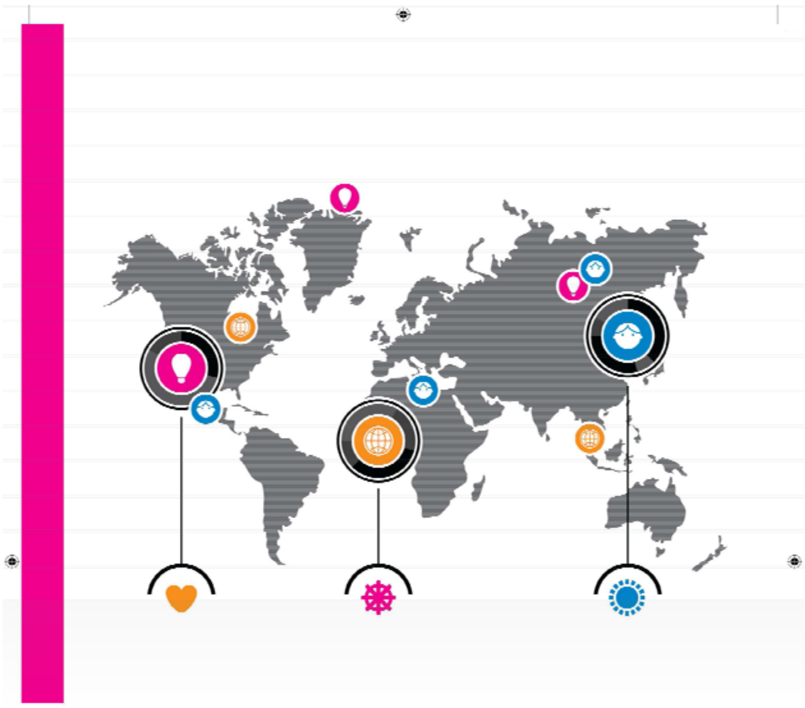

WP4 Sustainable Energy Action plans

D4.5_GIOVANNI XXIII ELEMENTARY SCHOOL ENERGY DIAGNOSIS, POLVERARA (PD)

Date: June 30 - 2014

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Contents

1 . ENERGY CERTIFICATION OR DIAGNOSIS?

Many variables come into play when evaluating a building's energy needs that must be jointly assessed to determine the specific incidents in energy consumption. We refer, for example, to the building's construction features, the thermodynamic behaviour of the materials used, the type of systems adopted, the efficiency of the installed electromechanical elements, any use of renewable energy sources as well as the amount of time the building is used (thus the time period in which a temperature of 20°C is considered maintained in the building during the winter and a temperature of 26°C in the summer, through the use of heat or cooling generators).

For each considered variable, the regulations that guide and regulate the calculation methods allow us to define various reference parameters, that in each case lead to the final quantification of needs for real building "use time".

The legislator, in accordance with UNI TS 11300-1, sets forth that **energy certification** must be drafted performing a Standard Evaluation, thus considering the real building and system features, but sets standard values for specific climate and building use parameters. Specifically:

- the average monthly outdoor temperature profile is used
- the building is considered heated 24 hours a day, for a heating period that has a traditional duration and that depends on the climate zone in which the building is located. In particular, or climate zone E, the traditional heating season lasts from October 15 to April 15.

From the design standpoint, since we intend to accurately assess the benefits of energy savings or efficiency improvement works, it is necessary to most possibly implement the most realistic calculation model, also supported by comparisons with actual consumption in previous years. Considerations will then be made starting from this model. This means that to conduct an **energy diagnosis**, and, in fact, the cited regulation requires an Evaluation Adapted to Use, considering, in addition to the real building and system features, the times of use and actually foreseen internal and external temperatures.

This document, after a brief description of the building's current conditions, provides reference data in the first part for building energy classifications through energy certifications and, in the second part, it assesses the efficiency of some actually feasible energy efficiency improvement and savings works.

2. THE ACTUAL CONDITIONS

2.1 The building

This project refers to the Giovanni XXIII elementary school in the town of Polverara (PD).

It is a two-storey building, whose ground surface is 1,041 square metres made up of:

- a large floor-to-ceiling central atrium on which, on both floors, the teaching and service spaces overlook (see portion highlighted in light blue in figure 2);
- the adjacent gym (see portion highlighted in pink in figure 2).

Figure 1. Aerial view of the Polverara elementary school

The building was built in 1960.

The bearing structure is made up of reinforced cement pillars in the central atrium and brick blocks for the backbone walls. The floors are made of concrete and masonry, the ground floor is elevated by 30 cm to create ventilation space.

There are various types of door and window frames:

- the ones in the classrooms have wooden frames without insulation and single glass panes;
- frames in bathrooms, service areas and the gym have metallic frames without insulation and single glass panes;
- the large window frames in the central atrium are characterised by metallic frame and double glazes windows with 16 mm thick gap.

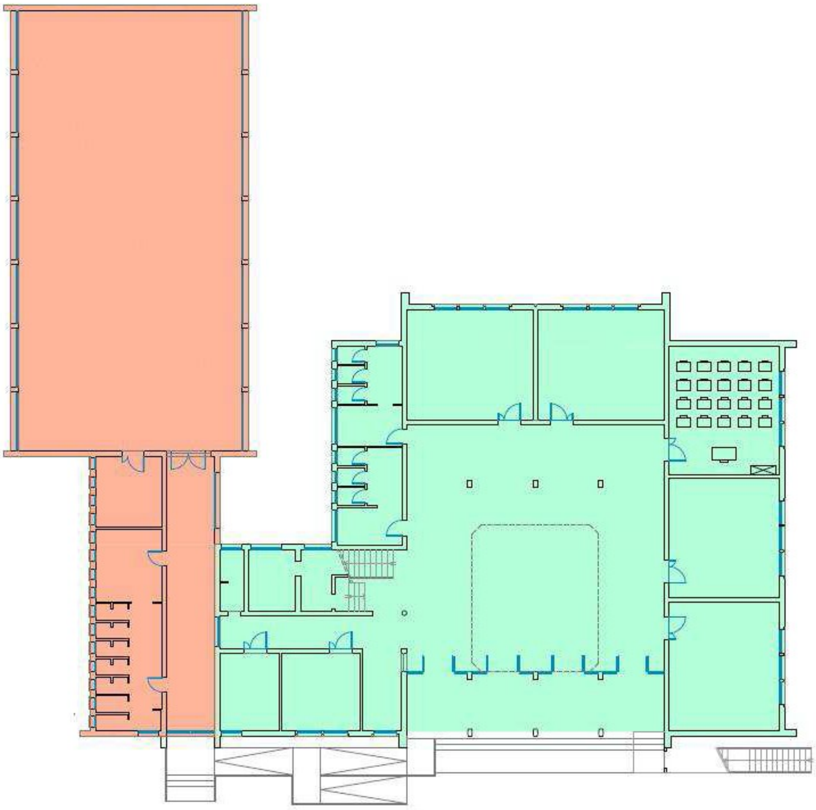

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Figure 2: School building floor plan: teaching spaces and gym

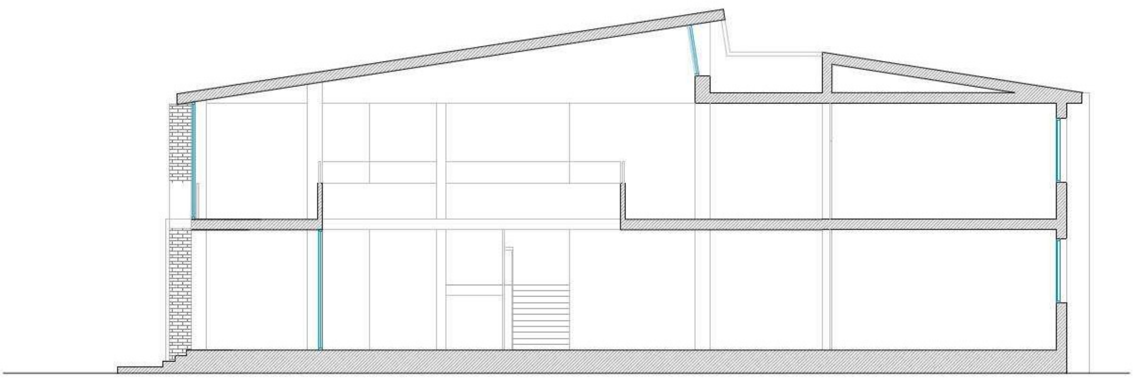


Figure 3: Section on the floor-to-ceiling central atrium

Following are some data helpful to the analysis.

