The European Union's Project IPA 2009, Implementation of Energy Efficiency Measures in Schools and Hospitals in Kosovo

SUPERVISION OF ENERGY EFFICIENCY MEASURES IN SCHOOLS AND HOSPITALS IN KOSOVO
Contract No. 2012/302-059

Technical Report, on the Monitoring Verification and Evaluation of the applied energy efficiency measures in 53 schools
(Located in 30 Kosovo municipalities)

24 September 2012–23 September, 2016

This project is funded by
The European Union

A project implemented by
Aecom Inocsa s.l.u and Aecom Ltd.

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1. EXECUTIVE SUMMARY

The entire project was funded by European Union under the IPA 2009 Annual Programme and managed by the European Union Office in Kosovo. The project "Implementation of Energy Efficiency Measures in Schools and Hospitals in Kosovo" involved the energy efficient refurbishment of 65 public buildings in Kosovo (63 schools and 2 hospitals). The project was designed to encourage more effective use of energy across Kosovo with the major goal to implement energy efficiency improvement in public buildings and the verification of energy cost savings, as well as CO_2 emission reductions achieved by these energy efficiency measures.

This document presents the results of the analysis for implemented Energy Efficiency Measures (EEM) on building envelope, heating system and lighting in 53 public buildings - schools.

Table no.1 below, Executive Summary, illustrates that significant energy consumption savings have been achieved for all refurbished buildings with annual savings of an average of **62%** which amounts to **21,420,899 kWh/year** over the course of the entire project. Difference in average annual specific CO_2 emissions reduction follows the same pattern as energy consumption, which is **62%** in total or **8703 t/a**. The Equity Payback Period (EPP) for EE Measures is **7.26 years**, while the EPP for total investments is **8.46 years**.

Table 1: Executive Summary

Executive Summary		
Energy consumption before EE measures	34,391,716	kWh/year
Energy consumption after EE measures	12,970,817	kWh/year
Net energy savings	**21,420,899**	**kWh/year**
Net savings	1,232,788	€/year
Investments EE Measures	9,922,616	€
Investments Non EE Measures	1,817,635	€
Total Investment EE and Non EE Measures	11,740,251	€
CO_2 Reductions	8,703	[ton CO_2/year]
Equity payback / EE Measures	7.26	years
Equity payback / Total Investment	8.46	**years**

2. INTRODUCTION

In Kosovo, the vast majority of public buildings are large energy consumers due to poor thermal characteristics of building fabric and inefficient heating equipment. As the country faces big challenges due to both low and unsteady levels of energy production and high and increasing energy consumption, investing in energy efficiency measures in existing and new buildings is crucial. A set of energy efficiency measures was implemented in order to create environmentally friendly and energy conserving buildings while maintaining indoor thermal comfort.
This project lasted from September 2012 to September 2016, with the objectives as listed below:

- ✓ Implementation of energy saving measures on building envelope, heating system and interior lighting,
- ✓ Increase in end-user satisfaction about energy efficiency and indoor comfort,
- ✓ Raising awareness of the end users about energy efficiency and rational use of energy.

This document summarizes the project outcomes through energy and carbon savings as well as investment payback period. The results are presented in the respective sections of this report.

The main project aim was to boost the implementation of Energy Efficiency Measures in Kosovo by providing exemplary models and best practices for implementation and replication in other municipalities and raising awareness about the potential for practical implementation of Energy Efficiency and possible Renewable Energy Resources at municipal level. The other aim was to facilitate the initiative for Energy Efficiency in Kosovo by supervision of the implementation of Energy Efficiency Measures and Monitoring, Verification and Evaluation (measurements) at a local level across Kosovo school and hospital buildings.

2.1 Kosovo Energy benchmarks

There are no detailed energy benchmarks available for Kosovo schools; therefore the results of this project can be used as a good trend indicator and this issue could be addressed in similar future projects by long term monitoring period and increasing the number of buildings. They represent typical practice figures against which energy bills/metered data can be compared for assessing performance on an A-G scale. Measured results for schools can be compared with corresponding benchmarks in the region of South East Europe and some EU countries. These measures could be also used as a part of the operational energy ratings system to implement Energy Performance of Buildings Directive (EPBD), lately considered by the Kosovo Government, namely the Ministry of Environment & Spatial Planning and the Ministry of Economic Development.

3. BACKGROUND

Kosovo has established a favorable regulatory framework and institutions to support energy efficiency and renewable energy resource development programmes and projects. Under the existing Kosovo legislation, energy efficiency is, to a certain extent, covered by the following laws currently in force, namely: the Law on Energy, the Law on Electricity, the Law on Energy Regulation, the Law on Construction and the Law on Energy Efficiency. These laws are supplemented by a set of secondary legislation on energy efficiency in the form of administrative instructions.

In order to encourage more effective use of energy across Kosovo, the EU Office in Kosovo has provided further support to Kosovo municipalities in implementing energy efficiency measures in public buildings, particularly in 63 schools across different municipalities and 2 hospitals in the Municipality of Prishtina. The proposed measures to promote more rational use of energy were focused on:

- Building envelope improvements (such as external thermal insulation of buildings, replacement of external windows and doors, waterproof roof insulation, etc.);
- Heating systems, electrical and lighting systems, air conditioning and ventilation control systems;
- Introduction of renewable energy resources, such as solar panels for hot water production, solar-assisted space heating systems, etc.

3.1 Project Synopsis

3.1.1 Overall objectives

Energy efficiency improvements in the 63 schools and 2 hospitals in Kosovo, through implementation of energy efficiency measures on building envelope, heating system and interior lighting, thus make heating more affordable. This is an integrated approach aimed at the most effective and economical option, taking into account the positive environmental impact of reduced energy consumption and the security of supply and distribution cost aspects related to it.

3.1.2 Project Purpose

The purpose of the service contract is to ensure supervision of implementation of energy efficiency measures in selected public buildings and to monitor, verify and evaluate through energy and cost savings, investment payback, as well as CO_2 emission reduction achieved through implementation of energy efficiency measures in the selected public buildings.

3.1.3 Planned results

Result 1 - Ensure through competent supervision and effective coordination between two different works contractors the timely completion of all contractual works in accordance with the tender documents, design drawings and employer's requirements and that works are in compliance with the Terms of Reference. All works must be executed to the full satisfaction of the Contracting Authority and in close cooperation with the final Beneficiaries and all other relevant stakeholders, such as the Ministry of Local Government Administration (MLGA), Ministry of Economic Development (MED) and the Ministry of Health (MoH).

Result 2 - Successful handing over of the schools and hospitals to the Beneficiaries after issuance of the Provisional Acceptance Certificate.

Result 3 - Ensure through competent supervision that all defects are properly dealt with and remedied during the 12-month Defects Liability Period (warranty period).

Result 4 - Technical Report provided on the Monitoring, Verification and Evaluation (MVE) of implementing energy efficiency measures carried out during the 12-month Defects Liability Period.

Result 5 - Issuing of Final Acceptance Certificates after successfully passing the Defects Liability Period.

Result 6 - The direct Beneficiaries have an improved awareness on Energy Efficiency Measures in public buildings and enhanced knowledge in the operation of the installed facilities, reporting methodology, quality assurance, site coordination; and supervision, testing and inspections.

Result 7 - The Beneficiaries and the public in general have an increased awareness on environmental issues related to the implementation of EEM in public buildings.

4. PROJECT DESCRIPTION

4.1 DESCRIPTION OF THE ASSIGNMENT

4.1.1 Global and Specific Objectives of the Contractor

To enhance energy efficiency in public buildings, through implementing energy efficiency measures and use of renewable energy resources that will reduce the harmful impact on the environment.
Design and refurbishment of 63 schools and 2 clinics in a "Design and Build" Contract in terms of improving energy efficiency, through the following works:

- Thermal insulation of facades
- Thermal insulation, partial replacement and in some cases complete replacement of roofs
- Replacement of windows and doors
- Repair and retrofitting of windows and doors
- Replacement or rehabilitation of heating systems
- Implementation of solar thermal systems
- Replacement of lighting systems
- Replacement or rehabilitation of sanitary systems
- Replacement of rehabilitation of other selected works

4.1.2 Responsibilities of the Consultant

The Consultant has supervised, on behalf of the EU Office in Kosovo, all the works for the implementation of Energy Efficiency Measures which were carried out in 63 existing schools across different municipalities and 2 hospitals in municipality Prishtina. In addition, during the Defects Liability Period, the Consultant performed the monitoring, verification and evaluation (MVE) through energy and cost savings, investment payback period, as well as CO_2 emission reductions achieved through the implemented energy efficiency measures.

The Consultant was involved in all stages of the implementation of the project and the Defects Liability Period of all lots: i.e. design review and approval, supervision of preparatory works, construction works, supply, installation, testing, commissioning, as well as the monitoring, verification and evaluation of the implemented energy efficiency measures which were carried out during the Defects Liability Period. Subject of this report are 53 schools divided in 3 lots; Re-Launch Lot 1 (20 schools), Lot 2 (25 schools) and Re-Launch 2 (8 schools).

