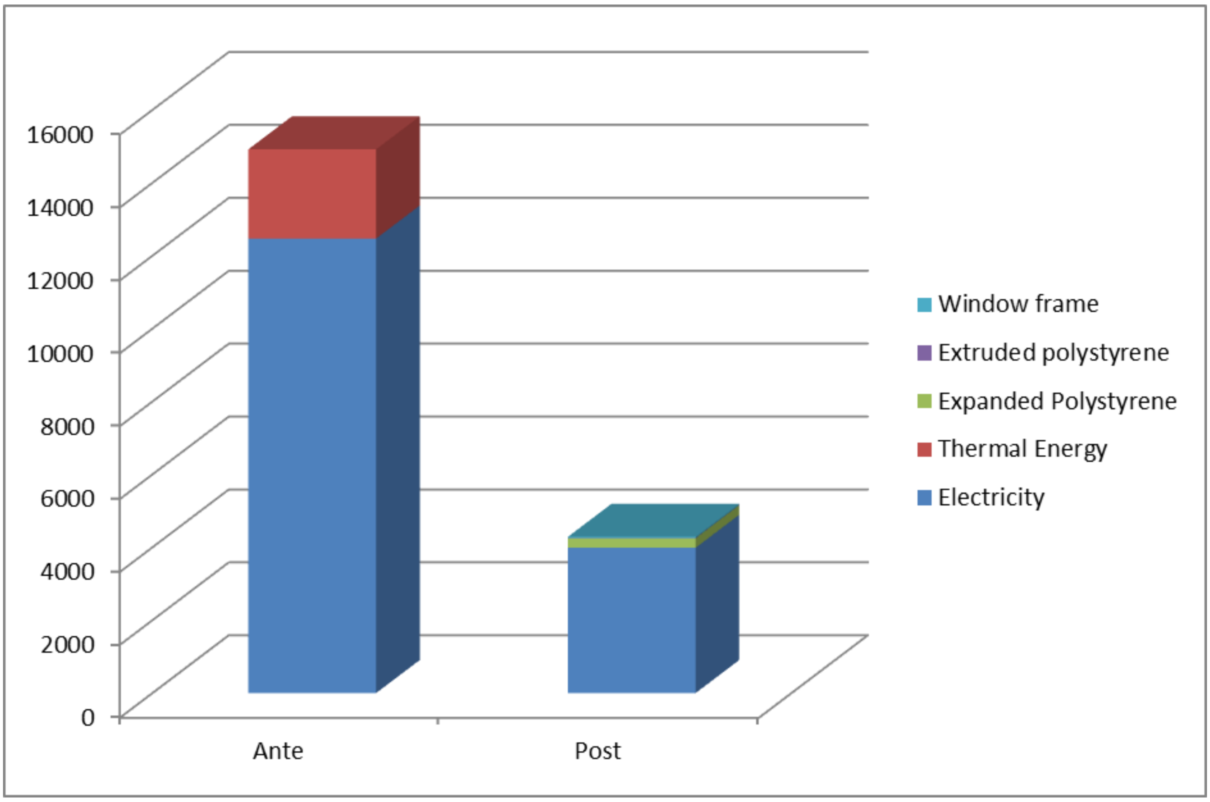


Don Milani - Post (1 year)

Process plan:Reference quantities

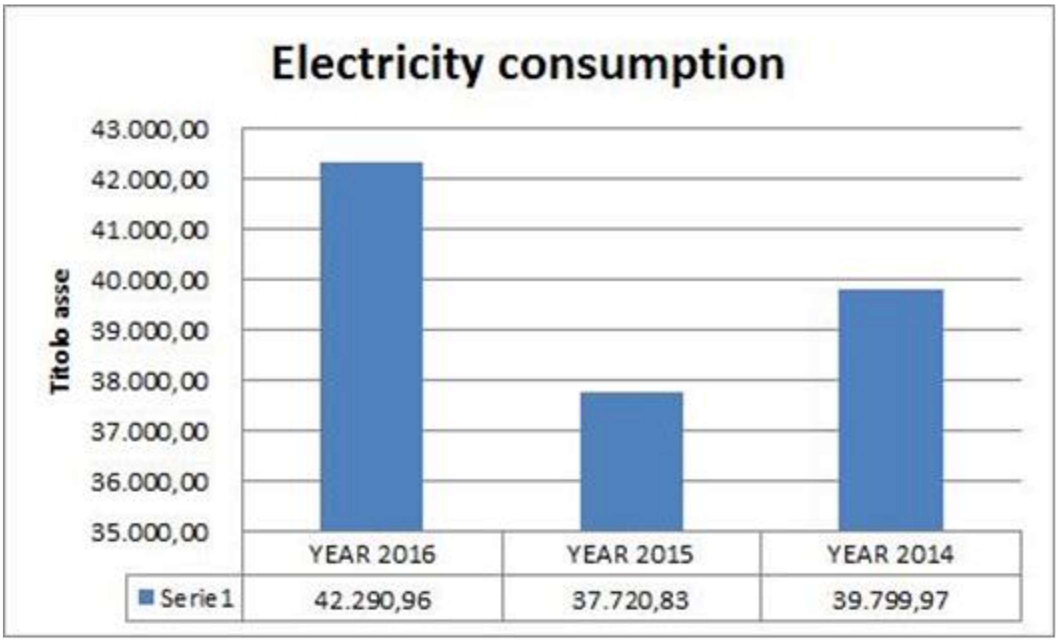


Results



After the proposed renovation, the school overall emissions decreased of around 70% respect the initial conditions considering the avoided impacts of the electricity produced. The impact due to the materials used for the restoration contributes for a 7% of the Post intervention emissions.

Sassatelli primary school in Castel San Pietro Terme
Description
The Sassatelli is a primary school, located in Castel San Pietro Terme, in the Metropolitan City of Bologna. The building was built in 1985 and the structure is in concrete. The building Is constituted by 4 rectangles. The structure is constituted by not-insulted bricks .The not-insulated roof is made up of sloping pitches and tiles. Also the basement is not-insulated and it is realized with reinforced concrete and hollow bricks.
Initial Energy Requirement



Aim of the renovation plan

After collecting the preliminary data it is clear that the school building does not meet the minimum requirements of current Italian legislation. It is therefore necessary to conduct a thorough analysis to verify which improvement actions are applicable to achieve the minimum legal requirements or even to reach the nZEB class.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	ANTE IMPROVEMENT ACTIONS (kWh)	POST IMPROVEMENT ACTIONS (kWhp)
Heating	584.904,07	93.793,89
Cooling	0	0
Lighting	99.889,92	84.134,75
Domestic Hot Water Production	613,95	613,95
Ventilation	0	0

Post improvement actions are expressed in terms of primary energy, the final electricity consumption is estimated to be 84.493,20 kWh.

The installation of a photovoltaic solar system with monocrystalline silicon panels was hypothesized too. The strings is designed as shown in figure 23: 80 sqm of silicon panels with a peak power of 12 kW (South exposure). The inclination of the panels is about 20° and the annual production is expected to be around 14.400 kWh.

Materials and components

Envelope

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)
External walls insulation	extruded polystyrene foam	10 cm	0,200	0,260
Ventilation and roof insulation	Extruded polystyrene foam + air	14 cm + 10 cm	0,200	0,220
Basement insulation	expanded polystyrene + polyurethane	3 cm + 8 cm	0,200	0,220