ELEMENTARY SCHOOL	
FLOOR SURFACE [m^2]	1,447.649
HEATED GROSS VOLUME (V) [m^3]	7,799.846
DISPERSIVE SURFACE (S) [m^2]	3,613.310
S/V ratio	0.463
No. OF FLOORS	2

Table 1: General school building features

Figure 4. South-West side view

Figure 5. First floor landing – central atrium

2.2 Heating system

The school building is one of the 5 public utilities in the Town of Polverara connected to the district heating plant.

The district heating plant has a single biomass heating plant from which the heat energy necessary for the various connected buildings is generated.

The district heating plant sub-station that services the school includes the heat exchanger, through which energy is transferred from the district heating plant to the town circuit, equipped with the relevant safety, protection and control devices; it also includes circulation pumps and energy meters.

A building located in the school garden houses the heating plant with methane powered boiler servicing the district heating plant, that is used when the main biomass boiler is not running to guarantee service continuity.

Figure 6. Details of the methane plant servicing the district heating plant

2.3 Energy Certification in current conditions

Calculations were made for energy certification of the building in its current conditions according to the standards set by regulations in force: the following table indicates the results obtained according to that set forth by Decree June 26, 2009 “National guidelines for building energy certification”.

Address	**Via Roma, 17, 35020 Polverara (PD)**		
Cadastral references	**Map 209, sheet 5**		
Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**

Energy performance index for heating (Ep, i)	**35.4 kWh/m^3**
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**
Global energy performance index (Ep,gl)	**35.4 kWh/m^3**
Season average global yield (ηgn)	**103.3 %**

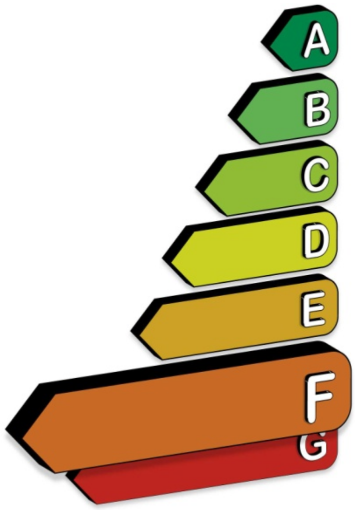


Table 2: Building energy classification calculation results

3. CONSUMPTION ANALYSIS AND ALIGNMENT

3.1 Annual heat energy consumption

The building was connected to the district heating plant in 2012.
According to that indicated in the bills, it can be estimated that the **heat energy demand for heating is about 40,000 kWh.**

FUEL DEMAND ESTIMATE				
Bill period				
From	to	Demand		Billed
03/09/2012	12/11/2012	0	€	11.97
12/11/2012	04/02/2013	58,320	€	5,619.36
04/02/2013	01/04/2013	45,620	€	4,421.19
01/04/2013	03/06/2013	7,710	€	716.01
03/06/2013	02/09/2013	0	€	17.95
		111,650	**€**	**10,786.48**

Table 3: Annual heat energy demand

Analysing the bills, the annual expense was about **0.097 €/kWh,** <u>including energy cost, grid services, excise taxes and VAT</u>.

This allows us to determine the specific parameters with which, from here on, estimates will be made on savings.

3.2 Calculation model and consumption alignment

In evaluating actual pre-work demand, compared to the values calculated by energy certification, we considered the consumption indicated in Table 4, taken from the building's use profile.

Certification results were thus modified according to the following criteria:

- 20° C is considered as the internal temperature
- the real plant operating time is considered, estimated in 9 hours/day, from October 15 to April 15
- calculations are made on a monthly basis, considering the average outdoor temperatures
- the global heat exchange coefficients remain that same as those determined in the energy certification calculation, starting from which
- the required building demand is determined (indicated as the working demand in the guide regulation) due to building dispersion due to ventilation and transmission, taking into account the solar and heat contributions generated inside the building by people and electrical devices.
- emission, regulation and secondary distribution subsystem heat yield are considered constant
- district heating plant exchanger losses remain constant since they only depend on the nominal exchanger power, according to UNI TS 11300/4

Following these criteria, a calculation model was constructed to identify demand:

- required by the building to maintain the set 20° C internal temperature
- necessary to meet plant losses

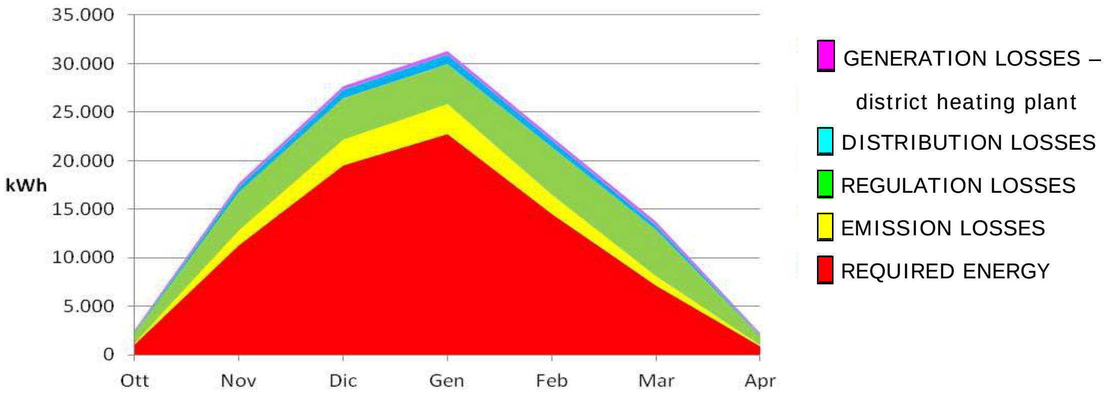
The following table provides the results obtained with the described calculations.

Required demand	***kWh/year***	**77,082**	
Emission losses	*kWh/year*	10,511	(ηe= 88.0%)
Regulation losses	*kWh/year*	24,188	(ηd,s= 78.0 %)
Distribution losses	*kWh/year*	3,576	(ηd,p-s= 96.9 %)
Generation losses	*kWh/year*	2,189	(ηe= 96.5 %)
Average seasonal yield		65.6 %	
Annual heat energy demand	**Sm3**	**117,546**	
Annual expense	€	11,356	

Table 4: Actual energy demand in current conditions

The graph indicates the monthly energy demand trend according to which the overall values indicated above were taken.

Please note that the adopted calculation model is aligned with gas consumption actually sustained by the condominium. In fact, 117,756 kWh demand was estimated faced with 111,650 kWh actual consumption sustained in the 2012-2013 season.



Graph 1: Energy simulation model in current conditions

4. PROPOSED INTERVENTIONS – ENERGY ANALYSIS

To reduce consumption, with consequent economic and energy savings, we propose a series of alterations to the building casing and system.

Interventions that concern the building casing are:

- Wall insulation with external lining;
- Roof insulation;
- Door and window frame replacement.

These interventions were proposed based on a building criticality analysis from the heat dispersion standpoint. The listed interventions, where possible, should meet the minimum heat transmittance requirements set by decree D.M. 28 December 2012 to gain access to the incentives set by the Energy Bill.