5. GENERAL DESCRIPTION OF BUILDINGS

Implementation of Energy Efficiency Measures was done across 34 municipalities in Kosovo, while 53 schools that are subject of this report are located in 30 of the 34 municipalities. They are located in different parts of respective municipalities, where 24 schools are in urban areas, 22 in rural areas and 7 are located in remote rural areas. The period of construction varies for different schools as they are built between the period of 1950 and 2005.

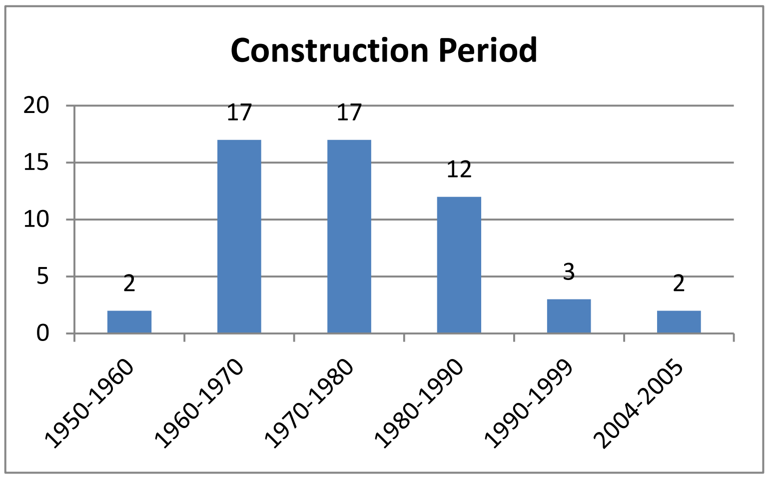


Chart 1Construction Period

Used construction system depends on the period of construction. Consultant founded the following construction systems with direct correlation to period of construction in the following order: from the construction period 1950-1970, buildings were built with massive construction system where walls and concrete slabs carry load; from the construction period 1980-2005, buildings were built with skeleton construction system, where

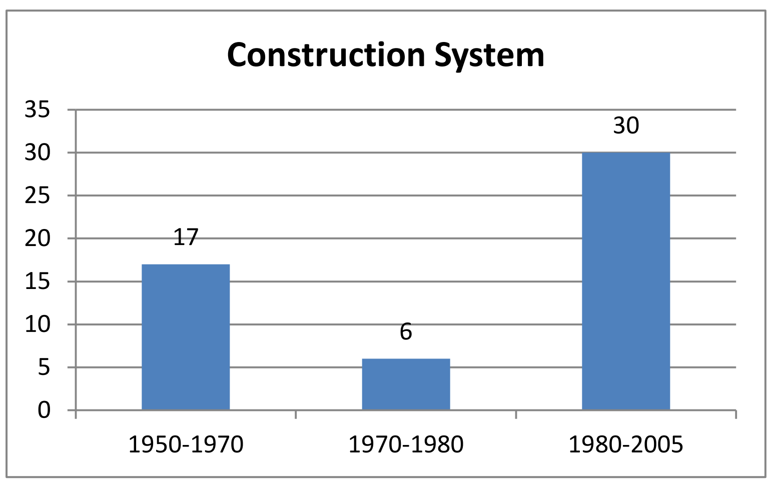


Chart 2 : Construction Period

concrete columns and beams carry load and stresses to foundation; from the construction period 1970-1980, buildings were built with a combined massive and skeleton system.

From the structural point of view, school buildings are in good condition. Main structural elements, such as columns, beams, slabs and roofs are without any remarkable failures.

Design and typology of schools are classified into three main types: central corridor connecting both segments of the building; classrooms and other areas located on the sides of corridors; schools, combined types with a high ratio of external walls to floor areas marked as more complicated designs in terms of energy efficiency.

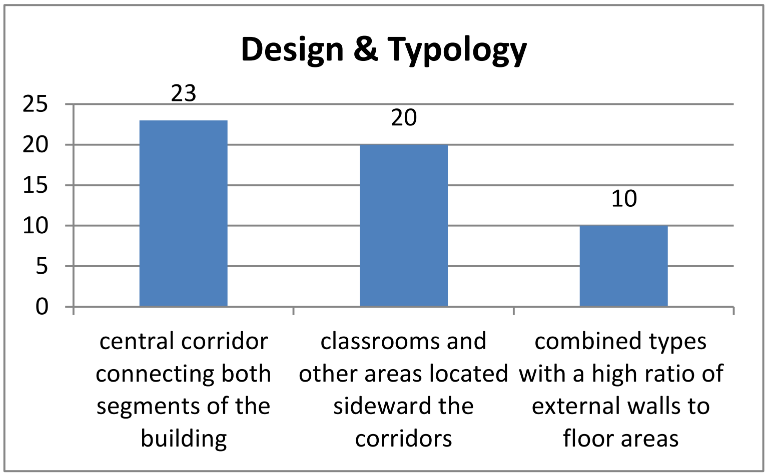


Chart 3: Design & Typology of schools

5.1 BUILDINGS DESCRIPTION

5.1.1 Building elements before implementation of Energy efficiency measures

This chapter contains a brief description of the main existing building elements, such as walls, roof, windows, doors and floors, **before** implementation of Energy efficiency measures.

5.1.1.1 External walls

The composition of the external walls depends on the construction period and type of the construction system. Consultant found that only 4 of 53 schools subject to this report, were thermally insulated before the Implementation of Energy Efficiency Measures, while the other 49 schools were without thermal wall insulation.

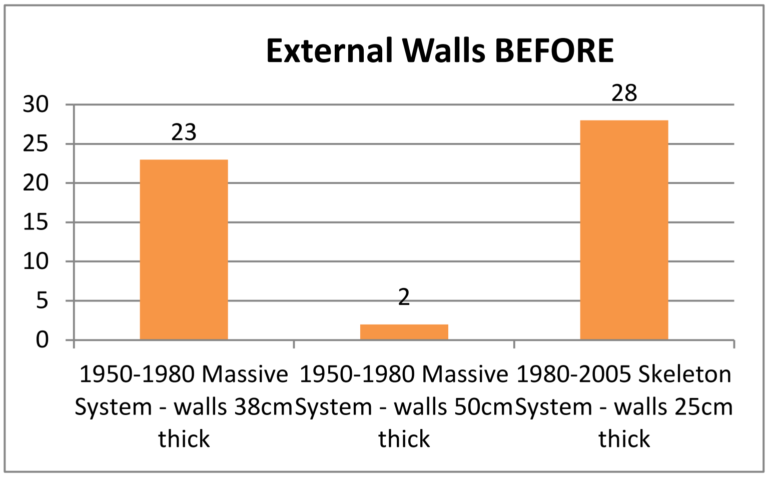


Chart 4 External Walls BEFORE EEM

Within the construction period 1950 – 1980, 25 schools were constructed. Most of them were built with massive construction system, with baring walls made of solid bricks. External walls of these schools were constructed with solid bricks plastered on both sides and with 38cm thickness (1+1/2 brick), and in 2 cases with 50cm thickness (1+1 brick).

Within the construction period 1980-2005, 28 schools were built with skeleton construction system, with hollow bricks. Most of the external walls were plastered on both sides, with exceptions in 6 schools, where the walls were constructed with hollow bricks plastered inside only, thus making thermal characteristics even worse than those of non-insulated blocks.

5.1.1.2 Roofs

Out of 53 schools subject to this report, 4 schools were covered by flat roofs, 44 with sloped roofs and 5 schools with combined flat and slope roofs. 5 schools were covered by corrugated asbestos plates, 23 by clay tiles and 2 schools were covered by bitumen shingles and the rest of the 19 schools were covered by corrugates steel sheets.

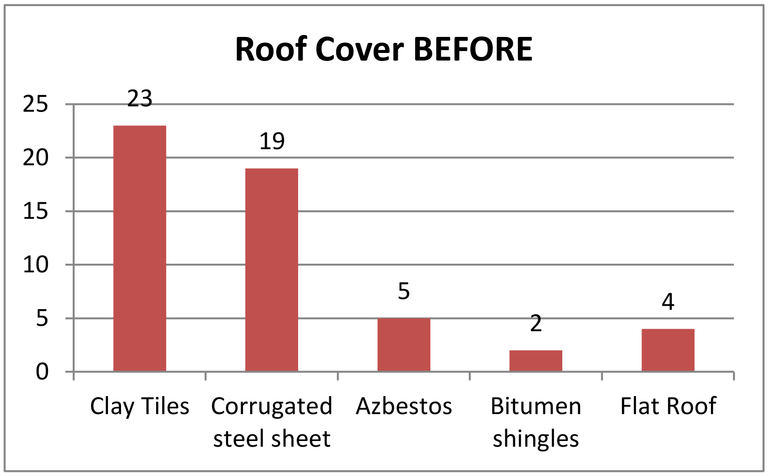


Chart 5: Roof Cover BEFORE EEM

Out of 53 schools, 2 were thermally insulated before the Implementation of Energy Efficiency Measures. The state of the roof cover in some schools was quite bad due to severe leakages, non-regular maintenance and lack of proper insulation causing condensation of the air humidity, especially during the winter.