Windows and Shading

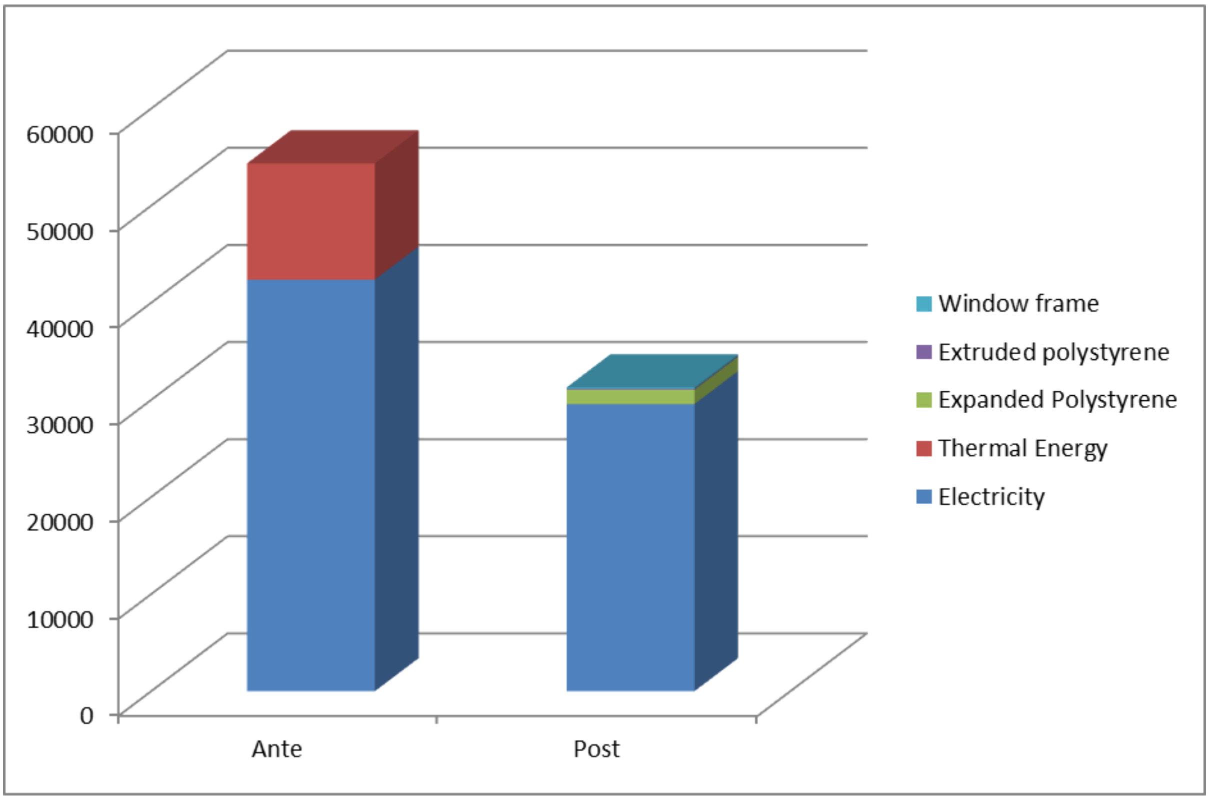
IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m^2*K)	$U_{limitvalue}$ (W/m^2*K)
Insulated windows	double glazed glass filled with argon and low-emission treatment	4/18/4 mm	0,711-0,819	1,40
Insulated rolling-shutter box	extruded polystyrene foam	-	0,674	-
High performances shading system	-	-	0,777	-

ACTION	*VOICE*	*U.M.*	*Unit Cost €/m^2*	*Total Cost €*
Building envelope	*External Walls Insulation*	m^2	65	400.000
Building envelope	*Basement Insulation*	m^2	55	44.200
Building envelope	*Roof Insulation and Roof Ventilation*	m^2	65	213.000
Building envelope	*Windows Insulation + Rolling Shutter box Insulation + Shading System*	m^2	650	230.000
Lighting System	*Relamping*	w	-	30.000
Heating System	*Geothermal Heat Pump + Insulated Distribution System + Radiant Floor System*	-	-	110.000

Heating System and Domestic Hot Water Production	*Thermal Solar System*	-	-	12.000
Renewable System	*Photovoltaic*	m^2	270	21.600
TOTAL				**1.060.800**

Model on GaBi software

Results



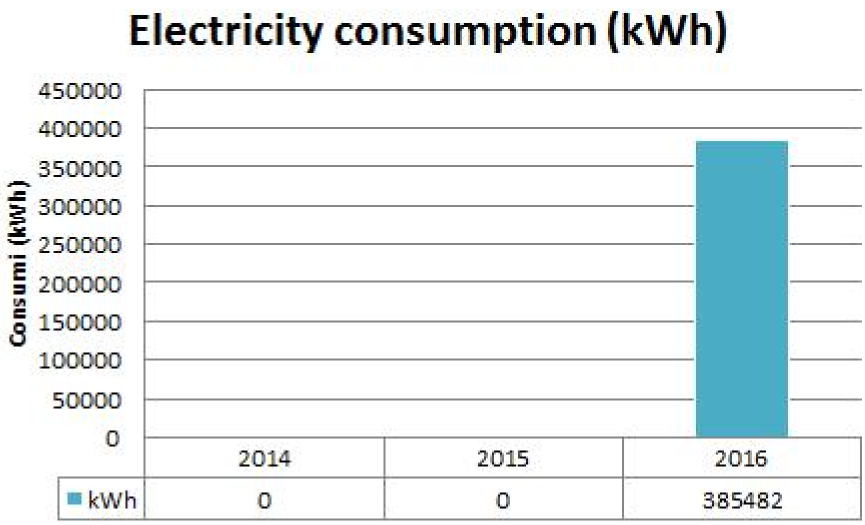
After the proposed renovation, the school overall emissions increase of around 42% respect the initial conditions considering the avoided impacts of the electricity produced. The impacts due to the materials used for the restoration contribute for a 5% of the Post intervention emissions.

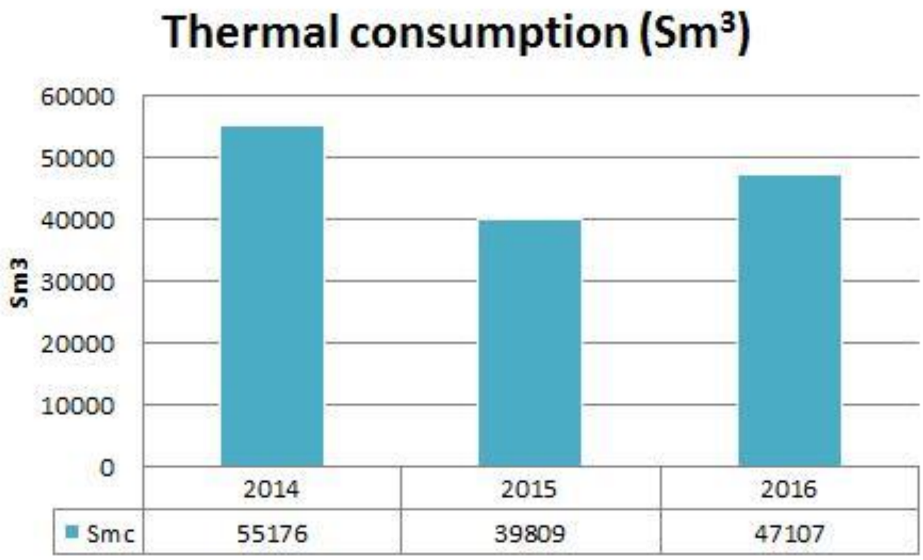
Scappi high school, located in Castel San Pietro Terme

Description

The Scappi is a high school, located in Castel San Pietro Terme, in the Metropolitan City of Bologna. Scappi school is a cooking school named after Bartolomeo Scappi, who lived in the sixteenth century and made famous by the detailed gastronomic treatise given to the press. According to Giancarlo Roversi, authoritative local historian, was the Bolognese "secret chef" of Pope Pio V. Built in 1987, it is today a considerable school reality with more than 1300 students and over 200 teachers, including technical-professional teachers with considerable experience and recognized skills. This rapid development is understandable above all by its close relationship with the territory, being able to respond to the needs and requests that are widespread in the provincial and regional areas. Scappi school maintains relationships with the best and most renowned hotels and restaurants in the Bologna area, both nationally and internationally, and can choose the most suitable locations for the internships reserved for students in the third year of qualification and two years post-qualification. For this reason, inside it, there is much equipment necessary for the students training.

Initial Energy Requirement





Aim of the renovation plan

After collecting the preliminary data it is clear that the school building does not meet the minimum requirements of current Italian legislation. It is therefore necessary to conduct a thorough analysis to verify which improvement actions are applicable to achieve the minimum legal requirements or even to reach the nZEB class.

The description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	ANTE IMPROVEMENT ACTIONS (kWh)	POST IMPROVEMENT ACTIONS (kWhp)
Heating	1.071.015,92	326.938,20
Cooling	0	0
Lighting	530.908,59	338.821,49
Domestic Hot Water	17.287,03	17.287,03

Production		
Ventilation	42.316,56	41.389,05

Post improvement actions are expressed in terms of primary energy, the final electricity consumption is estimated to be 364.632,96 kWh.

No increase in PV System is expected compared to the initial condition.