Regarding the heating plant, a feasibility study is underway to optimise biomass boiler and grid operations in general: for this reason, aspects that concern the part relevant to the district heating plant grid will not be discussed.

Analysing Graph 1 reveals that the plant losses are all negligible compared to the required demand, except for regulation losses.

For this reason, the proposed intervention concerning the heat plant is:

- Installation of thermostatic valves.

4.1 Wall insulation with external lining

4.1.1 Intervention description

The school building is subject to thermal bridges, zones that represent a higher thermal flow density than the adjacent construction elements. In particular, these critical dispersion points are near connections between wall and wall, between walls and floors and between walls and window/door frames due to geometric diversity (difference between the dispersive surface area on the internal and external sides), and due to material diversity at material interweaving with different thermal conductivity in the building casing (curbs, shutter boxes, architraves).

To attenuate this phenomena, we propose the external building walls be insulated with a "lining" system. With this construction system, the problems concerning thermal bridges and deformations due to heat stress such as cracks, detachments, infiltrations, are cancelled out or, at least, highly attenuated: all wall equipment is placed in stationary thermal and hygrometric conditions despite the great temperature and/or humidity differences between the outdoors and indoors.

These walls, no longer dissipating heat outwards, provide a significant thermal flywheel function. This corresponds to having a hot mass, that crosses its internal surfaces, exchanging heat with the rooms, in the heating intervals and interruptions. Even in the dead of winter, the healthy air exchange can occur without having to intensify heating: the heat accumulated by the wall mass quickly and evenly regenerates the most comfortable conditions. The casings and structures under the "lining", no longer receiving intense thermo-mechanical strain, are kept unaltered.

Figure 7 illustrates how the facades are characterised by thermal bridges. These images were taken with a thermal imaging camera, a special camera that detects infrared radiations and to create maps of the exposed surface temperatures. The image taken with the heat imaging camera is built on a pixel matrix. The instrument electronics "read" the energy value stored by each single pixel and generates an image of the observed object in false colours: the absolute temperature value of each point of the image can be measured. The obtained temperature map is not reliable for an accurate temperature measurement in the various points of the lining since it was taken in the summer, with high outdoor temperature, so much so that the walls were fully heated. Despite the fact that the high temperatures recorded are not significant, the image still reveals that there are areas with different temperatures at thermal bridges.

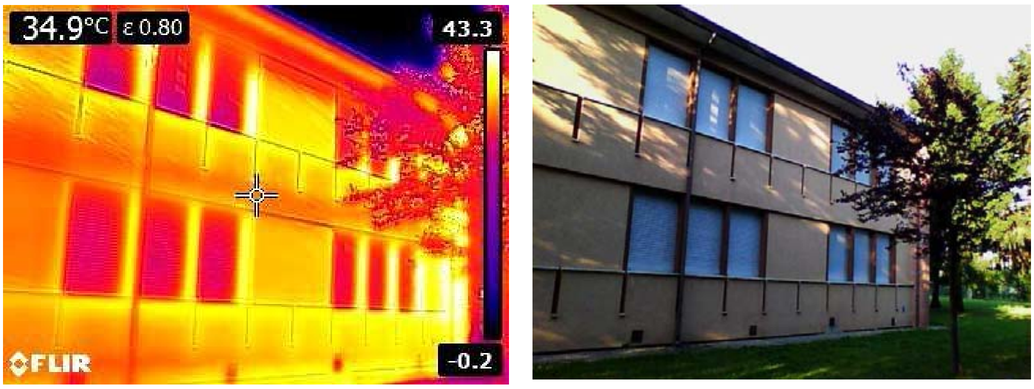


Figure 7. Images taken with the infrared heat imaging camera: South-West side view

A cost of 100 €/m^2 (VAT include) is calculated for lining installation, corresponding to the maximum incentive value.

The estimated cost takes into account all the intervention phases, not only the purchase of the insulation material; for example, the expense also depends on the scaffolding that must be installed to easily work on all sides of the buildings and over the full height.

Another item considered in lining system installation is the cost of preparing the anchoring base. Plaster wear must be monitored. If in poor conditions, it must be brushed and the wall surface cleaned with a pressure washer and hot water until the existent paint is fully removed; if the paint is in good conditions, the surface can be treated with a sealant and adherence test run.

After preparing the base structure, insulation panels are then glued on with specific adhesive mortar.

In addition to gluing, the panels must be mechanically secured with specific dowels made up of a disk and leg. The disk presses the insulation against the support without damaging it by punching while the leg is the element that must guarantee hold to the support. After installing the panels and before completing the levelling layer, metallic reinforcement elements must be applied on corners using adhesive mortar, pressing against the corner and having the excess adhesive flow out of the holes in the profile.

Before the finish, the intervention includes the creation of a levelling layer: the reinforcement mesh is sunk into the levelling mortar about 2 mm deep.

After apply the primer, work can be finished with the plaster lining.

We assume the walls will be insulated with 10 cm thick polyurethane foam panels, according to the transmittance values accepted by the regulation to access the incentives set by the Energy Bill (≤0.23 W/m2K external wall with lining transmittance).

4.1.2 Cost-benefit evaluation

The analysis includes the calculation of heat dispersion (analysis of heat exchange coefficients by transmission) through the various building casing parts: 26% through external slabs, 25% concerning external walls, 30% windows and 19% the ground floor.

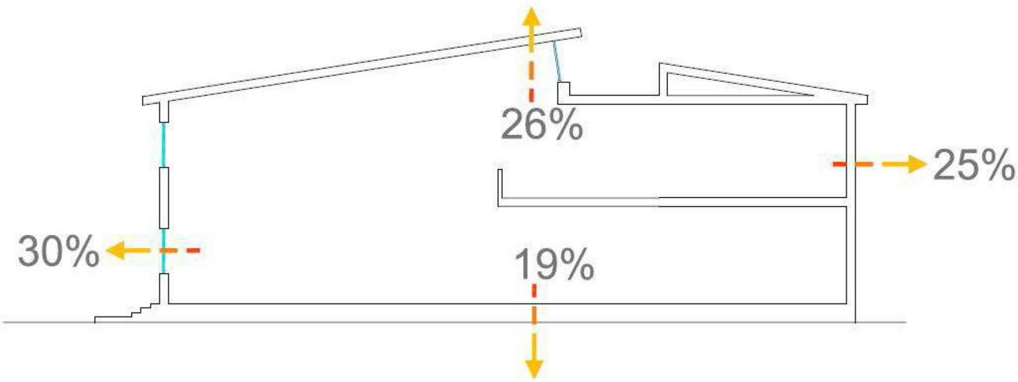


Figure 8. Heat dispersions through the various building casing components

Simulating the installation of insulation slabs on the building exterior reduces post-intervention heat dispersion through the walls by 75%.