5.1.1.3 Windows

Window frames were made of different materials, such as wood, steel, aluminum and PVC. Majority of the windows were double glazed with poor air tightness, damaged hardware and in bad condition, while some of the windows were single glazed and in really bad condition. Most of the windows were foreseen to be replaced completely or to be repaired and retrofitted.

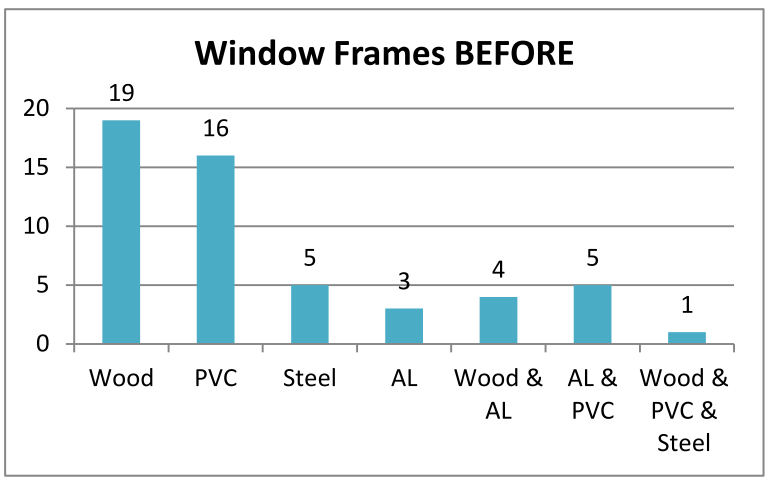


Chart 6: Window Frames BEFORE EEM

5.1.1.4 External doors

Door frames were made from different materials, such as: wood, steel, aluminum and PVC. Majority of the doors were single glazed with poor air tightness, damaged hardware and in really poor condition, while some of the doors were double glazed and also in poor condition.

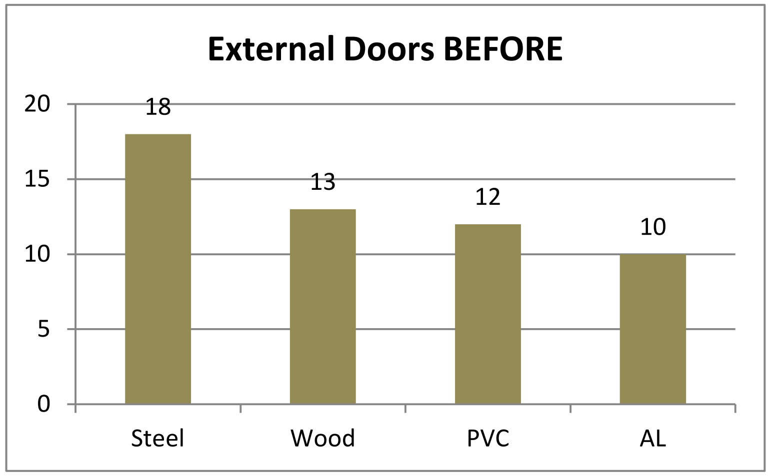


Chart 7 External Doors BEFORE EEM

5.1.1.5 Floors

Floors were made of different materials, such as: wood, parquet, teraco, ceramic tiles and PVC. Usually floors in corridors were made from teraco. There are a few cases where floors were made from ceramic tiles or PVC. Classroom floors were usually made from PVC, wood or parquet flooring. In schools with gyms, in most of the cases, floors were constructed as parquet floors and only in a few cases did we find PVC flooring.

Floors in bathrooms were constructed in most of the schools from ceramic tiles and in a few of them, teraco was used as final floor layer.

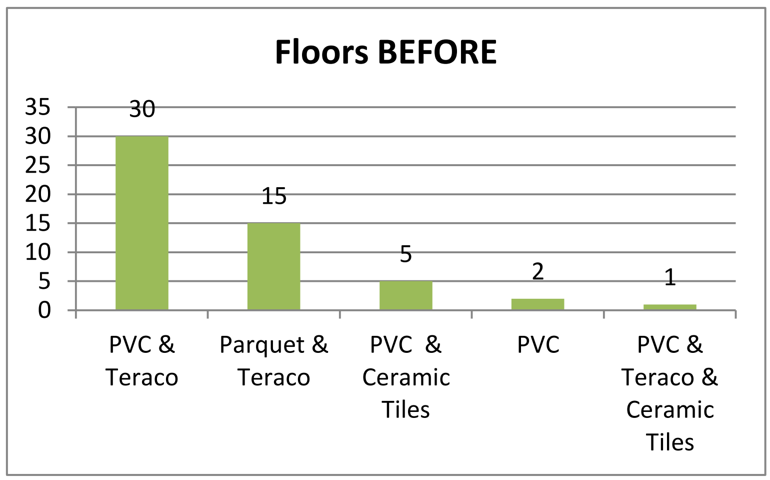


Chart 8 Floors BEFORE EEM

The condition of the floors in almost 50 % of the classroom areas were in poor condition; in 25 out of the 53 schools in total subject to this report.

5.2 BUILDINGS DESCRIPTION AFTER IMPLEMENTATION OF ENERGY EFFICIENCY MEASURES

5.2.1 Building elements after implementation of Energy efficiency measures

This chapter contains a brief description of the main building elements, such as walls, roof, windows, doors and floors **after** implementation of Energy efficiency measures.

5.2.1.1 Walls

External WALLS (FACADE – Thermal Insulation Composite System)

This section deals with the external thermal insulation composite system (ETICS) at 49 schools without prior insulation and at 2 schools with no sufficient thermal insulation; total of 51. The works include entire thermal insulation of the vertical facade, which also comprises of thermal insulation of projections of columns and beams, windows and door reveals/soffits and lintel areas, all canopies, balconies, cantilevers, overhangs and overhang eaves.

The objective of this measure was to thermally insulate the building envelope and to avoid cold bridges, with special attention to the transition zone from facade to roof. Materials used:

- XPS Extruded Polystyrene according to EN 13164 for the façade, 5 cm thickness, from up to 50-60 cm above ground level, with lambda < 0,04 W/m^{2}K, and compressive strength > 300 kPa (> 0,30 N/mm^2),
- EPS-F Expanded Polystyrene according to EN 13163 for the façade, 8 cm thickness, above 60 cm from ground level, lambda < 0,04 W/m^{2}K, compressive strength > 150 kPa (> 0,15 N/mm^2).

5.2.1.2 Roofs

SLOPED ROOFS

Possible ROOF works related to the placing of thermal insulation and concrete screed as protection layer in steep roofs are listed below:

a) If the roof attic is accessible and the roof covering and structure were in good condition, thermal insulation was placed on the floor above the roof slab; 11 schools.
b) Where the roof is functional but not accessible for thermal insulation works, the roof was partially uncovered and reassembled again, using same materials; 8 schools.
c) Where the roof covering was deteriorated, it was replaced, including all tinsmith works; 21 schools.
d) If the roof structure was deteriorated, the roof was entirely replaced, including all tinsmith works; 5 schools.

The total number of schools is 11 + 8 + 21 + 5 = 45. In four remaining schools there was a combination of type a) & b) (2 schools) and b) & d) (2 schools). This concludes the number of 49 schools were the roof thermal insulation was implemented at sloped roofs.

Thermal Insulation was placed on the roof slab in most of the schools and between rafters only in a few cases:

- o The first case, the thermal insulation on the roof slab was of 160 mm thickness, EPS W 20 boards according to EN 13163, with a thermal conductivity: lambda < 0,04 W/m^{2}K, the compressive strength ≥ 100 kPa (≥ 0,10 N/mm^2) on PE foil as the first layer. Where the roof attic is walkable, the thermal insulation boards were protected with a concrete creed. Where the roof attic is not walkable, only PE foils protect the insulation boards.
- o The second case, the thermal insulation between rafters was placed with 16 cm thickness of rock wool according to EN 13162, with a thermal conductivity: lambda < 0,04 W/m^{2}K, PE vapor barrier, wooden boarding and gypsum plasterboards.

FLAT ROOFS

This type was implemented only in 2 schools, where it was combined with slope roofs.

Works included flat roof layers (top to down): 8cm gravel 13/32, geotextile, thermal insulation, 2 waterproofing membranes. Insulation is XPS extruded polystyrene boards with a smooth surface finish and half-lapped edges, thickness 160 mm, thermal conductivity: 0,036 - 0,040 W/m^{2}K, Compressive stress: ≥ 300 kPa (0,3 N/mm^2).