Materials and components

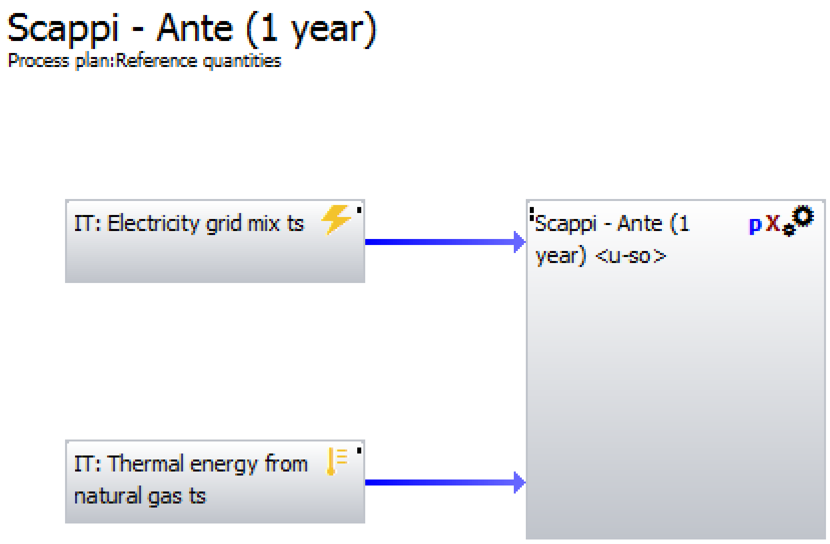
IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m²*K)	$U_{limitvalue}$ (W/m²*K)
External walls insulation	extruded polystyrene foam	11 cm	0,250	0,260
Ventilation and roof insulation	Extruded polystyrene foam + air	14 cm + 10 cm	0,212	0,220
Basement insulation	expanded polystyrene + polyurethane	3 cm + 7,2 cm	0,235	0,260

IMPROVEMENT ACTION	Material	Thickness	U_{value} (W/m²*K)	$U_{limitvalue}$ (W/m²*K)
Insulated windows	double glazed glass filled with argon and low-emission treatment	4/18/4 mm	0,711-0,819	1,80
Insulated rolling-shutter box	extruded polystyrene foam	-	0,674	-
High performances shading system	-	-	0,777	-

ACTION	*VOICE*	*U.M.*	*Unit Cost €/m²*	*Total Cost €*
Building envelope	*External Walls Insulation*	m²	65	160.000
Building envelope	*Basement Insulation*	m²	235	620.000
Building envelope	*Roof Insulation and Roof Ventilation*	m²	55	91.000

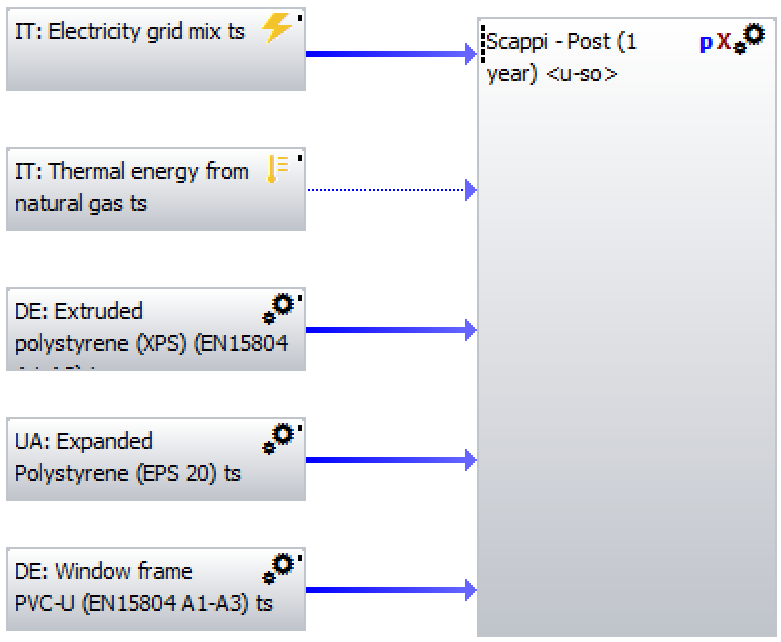
Building envelope	*Windows Insulation + Rolling Shutter box Insulation + Shading System*	m^2	850	650.000
Lighting System	*Relamping*	w	-	28.000
Heating System	*Geothermal Heat Pump + Insulated Distribution System + Radiant Floor System*	-	-	190.000
Heating System and Domestic Hot Water Production	*Thermal Solar System*	-	-	35.000
TOTAL				**1.774.000**

Model on GaBi software

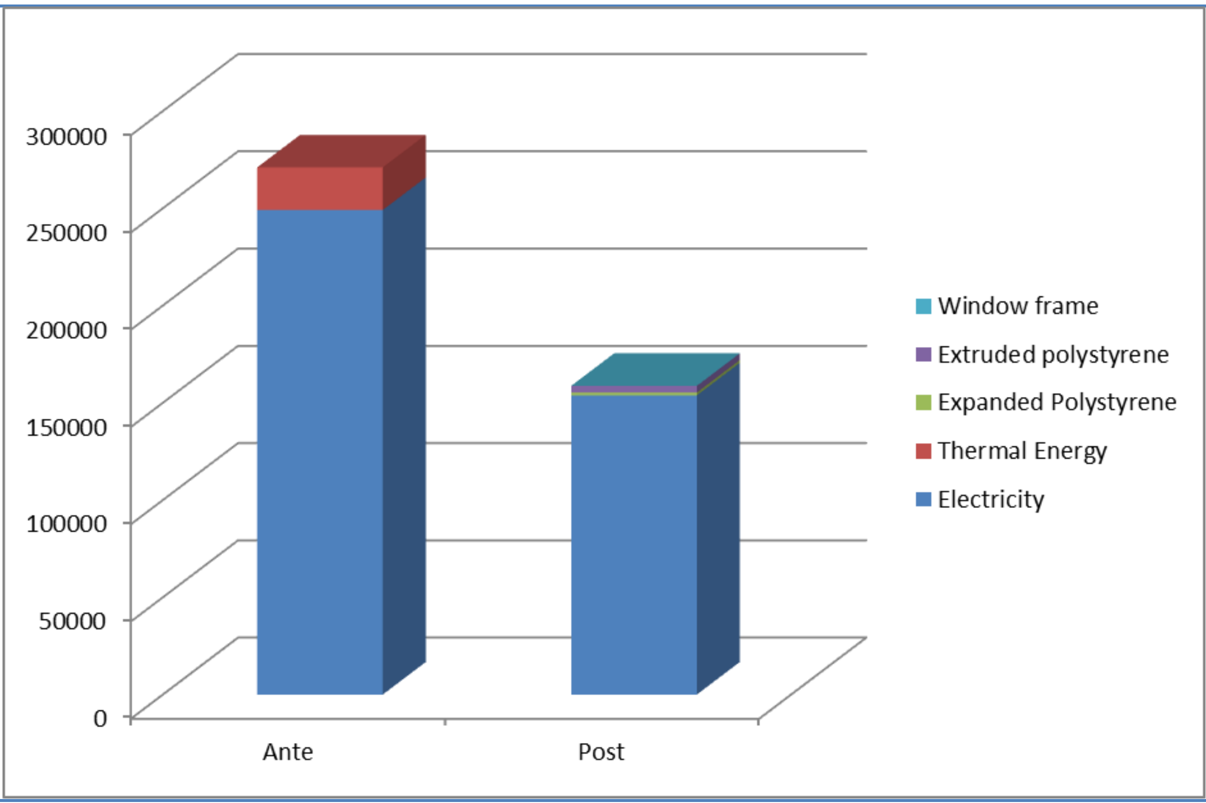


Scappi - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decrease of around 41% respect the initial conditions. The impact due to the materials used for the restoration contribute for around 3% of the Post intervention emissions.

Spain

Public School Juan Vicente Mora Carlet
Description
The Public School Juan Vicente Mora is located in Carlet. Carlet is a municipality in the *comarca* of Ribera Alta in the Valencian Community, Spain. It lies at an average altitude of 40m above sea level and is located 30 m to the south of the city of Valencia. The municipality is crossed from north to south by the River Magro, which carries little volume.
Initial Energy Requirement
School Energy Consumption: - Electrical Consumption: There is one Power Meter in the Main Electrical Box. - Diesel: There isn't Diesel Consumption. - Gas: There isn't Gas Consumption The electricity consumption average is 8.200kWh/month, about 1.600€/month. In 2017 the annual electricity consumption was 98.272kWh.
Aim of the renovation plan
The aim of the renovation plan is propose technical solutions to reduce the energy consumption also the CO_2 Emissions to achieve a NZEB. ***The full description of the renovation plan is presented in the Energy Audit document.***
Final Energy Requirement

ACTION	VOICE	Energy Consumption Savings (kWh/Year)	CO^2 EMISSIONS REDUCTION (ton CO2/year)
Envelope			
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	2080	0,35
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	3120	0,52
Plants	LED LIGHTHING REPLACEMENT	29950	5
	PRESENCE DETECTORS INSTALLATION	4985	0,83
	PV SOLAR PANELS INSTALLATION	39070	6,5
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE	4915	0,82
	ENERGY CONSUMPTION CONTROL	9830	1,64