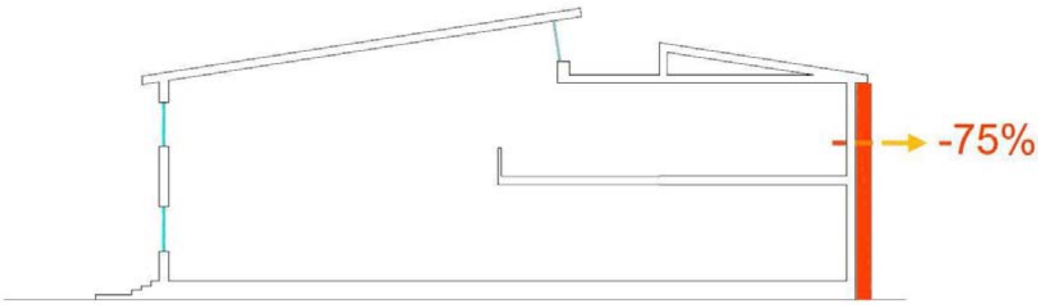


Figure 9. Heat dispersion reduction through the walls after external lining installation

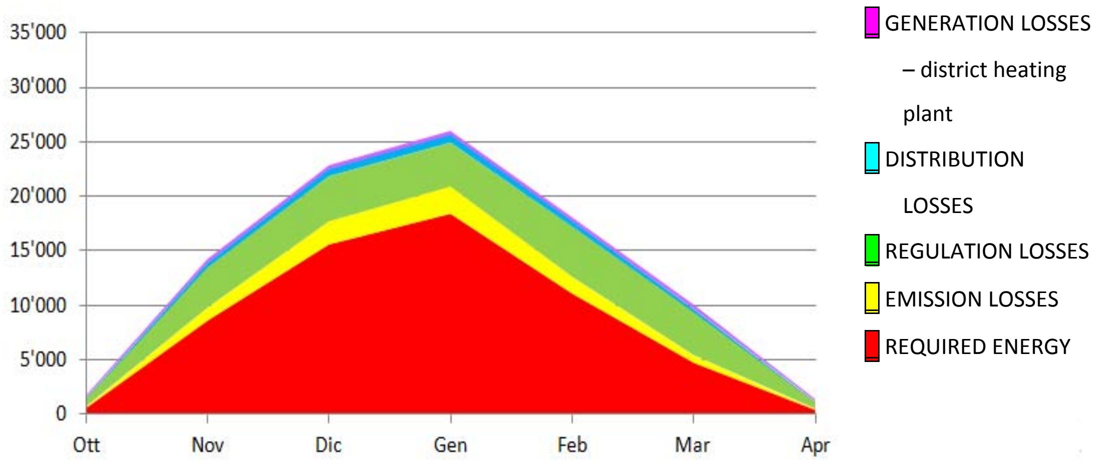
The data resulting from the intervention energy-economic analysis are thoroughly illustrated in table no. 1 enclosed to paragraph 6.

The provided summary reveals that the **intervention is not sustainable from the cost-benefit standpoint**. This occurs since the intervention is extremely costly compared to the resulting “appreciable" energy benefit. **The interventions on the building casing in this context are, in fact, only significant if supported by an alteration to the plant regulation** system (for example, with the introduction of thermostatic valves). Currently, in fact, reducing heat dispersion through the casing without providing the chance to regulate the energy contribution by each radiator will not lead to any reduction in consumption since the heat emission from the heating elements would remain unaltered.

WALL INSULATION WITH EXTERNAL LINING		
Energy savings	23,038	kWh
Cost saving	2,226	€/year
Intervention cost	130,000	€
Energy bill incentive	52,000	€
Pay back	35	years

Table 5: Energy analysis calculation results after external lining installation

From the comparison between the monthly post-intervention (Graph 2) and pre-intervention (Graph 1) energy demands, the reduction is graphically illustrated.



Graph 2: Monthly energy demand trend (kWh) post external lining installation

4.1.3 Post intervention energy certification

Following is the data on building energy classification after the assumed insulation intervention with external lining.

Address	**Via Roma, 17, 35020 Polverara (PD)**
Cadastral references	**Map 209, sheet 5**

Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**

Energy performance index for heating (Ep, i)	**29.7 kWh/m^3**
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**
Global energy performance index (Ep,gl)	**29.7 kWh/m^3**
Season average global yield (ηgn)	**101,5 %**

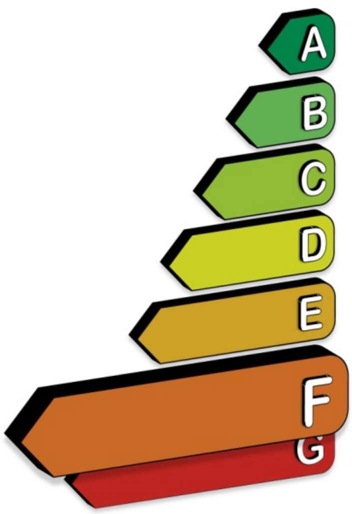


Table 6: Building energy classification calculation results post external lining intervention

4.2 Roof insulation

4.2.1 Intervention description

The building energy analysis indicates a significant percent of dispersions, about 25%, through the roof.

The following interventions are considered for insulation installation:

- Soft insulation on the garret extrados with a cost of approximately 36 €/m^2 (VAT included);
- Internal insulation with polystyrene panels in the floor-to ceiling central atrium roof intrados for a cost of approximately 100 €/m^2 (VAT included); alternatively, an intervention is hypothesised on this portion of the roof with external insulation and renovation of the roof sheath, for a cost of approximately 200 €/m^2 .

The intervention requires ≤0.20 W/m^2K roof transmittance values to access the incentives set by the Energy Bill.

4.2.2 Cost-benefit evaluation

Analysing an intervention of this type reduces heat dispersion through the roof by 82%.

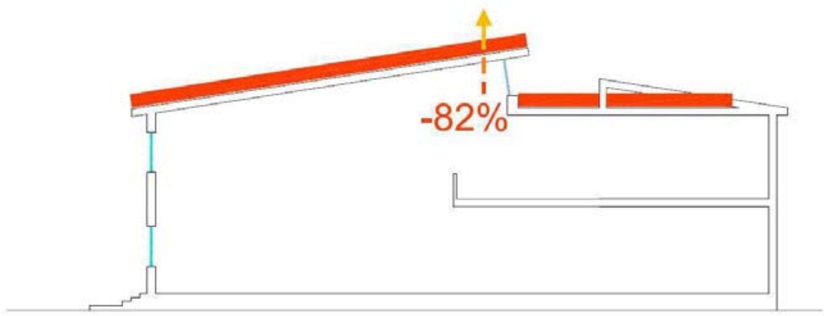


Figure 10. Heat dispersion reduction through the roof post insulation

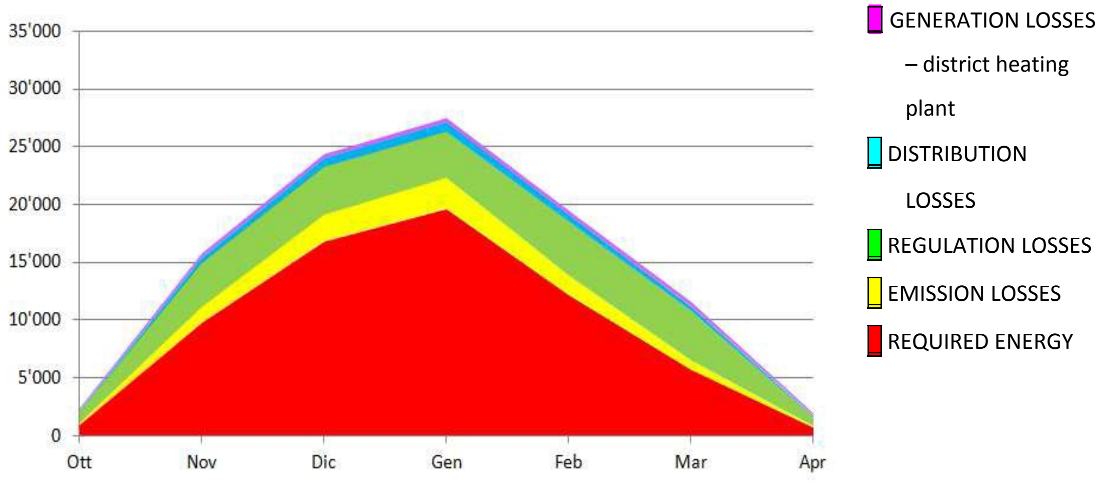
The data resulting from the intervention energy-economic analysis are thoroughly illustrated in tables no. 2 and 3 enclosed to paragraph 6: an abstract is provided below.