5.2.1.3 Windows

WINDOWS were completely replaced at 30 schools and partially in 11 schools with main characteristics as described below and according to Technical Specifications.

The heat transmission coefficient (Uw value) of the windows in accordance with DIN EN ISO 10077-2 is 1,8 W/m^{2}K at the maximum. Basic requirement of the casement profiles and window frame profiles are:

- All profiles are reinforced with steel shapes.
- PVC-U systems with a basic depth of minimum 70 mm.
- 5-Chamber profile system with minimum two sealing levels.
- Gaskets made of EPDM rubber are machine-rolled in the factory.
- Glazing dimensions are: 6 mm float glass-outside, 14 mm space between the glasses, filled with argon gas; 4 mm float glass-inside.

REPAIR AND RETROFITTING OF EXISTING WINDOWS

Repair and retrofitting of all existing windows was done in 8 schools and in 11 schools partial repair and retrofitting. Works comprised of the replacement or retrofitting of windows hardware, rubber joints, glass bead, broken glass, etc.

Windows were not replaced in four schools out the total of fifty three subject to this report.

5.2.1.4 External doors

Doors in 47 schools were replaced completely; repair & retrofitting was done in 3 schools, external doors at 3 schools were not replaced. Three types of external doors are installed at schools.

TYPE 1 – ALUMINIUM ENTRANCE DOOR / PORTAL

This type refers to all entrance doors. All doors with glass are equipped with laminated tempered glass, thermally insulated with gap filled with Argon between the glass sheets. Heat transmission coefficient (U_W value) of the entire door (frame + glass) is 1.8 W/m²K at maximum. Main entrance doors and escape doors are equipped with panic bars acc. to EN 1125.

TYPE 2 – EXTERNAL STEEL DOOR

This type refers to boiler doors. Steel door; 40 mm door leaf, double skinned, thin rebated on 3 sides, sheet thickness 1 mm; flat steel reinforcement; insulation made of mineral wool.

TYPE 3 – EXTERNAL PVC DOOR

This type refers to side doors. PVC doors follow the technical specifications of PVC Windows.

5.2.1.5 WIND FANGS

Out of 53 schools subject to this report, wind fangs were operational only in 20 schools, but 17 of them were in bad condition. All new wind fangs are installed at the main entrances, which are much more frequently used, in order to impact on the buildings energy performance.

New wind fangs are installed in 40 schools where it was technically and functionally possible. They were in good condition in 4 schools, while in the rest of the 9 schools, installation of wind fangs presented serious communication difficulties for children.

5.2.1.6 Floors

In the school classrooms with previous PVC flooring in bad condition, works comprised of: removal of existing PVC flooring, cleaning of the concrete surface and spackling it with polymer-modified leveling filler, new PVC flooring with 3.3 mm thickness produced for EN 14041.

In cases of school classrooms with previous wooden planks or parquet flooring, when it was applicable, works comprised of: installation of water proofing membrane, concrete screed with 2-3 cm of EPS thermal insulation protected with PE Foil and PVC flooring with 3.3 mm thickness produced for EN 14041.

5.3 HEATING SYSTEM

Energy efficiency improvements in the 63 schools and 2 hospitals in Kosovo, by implementation of energy efficiency measures takes into consideration an integrated approach where the heating system is an important part of an effective and economical option, taking into account the positive environmental impact of reduced energy consumption and the security of supply and distribution cost aspects related to it.

It is identified that in 28 schools a solid fuel-coal central heating system is used and only 8 schools have an installed system which uses boilers with burners for light oil as a fuel, in 17 schools there were stoves using wood as a fuel. It means in total, there were 45 schools using solid fuel for heating systems, both with boilers and stoves.

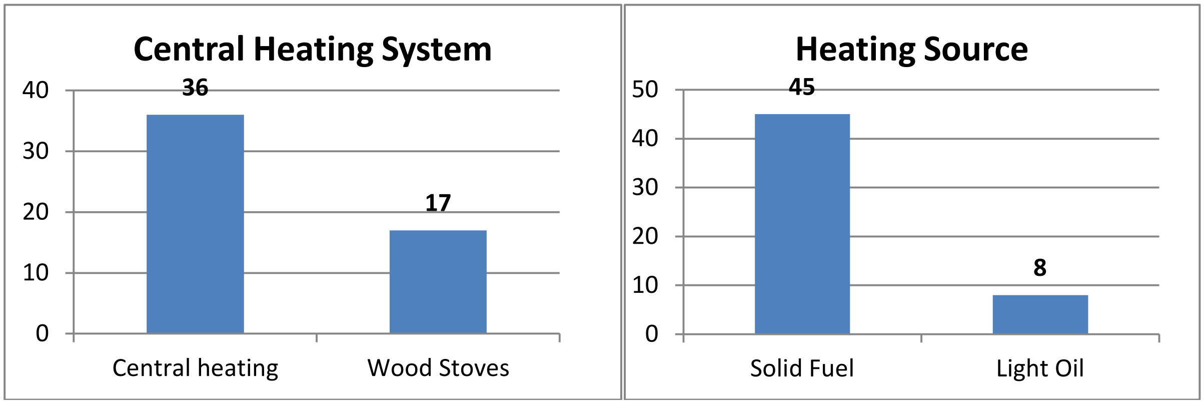


Chart 9: Heating Source and Central Heating System BEFORE EEM

Presented above is heating installation in 53 analyzed schools before and after implementation of Energy Efficiency measures. Information about the state of the installations "before" were collected during detailed site visits performed before starting the implementation process. On the other hand, the Supervisor has worked closely with Contracting Authority and the beneficiaries and Contractor as well, to approve the most efficient technical solution for each specific school building.

5.3.1 Heating systems before implementation of Energy efficiency measures

a. Boilers and Boiler rooms

Typically, existing buildings heating system consists of the boiler plant including substation and the distribution network with heating bodies-radiators. The boiler plant is usually located on the ground floor and works on solid fuel. The operation of this plant is in most cases outsourced, so the school authorities do not deal with particular expenses for heating or reimbursing related expenses.

Regarding the heating source, we identified boilers that use light oil and combined boilers using wood and coal.

Capacity of oil boilers were oversized and with very low efficiency, in range from 150kW up to 500 kW. In some schools, two boilers of 500 kW were installed, each operating on oil in an enclosed pressure system. They are joined on the same distribution collector. Also identified were boilers of modern design, tubular type with contemporary burners and heat production units which were well maintained. Boilers have low temperature corrosion protection circulators. The main problem of such installation was use of light oil as energy source which is fossil fuel with high price and significant environmental impact.

Characteristic school heating system was designed with two boilers in the boiler room, operating on light oil and each having nominal thermal capacity of 523 kW. State of the boilers was good, with the remark that monitoring and steering elements were either not in function or were broken. Also, there was still an old boiler from the period when this plant used to operate on coal.

Their location in the separate building was fully adequate, although it needed some retrofitting. The space offers an opportunity for accommodation of any new equipment that may be related to this system, or other activities, such as maintenance.

On one school premise there were oil boilers installed in the basement, two units, each with thermal capacity of 550 kW, complete with distribution manifolds for three loops. This plant was in quite good condition and was suitable for improvement to reach required efficiency. Because of high price and difficulties for ensuring sufficient quantities of light oil, this plant was switched off and heat production is provided by an alternative source.

In several schools in different regions of Kosovo, boiler plants using solid fuel were installed. There were also systems combined of two boiler units, located in a separate building attached to the school.

In some cases, the equipment in the boiler room consisted of a single boiler on solid fuel using coal and wood as fuel, working as pressurized, enclosed single loop system. Thermal insulation of the piping in the boiler room does not exist and since it was integrated into the building, this loss of heat was not evident.

Very often, boiler plants were installed in the basement and they work on solid fuel. The state of plants were often obsolete, with boiler units destroyed by corrosion, being old or worn out. Also, it was visible that the care for the equipment was completely absent. The entire plant was full of dirt, electrical switch boards were destroyed and dangerous.

Boiler units on solid fuel were with nominal thermal capacity of range between 150 to 250 kW each; installed in different periods, with the latest installed in 2007. As it was mentioned above, in 36 schools boilers using solid fuel were installed.

The most specific case was the boiler room for heat production done by single boiler unit converted from coal to oil. This unit has no automatic control at all. The burner operates only on base of the boiler water temperature.

b. Stoves

During inspection before implementation of the EE measures, we identified schools where there was a heating network installed which is out of use, so the heating was produced by stoves on solid fuel installed in the classrooms and administrative premises. But, very commonly, stoves were the only solution for heating in schools in far villages. In 17 schools installed were stoves with different capacities, construction and period of installation.