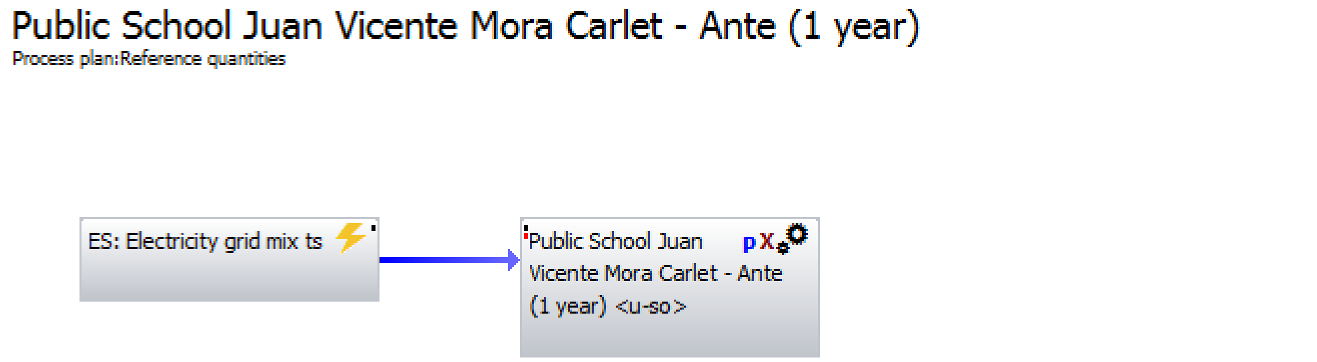
*** The saving has been calculated considering the energy saving achieved by implementing one single action and its effect on the baseline energy consumption. However, when implementing several actions, the baseline is altered due to the fact that every single measure provokes a reduction in the baseline energy consumption.*

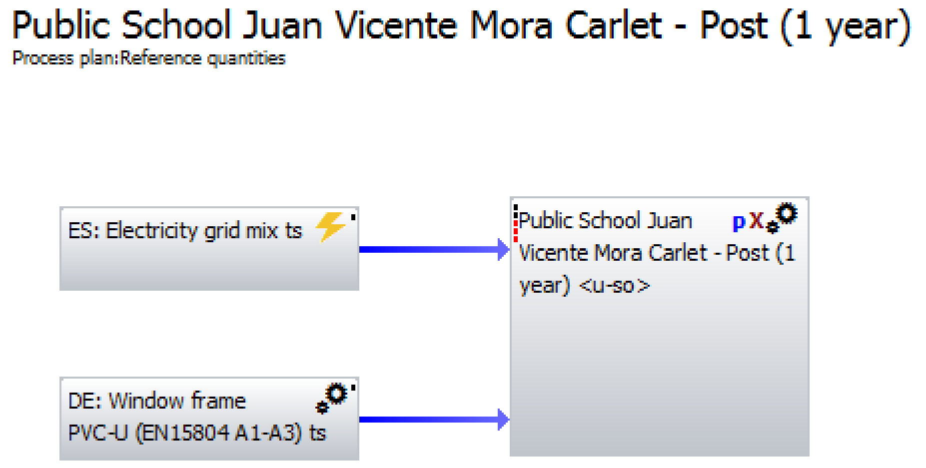
Materials and components

ACTION	VOICE	U.M.	Unit Cost €	Total Cost €
Envelope	LOW EMISSIVITY GLASS WINDOWS INSTALATION	821	5,8€/m2	4765
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	113	250	28250
Plants	LED LIGHTHING REPLACEMENT			19700
	PRESENCE DETECTORS INSTALLATION	29	70	2030
	PV SOLAR PANELS INSTALLATION	25,6KW	2,3€/Wp	58765
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE			5500
	ENERGY CONSUMPTION CONTROL			8000
	TOTAL			**127010**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software





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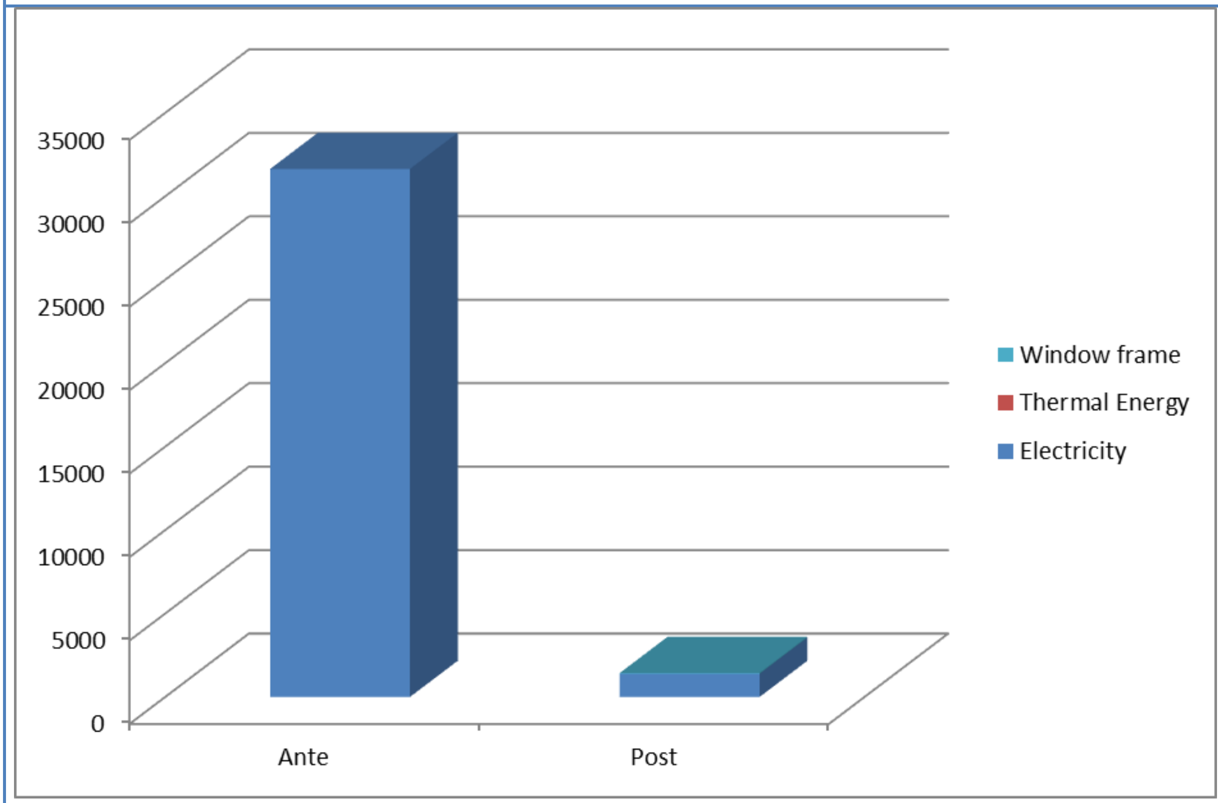


After the proposed renovation, the school overall emissions decreased of around 95% respect the initial conditions. The impact due to the materials used for the restoration contributes for a 3% of the Post intervention emissions.

Public School Les Comes L'Alcúdia

Description

The Public School Les Comes is located in L'Alcúdia.
l'Alcúdia is a municipality in the *comarca* of Ribera Alta in the Valencian Community, Spain.

It is located in the centre of the Ribera Alta administrative region. The town is located in the eastern part of the municipality. To the north is the River Magro, and to the south the River Júcar Royal Irrigation Canal. It lies 60 km from Valencia and 8 km from Alzira, the capital of the administrative region.
Initial Energy Requirement
School Energy Consumption: - Electrical Consumption: There is one Power Meter in the Main Electrical Box. - Natural Gas: Natural Gas Distribution to Supply the Boiler. The electricity consumption average is 2.600kWh/month, about 430€/month. In 2016 the annual electricity consumption was about 34.000kWh. The Natural Gas consumption average is 7.800kWh/month, about 550€/month. In 2015 the annual Natural Gas consumption was about 38.799kWh, in 2016 39.473kWh and in 2017 20.547kWh.
Aim of the renovation plan
The aim of the renovation plan is propose technical solutions to reduce the energy consumption also the CO_2 Emissions to achieve a NZEB. ***The full description of the renovation plan is presented in the Energy Audit document.***
Final Energy Requirement

ACTION	VOICE	Energy Consumption Savings (kWh/Year)**	CO^2 EMISSIONS REDUCTION (ton CO2/year)**
Envelope	OUTDOORS FACADE INSULATION	19285	3,82
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	2125	0,42
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	6375	1,26
Plants			
	PRESENCE DETECTORS INSTALLATION	1060	0,177
	REPLACEMENT THE GAS BOILER TO BIOMASS BOILER	895	10,28
	PV SOLAR PANELS INSTALLATION	13820	2,3
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE	3720	0,7
	ENERGY CONSUMPTION CONTROL	7435	1,4

*** The saving has been calculated considering the energy saving achieved by implementing one single action and its effect on the baseline energy consumption. However, when implementing several actions, the baseline is altered due to the fact that every single measure provokes a reduction in the baseline energy consumption.*