It reveals that the roof intervention **is not sustainable from the cost-benefit standpoint. This occurs since the intervention is extremely costly compared to the resulting "appreciable" energy benefit.** As in the previous case, **intervening on the lining without modify the regulation system does not lead to substantial energy savings.**

ROOF INSULATION Solution with external insulation in the central atrium		
Energy savings	14,609	kWh
Cost saving	1,411	€/year
Intervention cost	68,000	€
Energy bill incentive	27,000	€
Pay back	29	years
ROOF INSULATION Solution with internal insulation in the central atrium		
Energy savings	14,609	kWh
Cost saving	1,411	€/year
Intervention cost	52,250	€
Energy bill incentive	20,900	€
Pay back	22	years

Table 7: Energy analysis calculation results after roof installation

From the comparison between the monthly post-intervention (Graph 3) and pre-intervention (Graph 1) energy demand, the reduction is graphically illustrated.



Graph 3: Monthly energy demand trend (kWh) post roof insulation

4.2.3 Post intervention energy certification

Following is the data on building energy classification after the assumed roof insulation intervention.

Address	**Via Roma, 17, 35020 Polverara (PD)**		
Cadastral references	**Map 209, sheet 5**		
Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**
Energy performance index for heating (Ep, i)	**29.6 kWh/m^3**		
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**		
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**		
Global energy performance index (Ep,gl)	**29.6 kWh/m^3**		
Season average global yield (ηgn)	**100,9 %**		

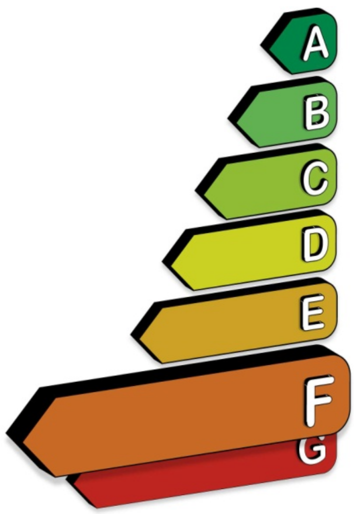


Table 8: Building energy classification calculation results post roof insulation

4.3 Thermostatic valve installation

4.3.1 Intervention description

The inspections held revealed that currently there is no heat regulation system. For this reason we propose the installation of thermostatic valves.

These are regulation systems that vary the supply flow to the heating element according to the power required by the environment, thus taking advantage of any free heat contributions.

The most common systems are fully mechanical: a valve driven by a head that contains fluid which dilates or shrinks as the temperature changes, opening or closing the valve.

Correct head operations must be checked after any collisions or tampering with these applications. Furthermore, checks must be made to ensure they are installed to correctly perceive the room temperature and not microclimates if the radiator is located, for example, behind a curtain, door or any other object that impedes normal heat emission in the entire room. Alternatively, we recommend installing a head with a remote climate probe so that this can read the actual room temperature.

There are also electronically control climate regulation systems: valves that are activated by an electrical actuator that is powered by a thermostat timer able to dialogue with several valves are installed on radiators. The thermostat timer reads the room temperature and sets the degree the valve opens.

The potential of this system is in the fact that, since electronically controlled, temperature values and operating times can be set for different heating zones according to use. This solution can be extremely interesting in the event of rooms used at different times of the day and on different days of the week (for example, laboratory classrooms): in this case, the temperature can be adjusted according to the number of people other free contributions (sun, electrical equipment, etc.) in addition to the “start” times for the various radiators.

4.3.2 Cost-benefit evaluation

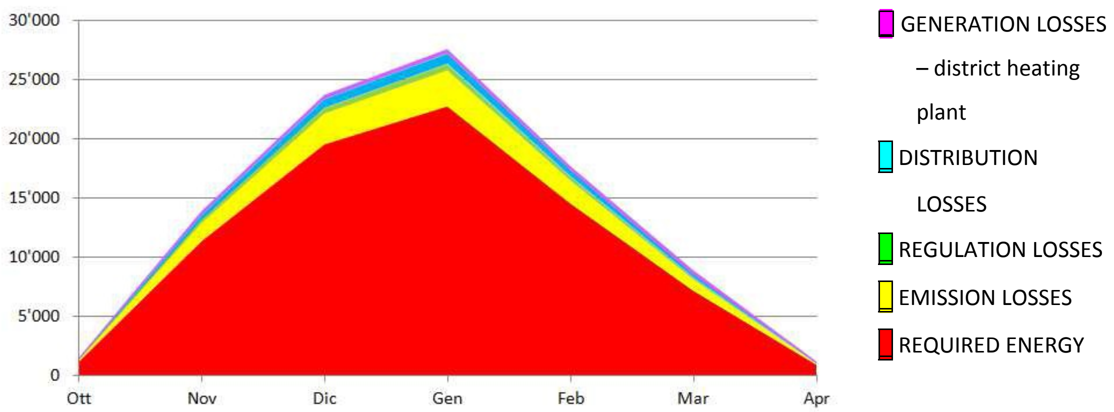
The data resulting from the intervention energy-economic analysis are thoroughly illustrated in table no. 4 enclosed to paragraph 6: an abstract is provided below.

This intervention is **recommendable from both the energy and economic savings standpoints**.

THERMOSTATIC VALVES		
Energy savings	23,117	kWh
Cost saving	2,233	€/year
Intervention cost	10,000	€
Pay back	5	years

Table 9: Energy analysis calculation results after thermostatic valve installation

From the comparison between the monthly post-intervention (Graph 4) and pre-intervention (Graph 1) energy demand indicates a substantial reduction in regulation loss.



Graph 4: Monthly energy demand trend (kWh) post thermostatic valve installation

4.3.3 Post intervention energy certification

Following is the data on building energy classification after the assumed thermostatic valve installation intervention.

Address	**Via Roma, 17, 35020 Polverara (PD)**		
Cadastral references	**Map 209, sheet 5**		
Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**
Energy performance index for heating (Ep, i)	**31.8 kWh/m^3**		
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**		
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**		
Global energy performance index (Ep,gl)	**31.8 kWh/m^3**		
Season average global yield (ηgn)	**114.8 %**		

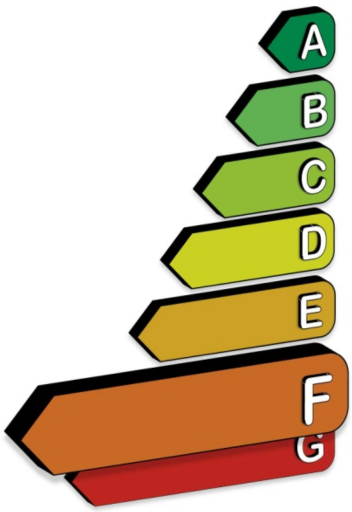


Table 10: Building energy classification calculation results post thermostatic valve insulation

4.4 Door and window frame interventions

4.4.1 Intervention description

Building door and window frames are a significant part of the heat dispersions through the casing, equal to 30%.

Figure 11: Photo of a typical school building window frame

To access Energy Bill incentives, we propose the windows are replaced with high energy performance frames with ≤1.5 W/m^2K transmittance values. Furthermore, thermostatic valves must also be installed to access the incentives.

Approximately 420 €/m^2 (VAT included) has been estimated to replace the window frames, shutters and install insulated shutter boxes.

4.4.2 Cost-benefit evaluation

Analysing an intervention of this type reduces heat dispersion through the door/window frames by 63%.

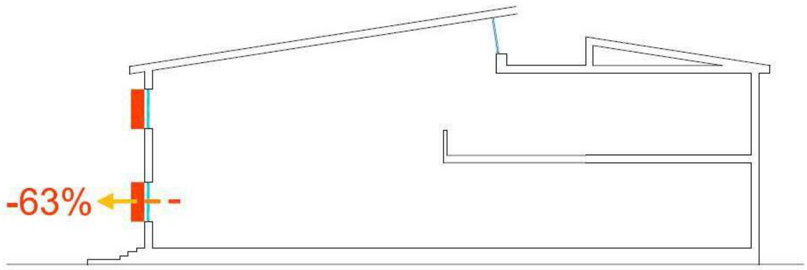


Figure 12. Heat dispersion reduction through windows post frame replacement

The data resulting from the intervention energy-economic analysis are thoroughly illustrated in table no. 5 enclosed to paragraph 6.