Moreover, heating by stoves on wood shows weaknesses resulting with occurrence of condensation and generation of mold. Connections of the fume discharge of the stoves and their operation in general, represent danger of increased carbon monoxide concentration and fire risk.

Heating by stoves on wood was completely inadequate and insufficient. Stoves were installed in the classrooms and offices. Corridors and toilet blocks are not heated. Operation of stoves was not only providing insufficient building temperature level, but it also contributed to worsening of general hygienic state.

c. Reservoirs

As part of the light oil heating system in 8 schools, installed were seasonal on-the-ground tanks of 30,000 liters; usually nearby was a boiler house, on the access internal road. Often, thermal insulation of these tanks is damaged by looting.

The main obstacle to the existing system of one school building was related to the location of three oil reservoirs in the boiler room located in the basement of the new building. Besides the inadequate entrance, this was an issue of general fire safety.

d. Radiators and heaters

In most school buildings, in total 36 schools, radiators were steel panel type, equipped with simple radiator valves mostly in workable condition. However, in many of them, the handgrips were removed, so the flow regulation was only possible mechanically, by use of tools by the service personnel.

In addition, radiator covers were damaged or removed. Small repairs needed on radiator covers, valve handgrips, and similar could be considered due to lack of maintenance.

We have identified heating system made of cast aluminum radiator ribs. No interventions other than maintenance and small scale repairs were needed for these radiators.

In some schools, in the gym area, installed were aluminum casted radiators, at that time out of function. In other gyms we found air heaters connected to the heating network, currently out of operation, since the entire gym area was cut off of the heating system.

In addition, in some cases, there were some leaking radiators and radiator covers damaged or removed. Small repairs needed on radiator covers, valve handgrips and replacement of leaking radiators, especially in toilets and in some classrooms. Others needed cleaning and painting with high temperature resistant paint.

e. Network

Generally, the heating networks were in good shape. In some cases, this installation was new or recently repaired but in some schools they were buried and in unknown condition. Some school authorities stated that heating systems fulfill requirements, but during testing in the phase before implementation of EE measure, we identified leakages and performed additional reparations.

Typically, distribution systems, piping systems and valves are designed independently supply different parts of the school building and gym as well, throughout separate loops. The pipe network was standardly insulated in the boiler room by rock wool in the aluminum sheet shell, but very often damaged and poorly maintained. Similarly, boiler room piping systems suffered damages of thermal insulation.

Some of the distribution network insulation was damaged to some extent and needed to be repaired. This action is more related to good functionality of the system and its balancing.

f. Circulation pumps

Standard heating network has several loops, separate for the school and gym. On the distribution manifold, pumps were installed, with different nominal power of range from 450 W up to 2.2 kW. Installed circulation pumps were without any flow regulation and non-efficient.

g. Chimney

Typically, the boiler room has a chimney installed with the equipment. The chimney is made of steel sheet, with thermal insulation and shell. We have identified boiler rooms with no proper chimney, so it was recommended to build a new one.

h. General remarks

Besides comfort problems caused by poor solutions, it was obvious that the heating system was not sufficient, since there were even color changes in the classrooms on the places of local thermally weak areas, not only on thermal bridges, but also on entire walls and ceiling areas. Heating system shows weaknesses resulting with occurrence of condensation and generation of mold.

5.3.2 Heating system after implementation of Energy efficiency measures

Each premise has its own specifics regarding location of the boiler rooms, disposition of the equipment, location of the expansion vessels, and etc.

Typically, a boiler room is located on the ground floor of the school building. For the preparation of hot water a new heating system is used, as mentioned above, solid fuel fired boilers with operating temperature regime 90/70 ° C, with capacity range from Q = 100 kW up to 250 kW. Boiler is constructed from high temperature resistant steel of high quality attested materials.

Based on producers installation requirements, the boiler is connected to the open expansion vessel. All connection pipes to and from boiler room are insulated with thermal insulation of thickness s=40 mm (mineral wool or equivalent thermal insulation). In cases where expansion vessel is installed in a thermally unprotected location, it is mandatory for expansion vessel to be insulated with greater thickness according to technical calculations. In some cases, expansion vessel is installed on the roof with accompanying pipeline. Expansion vessel is insulated with mineral wool to prevent the system from freezing which may occur during the winter.

Size of the expansion vessel is determined to be 7% of the total water volume of the heating system. Boiler must be constructed in accordance with requirements from DIN 4702 and tested in accordance with requirements from standard EN 303-5.

From the main distribution collectors supplied with circulation pumps and three way valves, hot water supplies radiators throughout the school building. Boiler protection circulation pump system is installed to protect boiler from low temperature corrosion using a thermostat in return pipeline with *operating* temperature range 0˚C-60˚C.

Boiler is typically connected to the chimney with connection to fuel gas pipes. To increase boiler efficiency additional equipment is installed, cyclone CC 200-500 and adequate centrifugal fans intended for separating particles from the fuel gases. The fan is used for pulling fresh air into the combustion chamber, drawing fuel gas from boilers and their extracting through the chimney into the environment.

With the purpose of increasing system efficiency, in some systems, buffer tanks are installed, which absorb peaks in the demand for primary energy or be used as storage within an energy recovery context. They create a buffer volume of primary fluid that is available before passing into the distribution system. Distribution system consists of two identical distribution collectors with mounted circulation pumps, three way mixing valves, standard valves and indication of temperature and pressure.

Three-way mixing valve is a microprocessor-controlled valve designed to regulate the supply of water temperature to a radiant heating system by modulating the position of the valve. Mixed supply set points usually configured to reset from the outdoor air temperature.

An electronic unit control device was installed, to control boiler circuit, three way valves, hot sanitary water circuit, protection pump and recirculation pumps.

Circulations pumps are electronically commutated, regulated pumps consisting of two main parts of centrifugal pump of appropriate head and electronic regulator. Hydraulic part is hermetically sealed from motor assembly and has no moving seals. Pumps are powered by ECM permanent magnet motors that do not consume any energy to magnetize the rotor and thus provide high energy efficiency. An ECM motor is run by a frequency converter with an integrated PFC (Power Factor Correction) filter. Converter estimates current flow and head from the motor loading. That information is essential for differential pressure control.

In some schools, completely new radiator systems were installed, with the corresponding piping and radiators valves, but in some buildings existing radiators were in good condition and only refurbishment of installation was done, repair of certain radiators and similar. Automatic de-aeration valves are installed in higher points of the heating system ensuring proper distribution of heat.

5.4 Ventilation of sanitary facilities

This ventilation system is not considered as giving contribution to the energy efficiency but it was estimated as very important for the general comfort. Ventilation of sanitary joints is executed with spiral-fold ducts from galvanized steel sheets. Ventilation system in the toilets is done through PV-valves Φ125mm, ventilation capacity per toilet cell is V=80 m3/h.

The exhaust air is discharged with air fan through a circular duct TD-MIXVENT that is placed inside the toilet while on the outside of the building a fixed grate is placed. Control through a motion detector at the entrance, light and time switch is installed.

5.5 Electrical Installations

Electrical installations in most of the schools were very old with many defects on installations and in functionality. Being that schools were built in different time periods, there were three different types of electric installations.

The buildings are supplied with power by the public electric network of 0.4 kV. There are buildings with systems of TN-C type, which have combined neutral (N) and protective conductors (PE) in source of supply, TN-C-S type which have separate neutral (N) and protective conductors (PE) within installation and TT type where the consumer must provide their own connection to the earth, by installing a suitable earth electrode local to the installation.

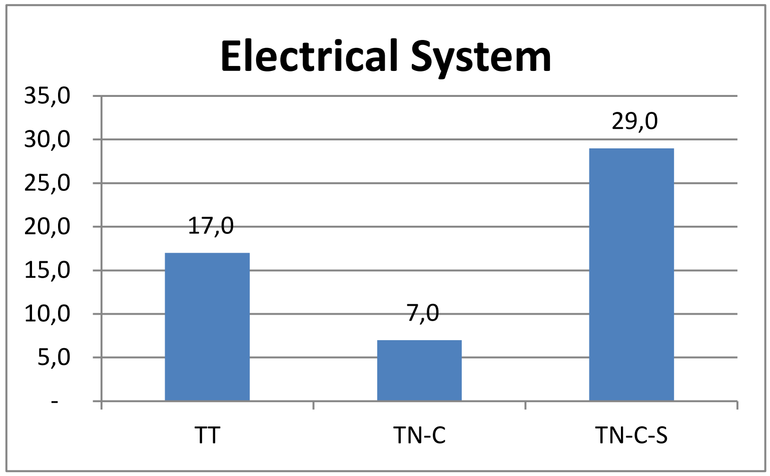


Chart 10 - Electrical System BEFORE EEM

From a total of 53 schools as presented on chart 10: schools with TT electric system, with TN-C electric system and with TN-C-S electric system.