Materials and components

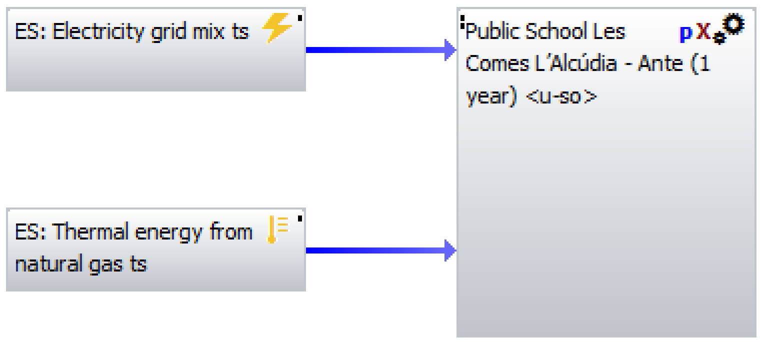
ACTION	VOICE	U.M.	Unit Cost €	Total Cost €
Envelope	OUTDOORS FACADE INSULATION	646	52,5/m2	33915
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	240	5,8€/m2	1390
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	127	250	31750
Plants				
	PRESENCE DETECTORS INSTALLATION	15	67,6	1015
	REPLACEMENT THE GAS BOILER TO BIOMASS BOILER			41950
	PV SOLAR PANELS INSTALLATION	9,4	2,6€/Wp	24335
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE			10200
	ENERGY CONSUMPTION CONTROL			8700
	TOTAL			**153255**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

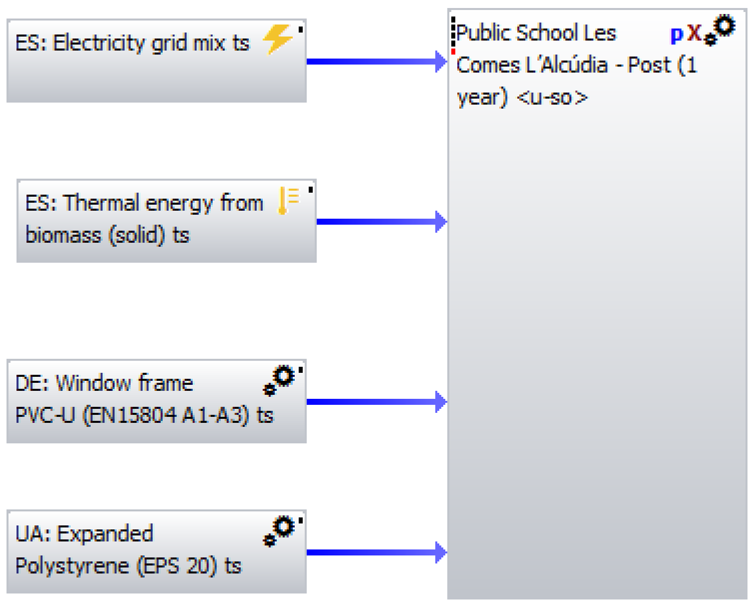
Public School Les Comes L'Alcúdia - Ante (1 year)

Process plan:Reference quantities



Public School Les Comes L'Alcúdia - Post (1 year)

Process plan:Reference quantities



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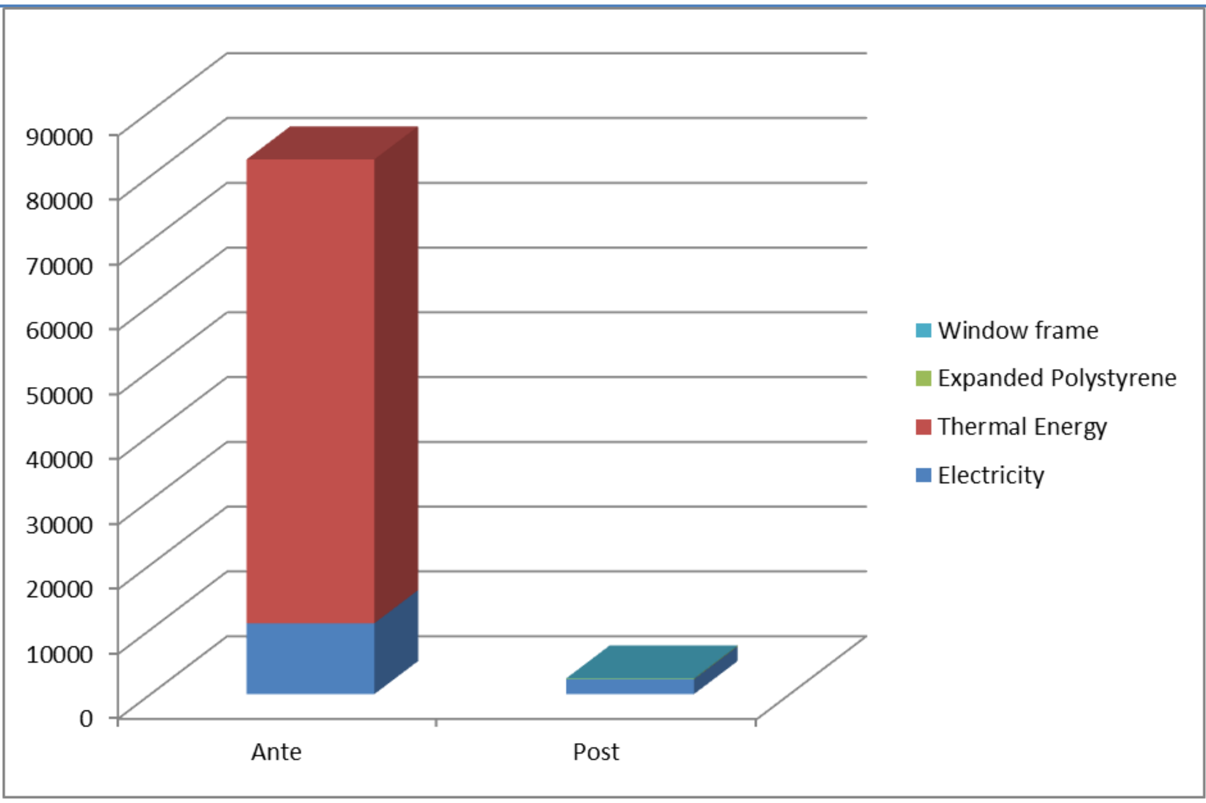


After the proposed renovation, the school overall emissions decreased of around 97% respect the initial conditions. The impact due to the materials used for the restoration contribute for a 6% of the Post intervention emissions.

Public School Luis Vives in Alzira

Description

The Public School Luis Vives is located in Alzira.
Alzira is a municipality in the comarca of Ribera Alta in the Valencian Community, Spain.
It covers an area of 111.46 square kilometres and, therefore, it is one of the largest in the Valencia Region. It lies 40 km from the capital. The municipality is divided into two sectors: The municipality is completely flat on the banks of the River Júcar. Towards the southeast lie the "Corbera", "Murta" and "Les Agulles" ranges, which encompass the "Murta", "Casella" and "Aguas Vivas" valleys. "La Garrofera" sector is broken by the eastern slopes of the "Sierra de Tous" range. The Town Hall (16th century), the medieval walls, the Church of Saint Catherine, the Municipal Museum, the Hermitage of Our Lady of Lluch, as well as numerous natural sites such as "La Casella", "La Murta" and "El Cavall de Bernat", as well as Murta Monastery.

Initial Energy Requirement

School Energy Consumption:
- Electrical Consumption: There is one Power Meter in the Main Electrical Box.
- Diesel: There is a Fuel tank to supply the boiler.
- Natural Gas: There is a Natural Gas Connection to supply the Preschool Building Natural Gas Boiler.
- Propane: Propane installation to supply the kitchen

The electricity consumption average is 8.000kWh/month, about 1200€/month.
In 2015 the annual electricity consumption was 98.461kWh, in 2016 was 88.873 kWh..

The Natural Gas consumption average is 2600kWh/month in 2015 about 200€/month, and 2000kWh/month in 2016 about 150€/month
In 2015 the annual gas consumption was 15.808kWh, in 2016 was 11.871 kWh.

Diesel Consumption (2015/2016) (100% Heating use):

Date	Consumption (litres)	Consumption[1] (kWh)	€/litro	Total Invoice (€) no Taxes	Total Invoice (€) with Taxes
20/01/2015	5000	51400	0,607024	3035,12	3672,4952
23/03/2015	3000	30840	0,607024	1821,072	2203,49712
20/01/2016	5000	51400			

100% Diesel Consumption is for Heating Use.