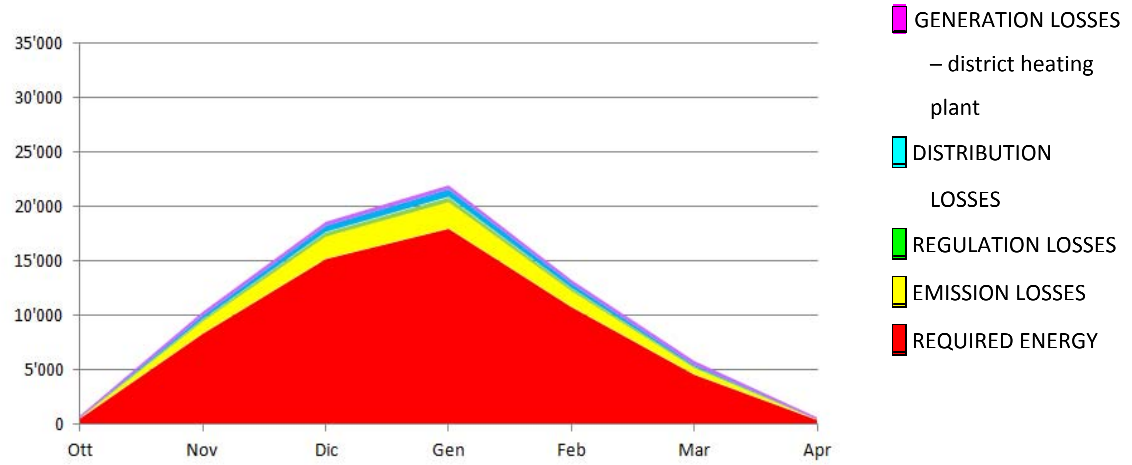
The following summary reveals that the **intervention is recommendable from the energy savings standpoint but the pay back time on the investment is rather long** (about 14 years).

A result of this type was foreseeable since replacing the frames is the most costly intervention of those analysed and affects a limited portion of the casing (if compared to the cost incurred). Valve installation makes the intervention appreciable but, the incentive foreseen by the energy bill is not sufficient to achieve short-term returns on investment.

FRAME REPLACEMENT		
Energy savings	45,872	kWh
Cost saving	4,432	€/year
Intervention cost	101,140	€
Energy bill incentive	40,456	€
Pay back	14	years

Table 11: Energy analysis calculation results following frame replacement

From the comparison between the monthly post-intervention (Graph and pre-intervention (Graph 1) energy demand, the reduction is graphically indicated. Furthermore, a reduction in regulation loss is noted.



Graph 5: Monthly energy demand trend (kWh) post frame replacement and thermostatic valve installation

4.4.3 Post intervention energy certification

Following is the data on building energy classification after the assumed frame replacement and thermostatic valve installation intervention.

Address	**Via Roma, 17, 35020 Polverara (PD)**		
Cadastral references	**Map 209, sheet 5**		
Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**
Energy performance index for heating (Ep, i)	**29.0 kWh/m^3**		
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**		
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**		
Global energy performance index (Ep,gl)	**29.0 kWh/m^3**		
Season average global yield (ηgn)	**100.5 %**		

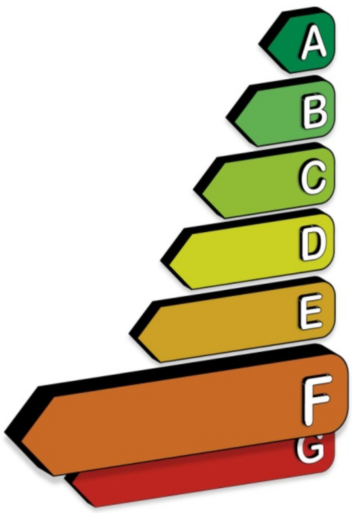


Table 12: Building energy classification calculation results post frame replacement and thermostatic valve insulation

4.5 Overall intervention

4.5.1 Intervention description

We foresee building intervention with global redevelopment:

- External lining;
- Roof insulation;
- Door/window frame replacement;
- Thermostatic valves.

4.5.2 Cost-benefit evaluation

Analysing an intervention of this type reduces heat dispersion through the various building casing elements outlined in Figure 13. *Heat dispersion reduction*

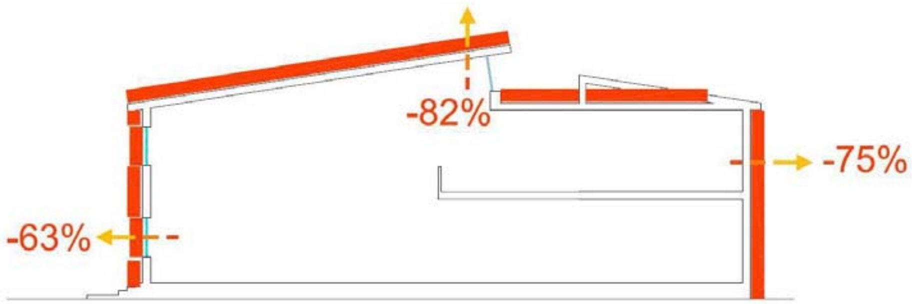


Figure 13. Heat dispersion reduction through the roof, frames and external walls post global redevelopment intervention

The data resulting from the intervention energy-economic analysis are thoroughly illustrated in table no. 6 enclosed to paragraph 6.

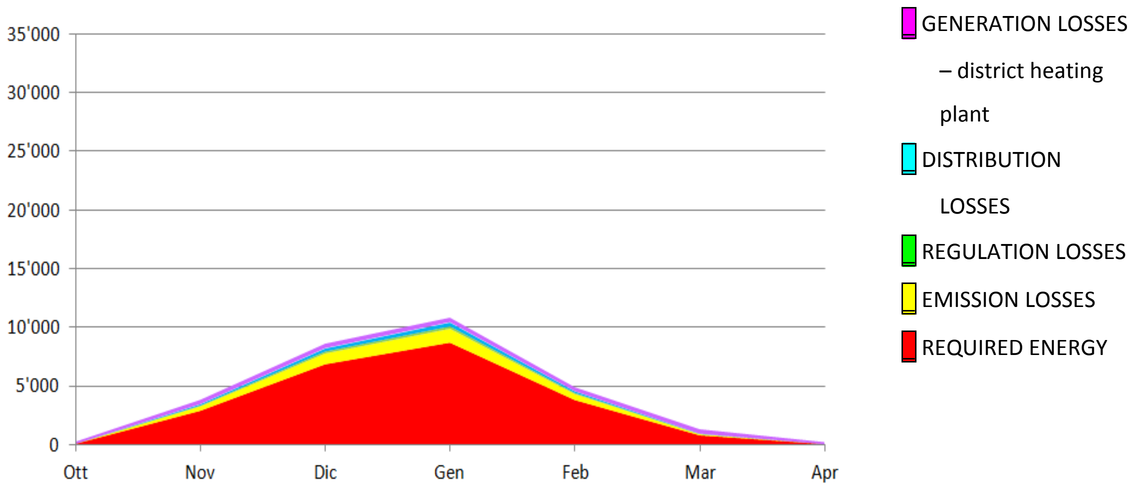
GLOBAL REDEVELOPMENT		
Energy savings	87,778	kWh
Cost saving	8,480	€/year
Intervention cost	283,400	€
Energy bill incentive	113,400	€
Pay back	20	years

Table 13: Energy analysis calculation results following global redevelopment

The summary in Table 13 reveals that **the intervention is recommendable from the energy savings standpoint. From the economic standpoint, high savings (8,500 € per year) corresponds to just as high an investment (285,000 €) recoverable in 20 years.**

Since the building is a point of reference for the community and new generations, an intervention to promote environmental sustainability could be envisaged, which should accompany every building choice regardless of the economic gains.