5.5.1 Lighting before implementation of Energy efficiency measures

Lighting systems in buildings were very poor; there were very low illumination levels and most of the lighting was out of function. Most of the light fittings were damaged or out of use due to damages on the installations or defect of cabling.
The measured illumination level in classrooms varies between 30 lx – 210 lx, in corridors between 25 lux - 95 lux, in offices at an average of 190 lux and in the gym -170 lux, which is very low according to European Norm EN12464. An average of 40% of the lighting was functional which means that general indoor comfort regarding lighting and electric installations was very low. There were three types of light fittings installed in buildings, as listed below:

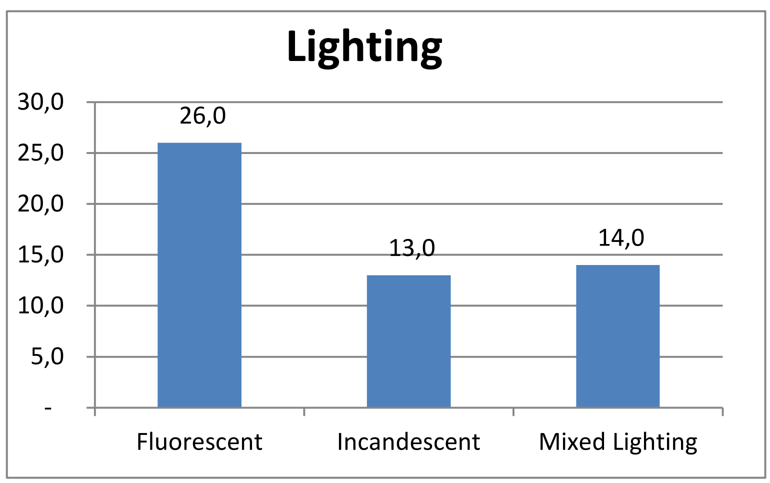


Chart 11 Lighting BEFORE EEM

- Fluorescent light fittings with electro-magnetic ballast
- Incandescent light fittings
- Reflectors with halogen light fittings.

Old buildings built between 1960 and 1980 usually had incandescent light fittings in all building areas including classrooms, offices, corridors, toilets and ancillary rooms with average illumination in classrooms at 60 lx.

Buildings that were built or renovated between 1980 – 1990 mainly had fluorescent light fittings with electro-magnetic ballast and low illumination in classrooms; offices and corridors with average illumination measured in classrooms of 170 lx, whereas lighting in toilets and ancillary rooms was incandescent. Reflectors were used only for gymnastic halls. From a total of 53 schools, breakdown is presented in chart 11.

5.5.2 Lighting after implementation of Energy efficiency measures

After renovations on lighting systems, general comfort increased significantly. Illumination level increased up to minimum 300 lux in classrooms, which is the minimum criteria for indoor lighting for schools and educational institutions.

The renovation of the lighting system included completely new light fittings in buildings including new cabling for power supply.

New lighting system implemented in schools consists of:

- For classrooms; fluorescent light fittings T8 2x36W/840 with electronic ballast and aluminum reflection.
- For corridors, fluorescent light fittings T8 2x36W/840 with electronic ballast and opal diffuser.
- For gymnastic halls, fluorescent light fittings T8 4x36W/840 with electronic ballast and aluminum reflection.
- For the toilets and other ancillary rooms, surface mounted luminaries with opal diffuser equipped with CFL 1x22W,
- Installation of manual switches and completely new cabling for lighting circuits.

5.5.3 Distribution Boxes before implementation of Energy efficiency measures

MDB (Main Distribution Box) and DB's (Distribution boxes) were very old, usually made of metal but in some buildings they were made of wood. Depending on the year of construction or renovation, fuses were convectional melting type or automatic tripping type. Mainly, there were no RCD (residual current device) protections on distribution boxes.

There were three types of distribution and electrical installations on beneficiary buildings:

- Distribution boards with conventional melting type fuses and no RCD protection (residual current device), installation Type TN-C with combined neutral (N) and protective conductors (PE) in source of supply;

- Distribution boards with automatic fuses and no RCD protection (residual current device), installation Type TN-C-S with separate neutral (N) and protective conductor (PE) within installation;
- Distribution boards with automatic fuses and RCD protection (residual current device), installation Type TT where the consumer must provide their own connection to earth, by installing a suitable earth electrode local to the installation.

From a total of 53 buildings, breakdown is presented in the chart below: 20 schools were with RCD protection,10 schools were with RCD protection only on some distribution boards and 23 schools were with no RCD protection at all.

From a total of 53 buildings, breakdown is presented in the chart below:10 schools were wiith conventional melting type fuse, 27 schools were with automatic fuses and 16 schools were with mixed fuses, automatic and conventional melting type.

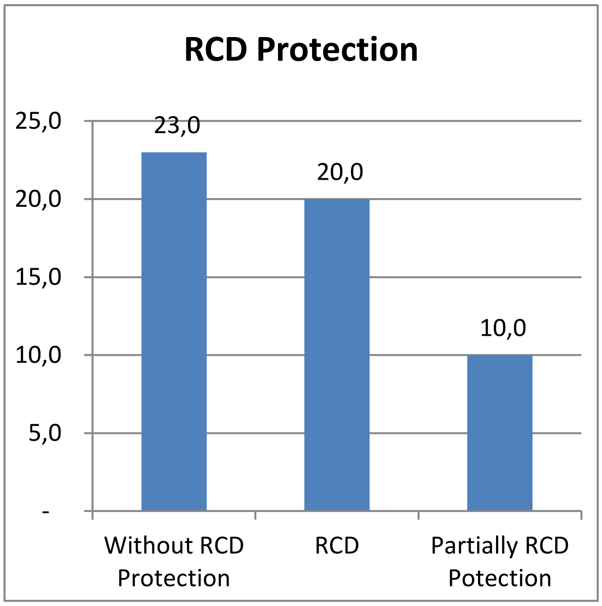


Chart 12 Fuse Protection BEFORE EEM

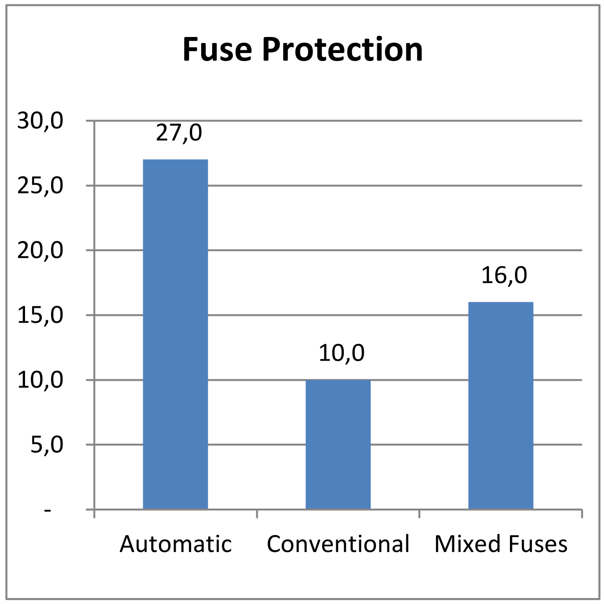


Chart 13 RCD Protection BEFORE EEM

5.5.4 Distribution Boxes after implementation of Energy efficiency measures

Only retrofitting of the Main Distribution Boards and all Distribution Boards was foreseen to be carried out.

Refurbishment of the current DB's was carried out according to EU regulations and technical specifications including new fuses, 24h timers complete with contactors for all lighting circuits, new RCD protections for each distribution board and all necessary connections.

Lighting groups are connected separately from the groups for the power sockets and other connections.

5.5.5 Boiler room electrical installations before implementation of Energy efficiency measures

There were two types of heating systems installed in buildings:

- Central heating systems
- Individual heating systems with wood stoves.

Electrical installations in boiler rooms in buildings with central heating were very old and partly functional. Fuses were of two types, conventional melting type and automatic type. Distribution Boards mostly were equipped with relays and contactors which were worn out and there was no RCD protection.

Buildings with individual wood stoves didn't have a boiler room, there was a wood stove in each room.
In a total of 53 buildings as presented on chart 14, 36 schools were with central heating systems and 17 schools were with individual wood stoves.