Propane Consumption: No data

Aim of the renovation plan

The aim of the renovation plan is propose technical solutions to reduce the energy consumption also the CO_2 Emissions to achieve a NZEB.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

	Energy Consumption Savings / Year	CO^2 EMISSIONS REDUCTION /Year
OUTDOORS FACADE INSULATION	54.255 kWh/year	13,7 ton CO^2/year
LOW EMISSIVITY GLASS WINDOWS INSTALATION	4.930 kWh/year	1,3 ton CO^2/year
REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	14.800 kWh/year	3,75 ton CO^2/year
LED LIGHTHING REPLACEMENT	8600 MWh/year	1,4 ton CO^2/year
PRESENCE DETECTORS INSTALLATION	4.250 kWh/year	0,71 ton CO^2/year
REPLACEMENT THE DIESEL BOILER TO NATURAL GAS BOILER	15.050 kWh/year	8,3 ton CO^2/year
PV SOLAR PANELS INSTALLATION	34.130 kWh/year	5,7 ton CO^2/year
ENERGY CONSUMPTION MANAGEMENT SOFTWARE	9.150 kWh/year	1,95 ton CO^2/year
ENERGY CONSUMPTION CONTROL	18.300 kWh/year	3,9 ton CO^2/year
TOTAL	163.615 kWh/year	40,71 CO^2/year

*** The saving has been calculated considering the energy saving achieved by implementing one single action and its effect on the baseline energy consumption. However, when implementing several actions, the baseline is altered due to the fact that every single measure provokes a reduction in the baseline energy consumption.*

Materials and components

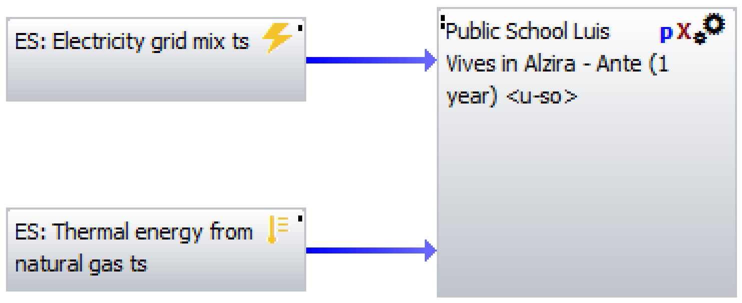
ACTION	VOICE	U.M.	Unit Cost €	Total Cost €
Envelope	*OUTDOORS FACADE INSULATION*	3400	52,5/m2	178500
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	452m2	5,8€/m2	2700
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	159	250	39750
Plants	*LED LIGHTHING REPLACEMENT*	4	60	2400
	PRESENCE DETECTORS INSTALLATION		70	2730
	REPLACEMENT THE DIESEL BOILER TO NATURAL GAS BOILER	1		23764
	PV SOLAR PANELS INSTALLATION	23,1kW	2,6€/Wp	60112
Others	*ENERGY CONSUMPTION MANAGEMENT SOFTWARE*			13950
	ENERGY CONSUMPTION CONTROL			11500
	TOTAL			**335406**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

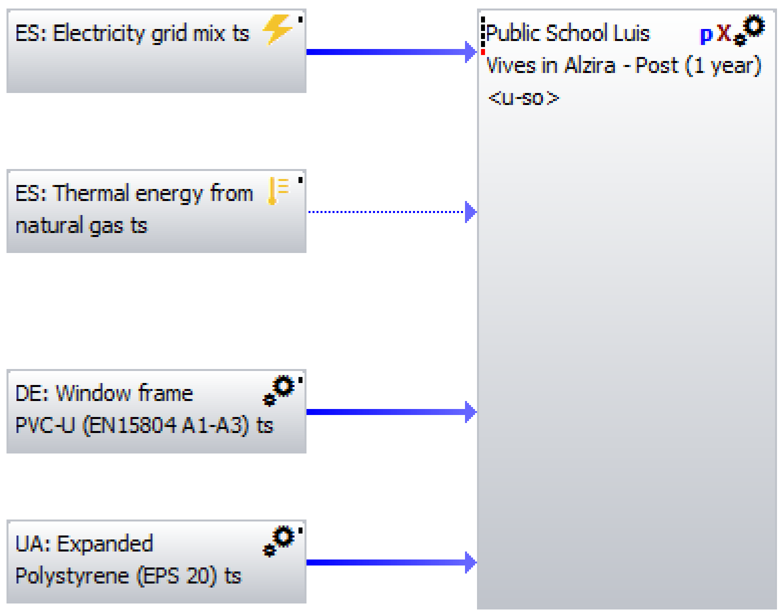
Public School Luis Vives in Alzira - Ante (1 year)

Process plan:Reference quantities



Public School Luis Vives in Alzira - Post (1 year)

Process plan:Reference quantities



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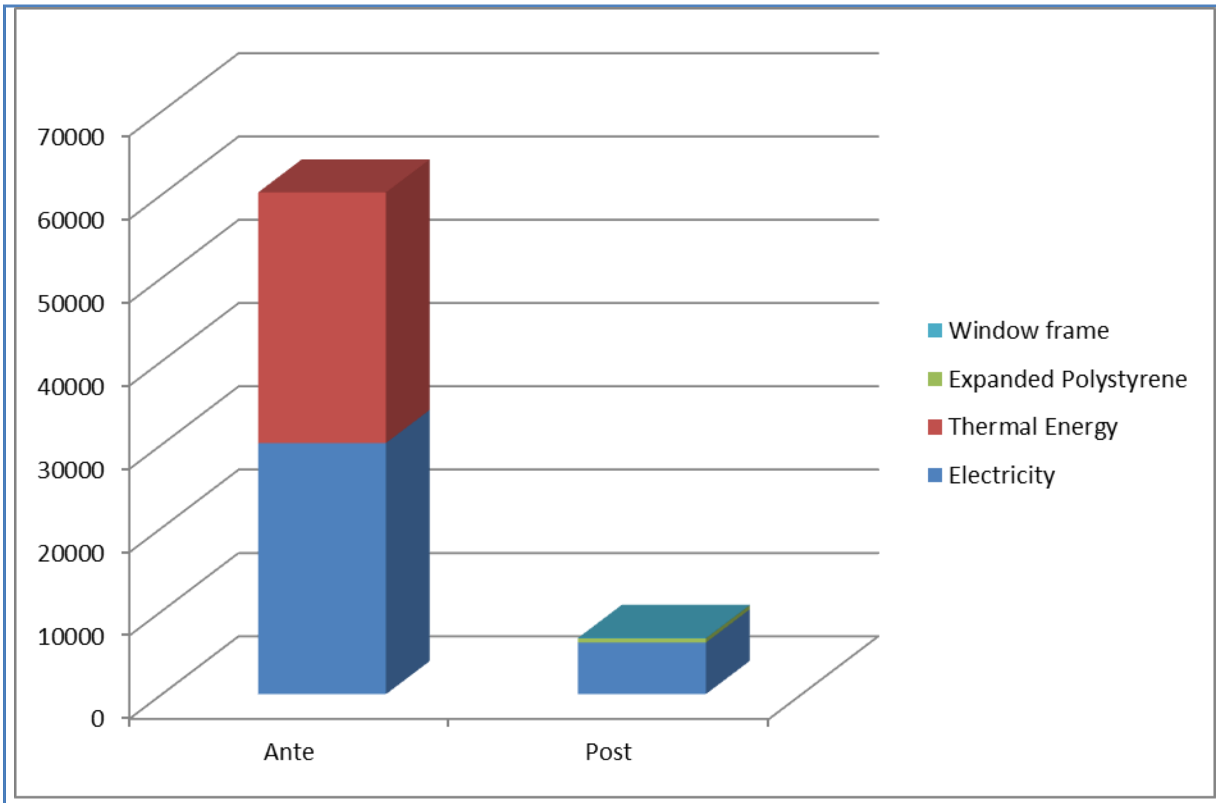


After the proposed renovation, the school overall emissions decreased of around 88% respect the initial conditions. The impact due to the materials used for the restoration contribute for a 8% of the Post intervention emissions.

Public School Sant Francesc de Borja in Llombai

Description

The Public School Sant Francesc de Borja is located in Llombai.
Llombai is a municipality in the *comarca* of Ribera Alta in the Valencian Community, Spain.
A municipality located on both sides of the River Magro, between the Caroig massif and the Sierra Falquera range. To the north, the municipality borders with Picassent, Real de Montroi and Montserrat de Alcalá, to the south with Alfarb and Catadau, to the east with Picassent and Alfarb, and to the west with Dos Aigües. It lies 28.8km from Valencia.

Initial Energy Requirement

School Energy Consumption:
- Electrical Consumption: There is one Power Meter in the Main Electrical Box.
- Diesel: There is a Fuel tank to supply the boilers.
- Propane: Propane installation to supply the kitchen

The electricity consumption average is 3.300kWh/month, about 740€/month.
In 2015 the annual electricity consumption was 40.826kWh, in 2016 was 39.072 kWh.