From the comparison between the monthly post-intervention (Graph and pre-intervention (Graph 1) energy demand, the reduction is graphically illustrated.



Graph 6: Monthly energy demand trend (kWh) post global redevelopment

4.5.3 Post intervention energy certification

Following is the data on building energy classification after the assumed global building redevelopment intervention.

Address	**Via Roma, 17, 35020 Polverara (PD)**		
Cadastral references	**Map 209, sheet 5**		
Heated gross volume	**7,799.8 m^3**	**S/V ratio**	**0.463 1/m**
Dispersive surface	**3,613.3 m^2**	**Working surface**	**1,447.6 m^2**
Energy performance index for heating (Ep, i)	**13.7 kWh/m^3**		
Energy performance index for hot water production (EP, acs)	**0 kWh/m^3**		
Energy performance index limit value for heating (Ep, I, lim)	**16.1 kWh/m^3**		
Global energy performance index (Ep,gl)	**13.7 kWh/m^3**		
Season average global yield (ηgn)	**112.0 %**		

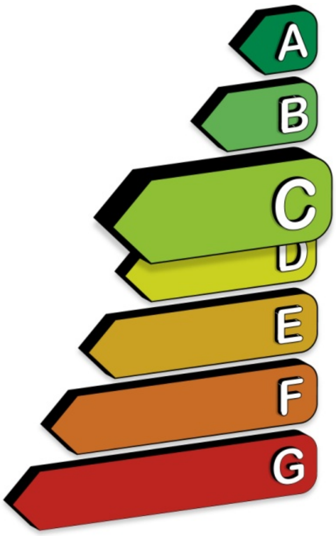


Table 14: *Building energy classification calculation results post global redevelopment*

5 CONCLUSIONS

The analysis reveals that:

- **Thermostatic valve installation is the most beneficial** in energy-economic terms (estimated 5-year returns on investment);
- **Frame replacement at the same time as thermostatic valve installation is the most expensive intervention** but the one that can provide **excellent advantages in energy savings terms** (estimated 14-year returns on investment with Energy Bill);
- **Global redevelopment is costly** but can provide excellent **benefits in energy savings terms**. Faced with long-term returns on investment (approximately 20 years with Energy Bill), consumption would be substantially reduced (8,500 € savings per year against the 11,000 € spent per year in current conditions);
- **Casing insulation (roof and external lining) without any change to the current regulation system are disadvantageous** since the contribution they could grant the building in energy savings terms would not affect the heating system: radiators would continue to emit heat in rooms without significant variations to the current conditions, with the sole result of increasing the internal temperature;
- The obtained results are in line with forecasts: pay back time for the proposed intervention investments is not short in any case, except for the sole intervention on heat regulation. This result is foreseeable since the public administration, not able to access the tax incentives for private citizens (that cover 65% of expenses), can only receive incentives by accessing the Energy Bill (that covers 40% of expenses incurred requiring an energy performance higher than that required for private citizen tax deductions).

6 ANNEXES

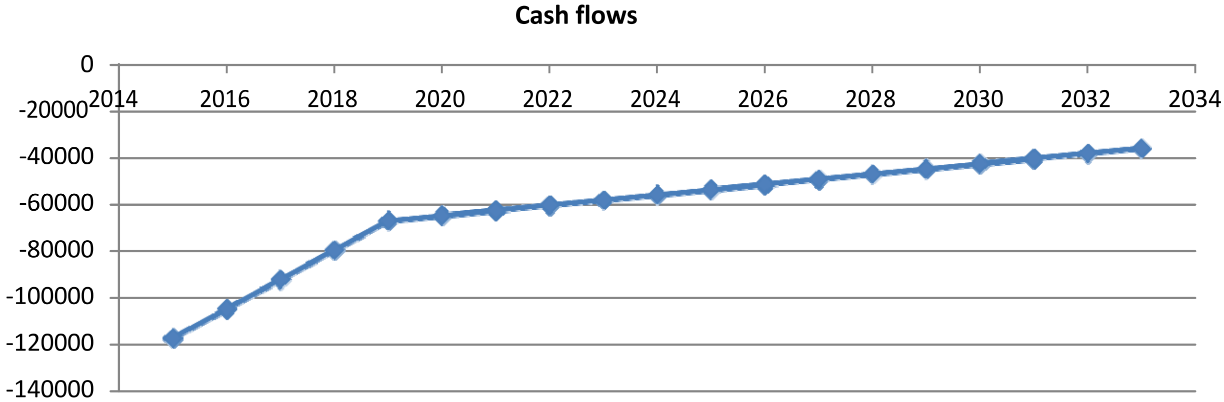
The following pages provide details on the significant analysis data for each assumed intervention.

1. WALL INSULATION: EXTERNAL LINING

Intervention description:

The intervention includes the installation of 10 cm thick polyurethane foam insulation panels on the external building walls that permit access to the incentives set by the Energy Bill.

Main external wall transmittance	0.91 W/m^2K
Post intervention wall transmittance	0.23 W/m^2K
Necessary energy demand	77,082 kWh
System yield	63%
Energy savings	**23,038 kWh**
Required specific energy cost	0.097 €/kWh
Cost savings	**2,226 €/year**
Intervention cost per m^2	100 €/m^2
Total intervention cost	**130,000 €**
Total Energy Bill Incentive	52,000 €
Pay back time	**35 years**

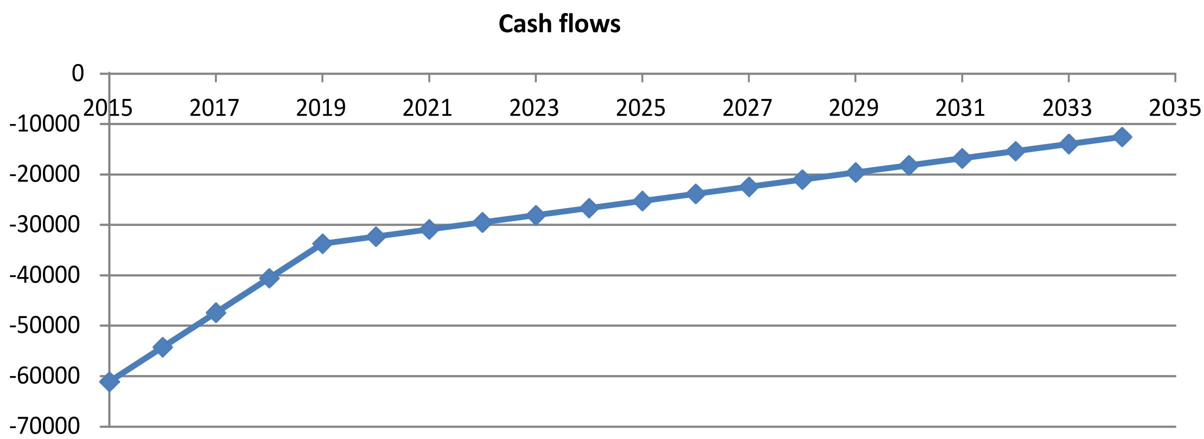


2. ROOF INSULATION (with external central atrium insulation only)

Intervention description:

The intervention includes the installation of soft insulation on the garret extrados and external roof insulation for the central atrium; it permits access to Energy Bill incentives.