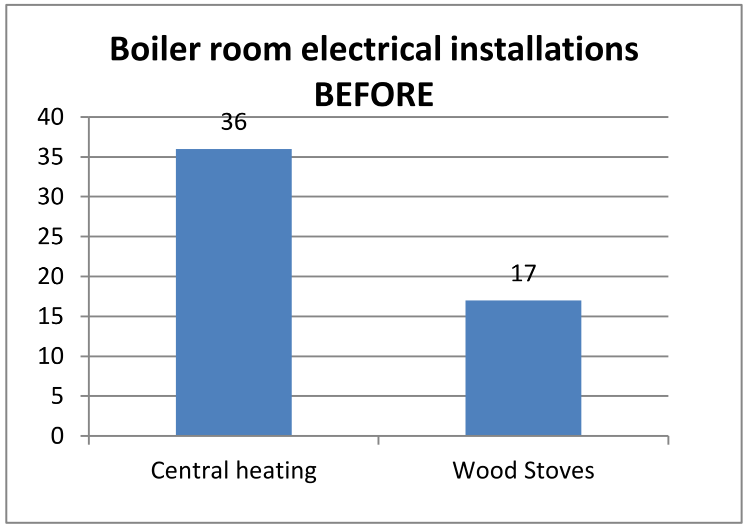


Chart 14 Boiler Room Electrical Installations BEFORE EEM

5.5.6 Boiler room electrical installations after implementation of Energy efficiency measures

Installations in the boiler room were carried out according to European Norms and Standards including:

- Installation of new Distribution Board in the boiler room including a main switch, contactors and relays, automatic switches for pumps, automatic controls, new RCD fuses and other elements
- Supply and laying of cables in the boiler room;
- Lighting installation in the boiler room;
- New automatic control for central heating according to European Standards.

Automatic Control has a central control unit with appropriate number of analogue and digital I/O, with possibilities for further connections with higher level management, temperature sensors on return water pipe, outside temperature sensors, room temperature sensor, actuators for the three-way valves and all necessary connections for the equipment.

6. Breakdown of implemented Energy Efficiency Measures

These works are divided into two categories; works which impact reduction of energy consumption and other works which have no impact on energy efficiency performance of school buildings. The second type of works is important in order to increase the overall indoor comfort in schools.

The following table displays the main categories of implemented works with respective investments per each type of work:

Table 2: Investment Cost

Item no.	DESCRIPTION	INVESTMENT COST
1	TOTAL ENERGY EFFICIENCY MEASURES	9,922,615.59
2	TOTAL NON ENERGY EFFICIENCY MEASURES	1,817,635.32
3	**GRAND TOTAL (53 schools)**	**11,740,250.91**

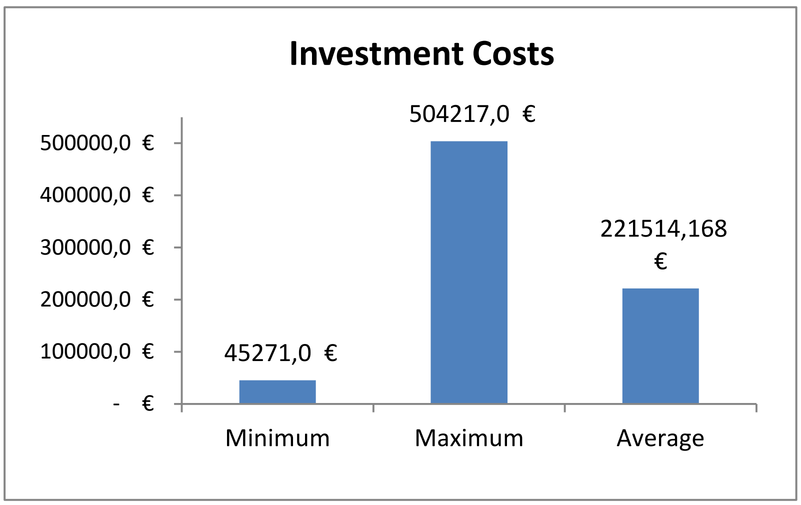


Chart 15: Total Investment (min, max, average)

6.1 Breakdown of unit investments of EEM per building

The works which impact reduction of energy consumption are divided into building elements and activities related to mechanical and electrical installations. The following table shows the main categories of implemented works with respective investments per each type of work:

Table 3: Breakdown of investment cost per building element and other activities

Item no.	WORKS DESCRIPTION	INVESTMENT COST
1	FACADE	1,191,941

2	ROOF	2,194,313
3	DOORS&WINDOWS	1,915,354
4	FLOOR	92,207
5	CENTRAL HEATING , HEATING STATION (CHS)	2,736,927
6	ELECTRICAL	1,697,874
7	SOLAR	94,000
	SUB TOTAL ENERGY EFFICIENCY MEASURES	**9,922,616**
8	NON ENERGY EFFICIENCY MEASURES	1,817,635
	SUB TOTAL NON ENERGY EFFICIENCY MEASURES	**1,817,635**
9	**GRAND TOTAL (53 schools)**	**11,740,251**

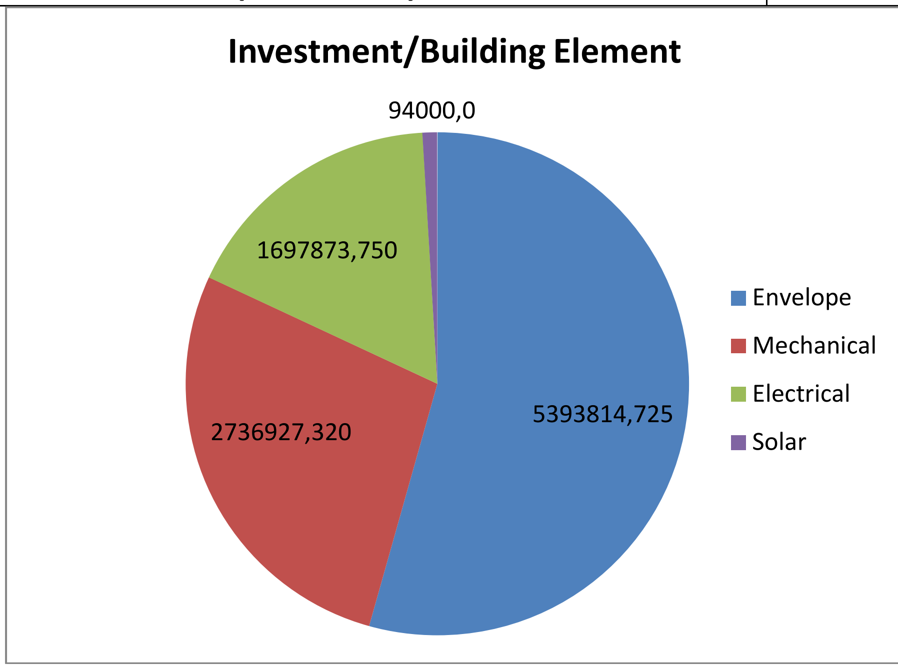


Chart 16: Diagram of total investments divided per activity

6.2 Specific investment in 53 schools

The average specific investment as presented in chart 17. is 97.12 €/m², where the highest specific investment is noticed at school no.34 "Migjeni" as 196 €/m², while the lowest specific investment is at school no.21 "Deshmoret e Kombit" with 37.76 €/m².

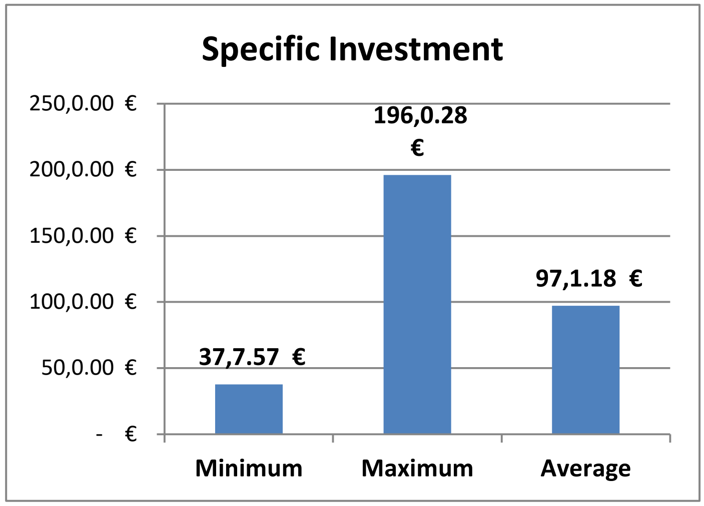


Chart 17 Specific Investment per m^2 (min, max, average)

The second school cannot be presented as a typical referent building, since the number of EE measures is quite limited. A referent school buildings for the lowest specific investment is school no.07 "Pandeli Sotiri" with 66.67 €/m², where most of the EE Measures, such as building envelope improvements and mechanical and electrical installations works are included.

7. Energy Consumption

Total energy consumption before the implementation of EE Measures is presented in the table below, which is **34,391,716** [kWh/a], while the total energy consumption after is **12,970,817** [kWh/a]; so the total savings for all 53 schools is **21,420,899** [kWh/a] with 62% in overall percentage.

Table 4: Total Energy Consumption

Total Energy Consumption		
Before	**After**	**Savings**
[kWh/a]	[kWh/a]	[kWh/a]
34,391,716	**12,970,817**	**21,420,899**

As described in table below, most of the savings are achieved through investments in the building envelope (external walls, roofs, windows & doors, and floors above ground) with savings of 58.56%.