Diesel Consumption (2015/2016) (100% Heating use):

Date	Consumption (litres)	Consumption[1] (kWh)	€/litro	Total Invoice (€) no Taxes	Total Invoice (€) with Taxes
11/03/2015	2.000	20.560	0,657851	1315,702	1591,99942
16/10/2015	3.000	30.840	0,552893	1658,679	2007,00159
02/03/2016	2.000	20.560	0,471074	942,148	1139,99908
24/11/2016	4.000	41.120	0,533058	2132,232	2580,00072

Propane Consumption: No data

Aim of the renovation plan

The aim of the renovation plan is propose technical solutions to reduce the energy consumption also the CO_2 Emissions to achieve a NZEB.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

ACTION	VOICE	Energy Consumption Savings (kWh/Year)	CO^2 EMISSIONS REDUCTION (ton CO2/year)
Envelope	OUTDOORS FACADE INSULATION	26694	6,78
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	2670	0,678
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	8010	2,03
Plants	LED LIGHTHING REPLACEMENT	1560	0,26
	PRESENCE DETECTORS INSTALLATION	2105	0,35
	REPLACEMENT THE DIESEL BOILER TO BIOMASS BOILER	1100	12,57
	PV SOLAR PANELS INSTALLATION	15000	2,5
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE	4325	0,95
	ENERGY CONSUMPTION CONTROL	8650	1,9
	TOTAL	**70114**	**28,018**

*** The saving has been calculated considering the energy saving achieved by implementing one single action and its effect on the baseline energy consumption. However, when implementing several actions, the baseline is altered due to the fact that every single measure provokes a reduction in the baseline energy consumption.*

Materials and components

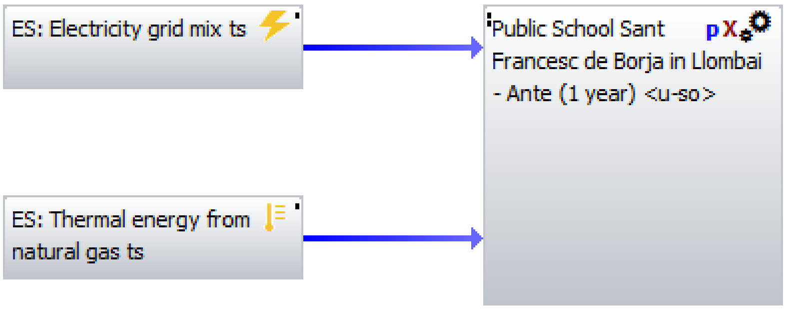
ACTION	VOICE	U.M.	Unit Cost €	Total Cost €
Envelope	OUTDOORS FACADE INSULATION	1120	52,5/m2	58800
	LOW EMISSIVITY GLASS WINDOWS INSTALATION		5,8€/m2	2625
	REPLACEMENT MAIN BUILDING EXISTING WINDOWS TO DOUBLE GLAZZED WINDOWS WITH ALUMINIUM FRAMES	183	250	45542
Plants	LED LIGHTHING REPLACEMENT		60	3125
	PRESENCE DETECTORS INSTALLATION		70	2730
	REPLACEMENT THE DIESEL BOILER TO BIOMASS BOILER	2		54000
	PV SOLAR PANELS INSTALLATION	10,2	2,6€/Wp	26415
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE			8120
	ENERGY CONSUMPTION CONTROL			7500
	TOTAL			**208857**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

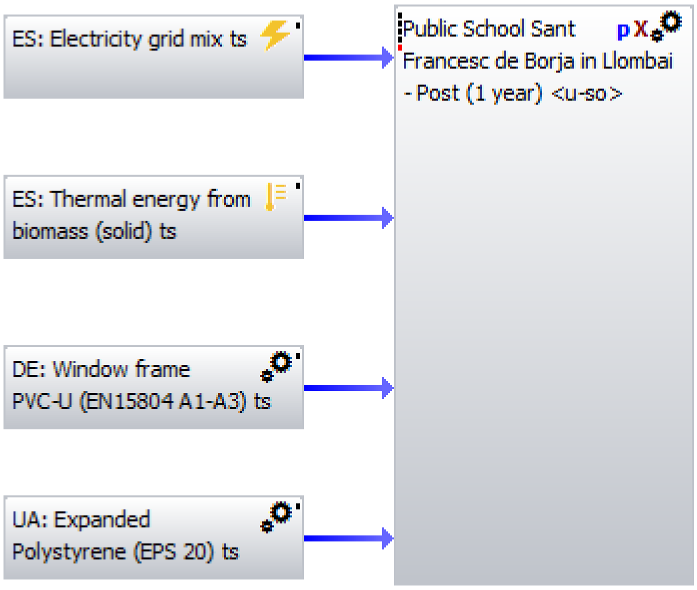
Public School Sant Francesc de Borja in Llombai - Ante (1 year)

Process plan:Reference quantities

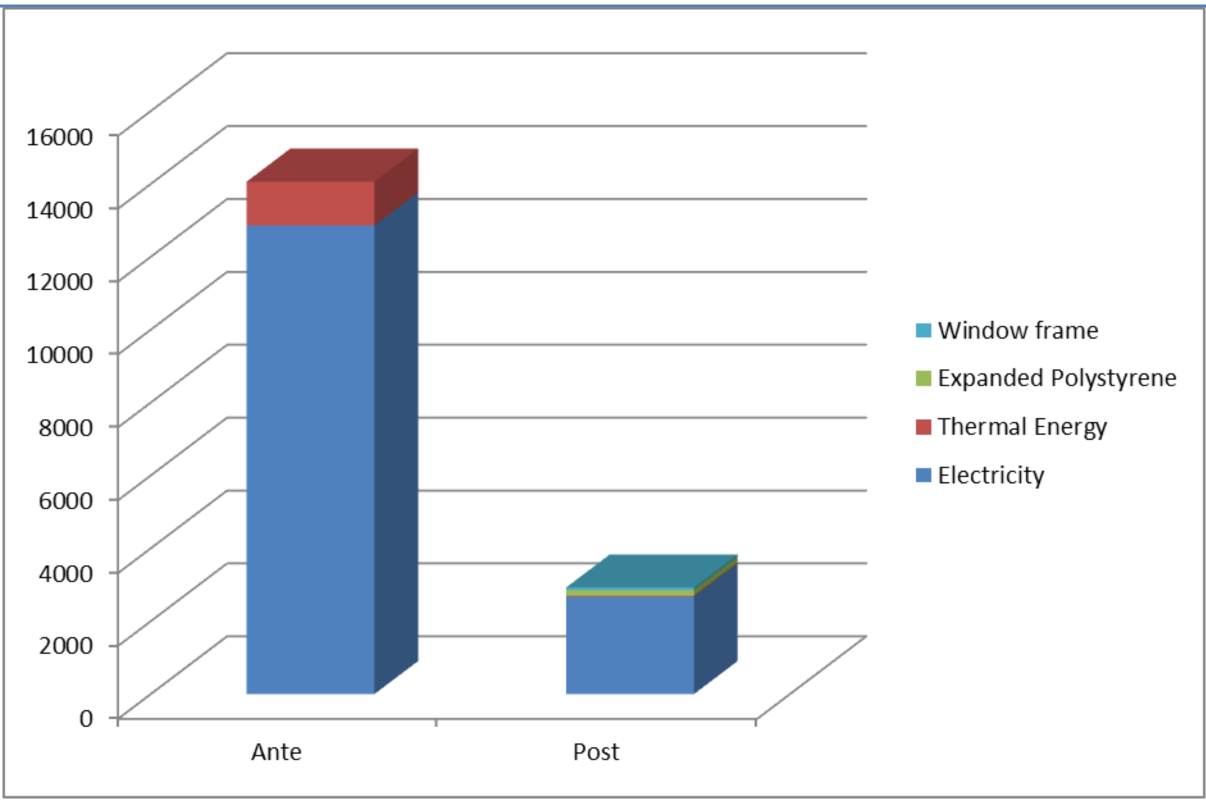


Public School Sant Francesc de Borja in Llombai - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 79% respect the initial conditions. The impact due to the materials used for the restoration contribute for a 8% of the Post intervention emissions.

Public School Sta. Maria d'Aigües in La Barraca d'Aigües Vives

Description

The Public School Sta. Maria d'Aigües Vives is located in La Barraca d'Aigües Vives.
La Barraca d'Aigües Vives is a minor local authority, belonging to Alzira, in the *comarca of Ribera Alta* in the Valencian Community, Spain.
It is located in the "Vall d'Aigües Vives" , at the foot of the "Serra de les Agulles". It was declared a minor local authority in 2003 and currently has about 875 residents.

Initial Energy Requirement

School Energy Consumption:
- Electrical Consumption: There are 2 Main Electrical Boxes with 2 power meters:
o SUPPLY 1: Calle Milagros Vélez, 4
o SUPPLY 2: Calle Convent D´Aigües Vives, 2 bajo

SUPPLY 1: The electricity consumption average is 1.900kWh/month, about 550€/month.
In 2015 the annual electricity consumption was about 34.000kWh.
SUPPLY 2: The electricity consumption average is 750kWh/month, about 200€/month.
In 2016 the annual electricity consumption was about 34.000kWh.

The Natural Gas consumption average is 7.800kWh/month, about 550€/month.
In 2015 the annual Natural Gas consumption was about 38.799kWh, in 2016 39.473kWh and in 2017

20.547kWh.

Aim of the renovation plan

The aim of the renovation plan is propose technical solutions to reduce the energy consumption also the CO_2 Emissions to achieve a NZEB.

The full description of the renovation plan is presented in the Energy Audit document.