Average roof transmittance	1.10 W/m^2K
Post intervention roof transmittance	0.2 W/m^2K
Necessary energy demand	77,082 kWh
System yield	64%
Energy savings	**14,609 kWh**
Required specific energy cost	0.097 €/kWh
Cost savings	**1,411 €/year**
Intervention cost per m^2	65 €/m^2
Total intervention cost	**67,925 €**
Total Energy Bill incentive	27,170 €
Pay back time	**29 years**

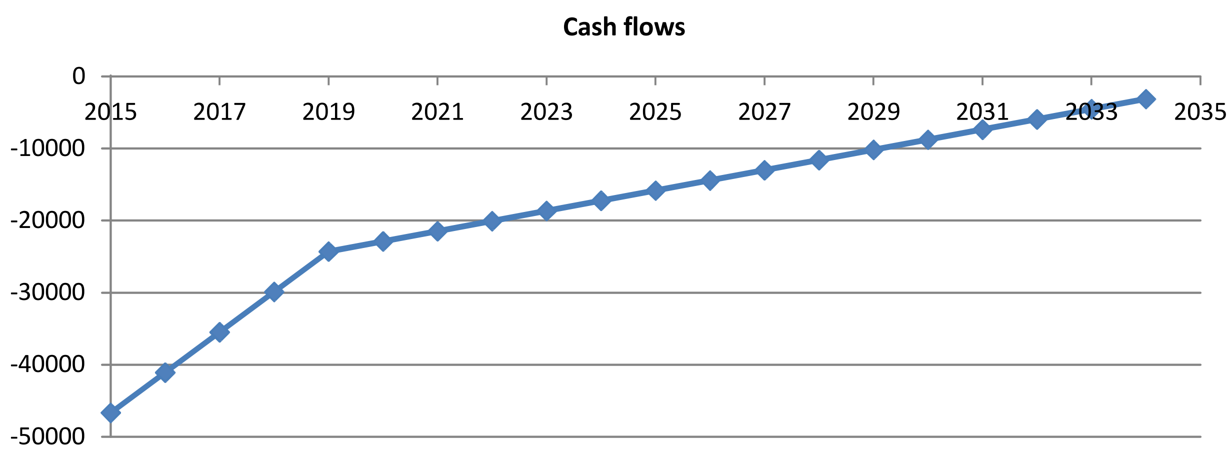


3. ROOF INSULATION (with internal central atrium insulation only)

Intervention description:

The intervention includes the installation of soft insulation on the garret extrados and internal insulation for the central atrium roof; it permits access to Energy Bill incentives.

Average roof transmittance	1.10 W/m^2K
Post intervention roof transmittance	0.20 W/m^2K
Necessary energy demand	77,081,62 kWh
System yield	64%
Energy savings	**14,609 kWh**
Required specific energy cost	0.10 €/kWh
Cost savings	**1,411 €/year**
Intervention cost per m^2	50 €/m^2
Total intervention cost	**52.250 €**
Total Energy Bill incentive	20,900 €
Pay back time	**22 years**



4. THERMOSTATIC VALVE INSTALLATION

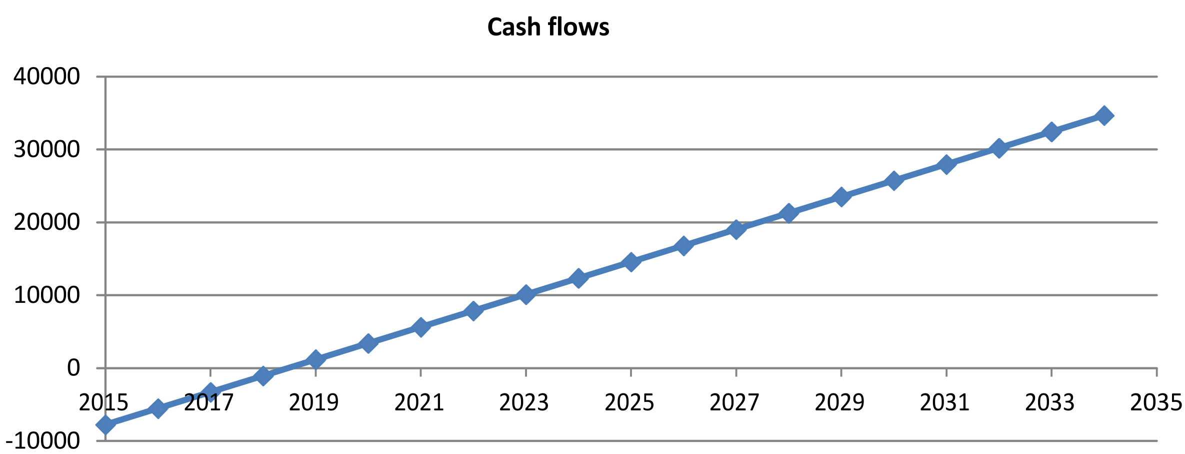
Intervention description:

The intervention includes the installation of thermostatic valves in radiators to improve the heat plant regulation system.

Necessary energy demand	77,082 kWh
System yield	82%
Energy savings	**23,117 kWh**
Required specific energy cost	0.097 €/kWh
Cost savings	**2,233 €/anno**

Total intervention cost	**10,000 €**

Pay back time	**5 years**

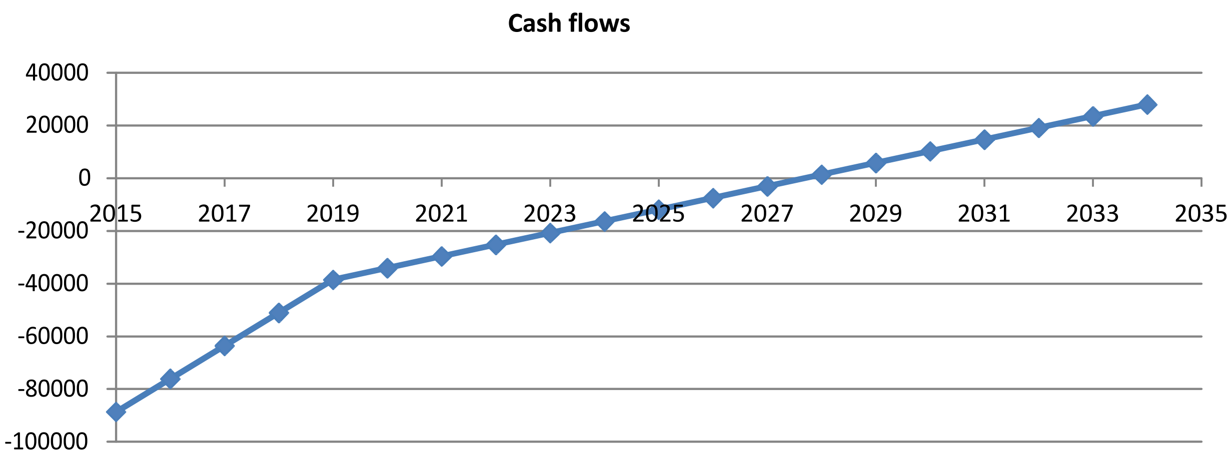


5. FRAME REPLACEMENT

Intervention description:

The intervention includes the replacement of the original frames with new high energy performance frames and the installation of thermostatic valves; it permits access to Energy Bill incentives.

Typical frame transmittance	4.00 W/m^{2}K
Post intervention wall transmittance	1.5 W/m^{2}K
Necessary energy demand	77,082 kWh
System yield	81%
Energy savings	**45,872 kWh**
Required specific energy cost	0.097 €/kWh
Cost savings	**4,432 €/year**
Intervention cost per m^2 for frame replacement	420 €/m^2
Total intervention cost: frames and valves	**101,140 €**
Total Energy Bill incentive	40,456 €
Pay back time	**14 years**



6. GLOBAL REDEVELOPMENT

Intervention description:

The intervention includes:
- Roof insulation,
- External lining,
- Frame replacement,
- Thermostatic valves,

And permits access to Energy Bill incentives.

Necessary energy demand	77,082 kWh
System yield	77%
Energy savings	**87,778 kWh**
Required specific energy cost	0.097 €/kWh
Cost savings	**8,480 €/year**

Total intervention cost: frames and valves	**283,390 €**
Total Energy Bill incentives	113,356 €
Pay back time	**20 years**