Final Energy Requirement

ACTION	VOICE	Energy Consumption Savings (kWh/Year)	CO^2 EMISSIONS REDUCTION (ton CO2/year)
Envelope	OUTDOORS FACADE INSULATION	1400	0,234
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	255	0,043
Plants	LED LIGHTHING REPLACEMENT	2940	0,49
	PRESENCE DETECTORS INSTALLATION	635	0,1
	PV SOLAR PANELS INSTALLATION	5310	0,9
Others	ENERGY CONSUMPTION MANAGEMENT SOFTWARE	765	0,128
	ENERGY CONSUMPTION CONTROL	1535	0,256
	TOTAL	**12840**	**2,151**

*** The saving has been calculated considering the energy saving achieved by implementing one single action and its effect on the baseline energy consumption. However, when implementing several actions, the baseline is altered due to the fact that every single measure provokes a reduction in the baseline energy consumption.*

Materials and components

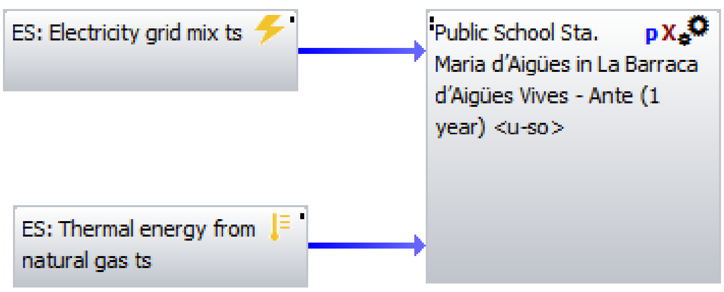
ACTION	VOICE	U.M.	Unit Cost €	Total Cost €
Envelope	**OUTDOORS FACADE INSULATION**	555	52,5/m2	29140
	LOW EMISSIVITY GLASS WINDOWS INSTALATION	61	5,8€/m2	355
Plants	**LED LIGHTHING REPLACEMENT**			3410
	PRESENCE DETECTORS INSTALLATION	10	68,5	685
	PV SOLAR PANELS INSTALLATION	3,7	2,6€/Wp	9600
Others	**ENERGY CONSUMPTION MANAGEMENT SOFTWARE**			3500
	ENERGY CONSUMPTION CONTROL			3600
	TOTAL			**50290**

Quantities of materials employed are gathered from the economic renovation evaluation

Model on GaBi software

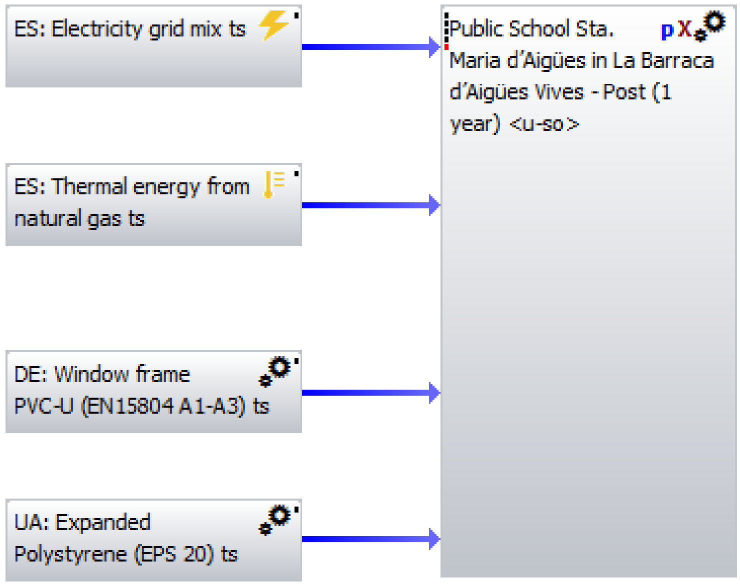
Public School Sta. Maria d'Aigües in La Barraca d'Aigües Vives - Ante (1 year)

Process plan:Reference quantities

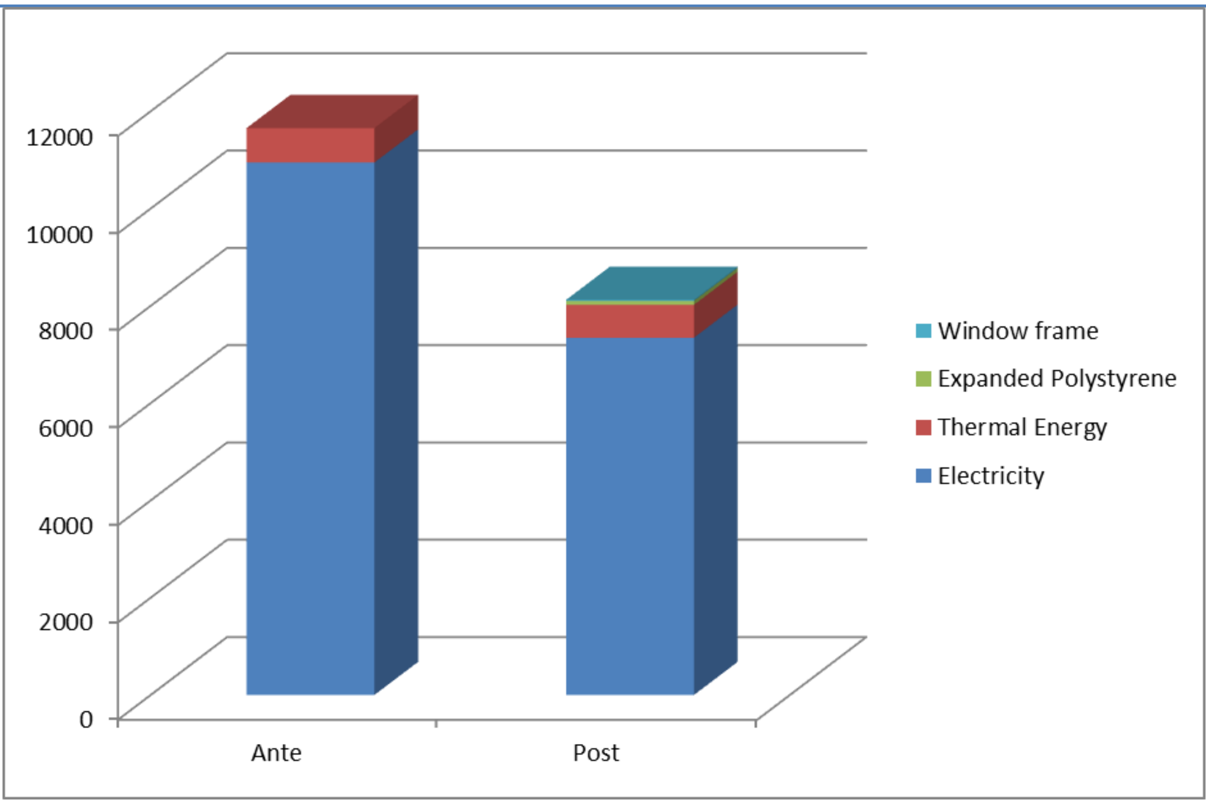


Public School Sta. Maria d'Aigües in La Barraca d'Aigües Vives - Post (1 year)

Process plan:Reference quantities



Results



After the proposed renovation, the school overall emissions decreased of around 30% respect the initial conditions. The impact due to the materials used for the restoration contribute for around 1% of the Post

intervention emissions.

Conclusions

The aim of this work was to evaluate the Carbon Footprint of schools considering the contribution both of energy and materials employed for the retrofitting of the buildings according to the results of the energy audits developed by partners.

The analysis of the energy audits reports produced by the project partners showed that, despite a reference template was used to develop the reports of the improvement actions, the way of gathering information and its completeness, the choice of the techniques adopted for the improvement and the tools for its evaluation widely depend from the regional practices and from the awareness of the involved technicians and designers. Moreover the same concept of nZEB building is different from one country to another. Results obtained from different schools are therefore not easily comparable. Moreover, information used to calculate the Carbon Footprint were not standardised, they are estimations and the choices depend on the personal expertise of the expert who made the energy audit.

The improving percentages deeply vary among the analysed schools even if we consider the same nations; in fact results obtained show improving in energy and emission saving from around 20 up to more than 90 percent from the initial conditions. In some cases the new design showed low advantages comparing to the initial one, this was due to the nZEB guidelines that recommend adopting high efficiency systems that are often electrical and can bring to these results in nations where the electricity mix entail high emissions. The solution, also suggested by the guidelines, is to cover the electricity needs by energy from renewable sources, including energy produced on-site or nearby. In some analysed schools a photovoltaic solar system was already present so that the advantage was already calculated into the initial results.

Impact due to the production of materials used into the renovation phase have been considered estimating a lifetime of 20 years, the share of impacts depend on different factors, for example it is important to notice that materials can have an important contribution when the retrofitting is significant and when the emission due the energy used are very low.

Results obtained deeply depend on the staring condition of analysed schools, improvements are significant when buildings are old or where the construction techniques adopted were not intended for energy saving, while when schools were more recent, where in the design and construction phases energy savings in buildings were adopted, where a solar system was already present, results obtained were lower but still significant. Finally, it have been noticed who dimensions and layout of buildings can affect the potential improvements that can be achieved.

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