Table 5: Energy savings per activity

Description	**Energy Savings**	
	[kWh/a]	**%**
Building Envelope	12,544,279	**58.56%**
Mechanical Installations	7,437,175	**34.72%**
Electrical Installation	1,387,875	**6.48%**
Solar Collectors	51,570	**0.24%**

Comparison of average specific consumption before and after retrofitting is presented in Chart/diagram no.20 where the average specific energy savings are 197 kWh/m^2,a.

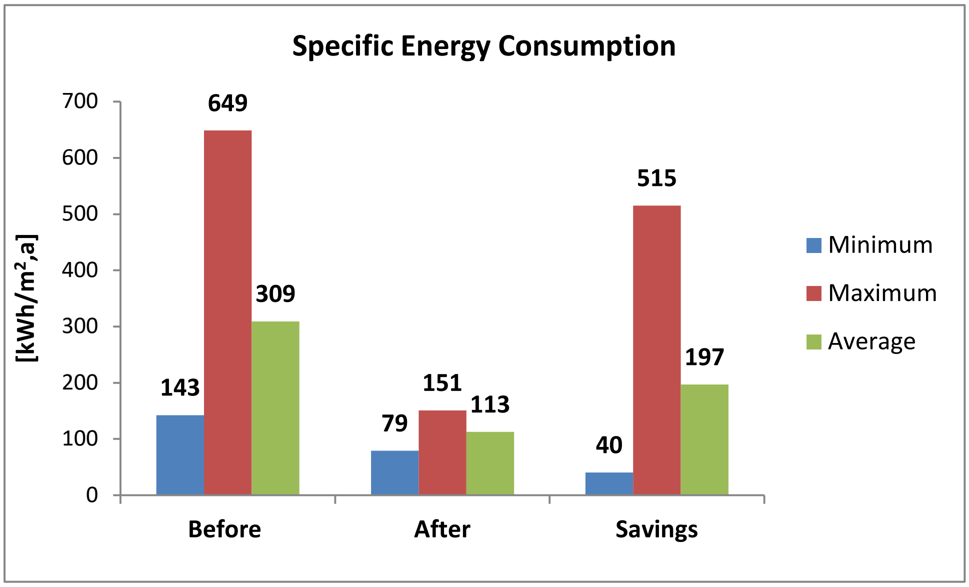


Chart 18: Specific Energy Consumption BEFORE, AFTER & SAVINGS

Detailed breakdown of energy conservation measures applied per building along with energy consumption before and after refurbishments is presented in the report for each respective school located in the annex portion of the report.

7.1 EPBD Labelling

Results of average specific energy consumption presented in Chart 21, show that based on Directive 2013/31/EU[1], school buildings are categorized in category **G** before implementation of EEM, while they have reached category **D**, quite close to category **C**, after implementation of measures.

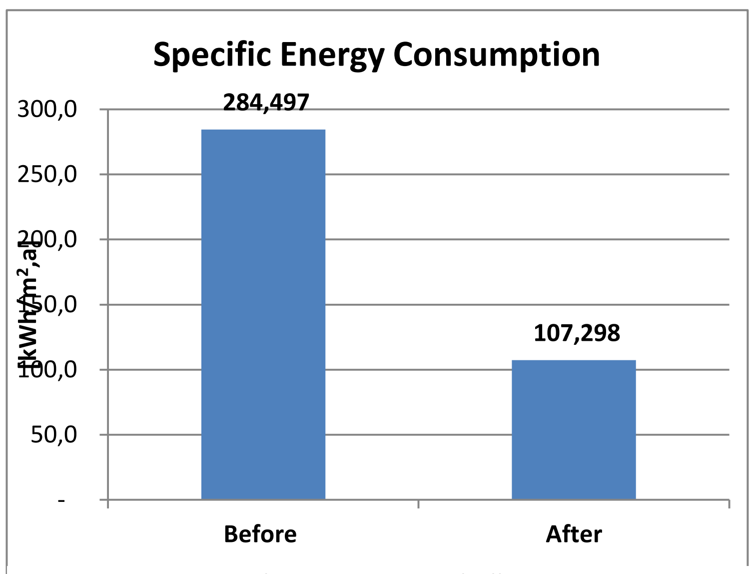


Chart 19: EPBD Labelling

[1]Directive 2010/31/EU of the European Parliament and the Council on the Energy Performance of the Buildings

8. CO_2 Reductions

The difference in average annual specific CO_2 emissions reductions follow the same pattern as energy consumption, which is 62% in total or 8703 t/a. The chart below indicates an average of 164 t/a of carbon emission reductions for schools. The highest CO_2 emission reduction is noted at Mitrovica school no.34 “Migjeni” with cca 525 t/a, while the lowest is at Malisheva school no.21 “Deshmoret e Kombit” with cca 16 t/a.

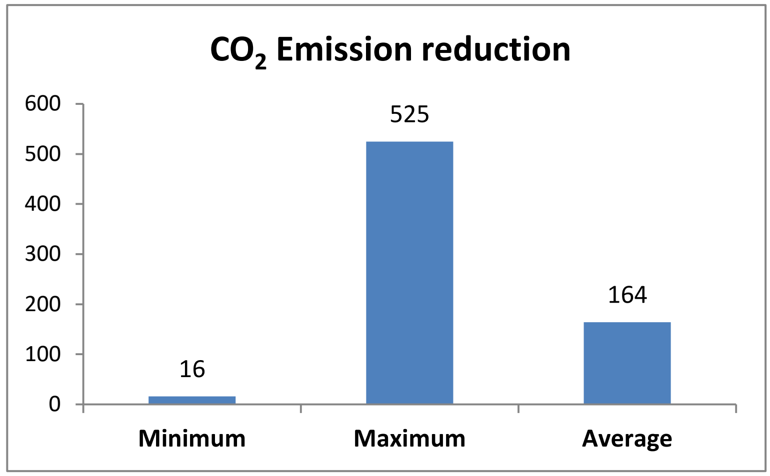


Chart 20 : CO2 Emission Reduction (min, max, average)

9. Thermal Comfort

Energy-efficient buildings are only effective when the occupants of the buildings are comfortable. If they are not comfortable, then they will use alternative means of heating or cooling a space such as space heaters or window-mounted air conditioners that could be substantially worse than typical Heating, Ventilation and Air Conditioning (HVAC) systems. This situation was present almost in all school buildings. All these buildings were huge energy consumers that did not fulfill basic comfort conditions. Therefore, the baseline of analysis of implementation of Energy Efficiency Measures, energy consumptions, energy savings and reduction of CO2 emission is established based on comfort conditions.

Thermal comfort is difficult to measure because it is highly subjective. It depends on the air temperature, humidity, radiant temperature, air velocity, metabolic rates and clothing levels and each individual experiences these sensations a bit differently based on his or her physiology and state.

According to the ANSI/ASHRAE Standard 55-2010, thermal comfort is defined as “that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.” Also known as human comfort, thermal comfort is the occupants’ satisfaction with the surrounding thermal conditions and is essential to consider when designing a structure that will be occupied by people.

A cold sensation will be pleasing when the body is overheated, but unpleasant when the core is already cold. At the same time, the temperature of the skin is not uniform on all areas of the body. There are variations in different parts of the body which reflect the variations in blood flow and subcutaneous fat. The insulation quality of clothing also has a marked effect on the level and distribution of skin temperature. Thus, sensation from any particular part of the skin will depend on time, location and clothing, as well as the temperature of the surroundings.

Upon completion of the interviewing procedure, the questionnaires are collected and archived in separate files for separate fields and each selected building. General information about building, building location, reference room and outdoor temperature were filled in on questionnaires by surveyor.

Knowing that interviews were anonymous, Consultant used the same numbering for both thermal and social surveys. Moreover, all general information, such as gender, age and profession, as well thermal survey and awareness answers were labelled with specific numbers for easier data processing. For this purpose, tables of legends which clearly define each category were designed. Attached to this report are samples of Legend sheets.

All answers separated by respondent, respondents' age, gender, profession and institution were then collected in separate tables for further statistical analysis.

Consultant designed unique tables with range of ratings. Using standard statistical analysis for Thermal Environment Survey, Consultant used the Predicted Mean Vote (PMV) which refers to a thermal scale that runs from Cold (-3) to Hot (+3), originally developed by Fanger and later adopted as an ISO standard. The recommended acceptable PMV range for thermal comfort from ASHRAE 55 is between -0.5 and +0.5 for surveyed spaces in all selected buildings.

The vote predicted was only the mean value to be expected from a group of people and he extended the PMV to predict the proportion of any population that will be dissatisfied with the environment. A person's dissatisfaction was defined in terms of their comfort vote. Those who vote outside the central three scaling points on the ASHRAE scale were counted as dissatisfied. PPD is defined in terms of the PMV and adds no information to that already available in PMV. The distribution of PPD is based on observations from climate chamber experiments and not from field measurements.

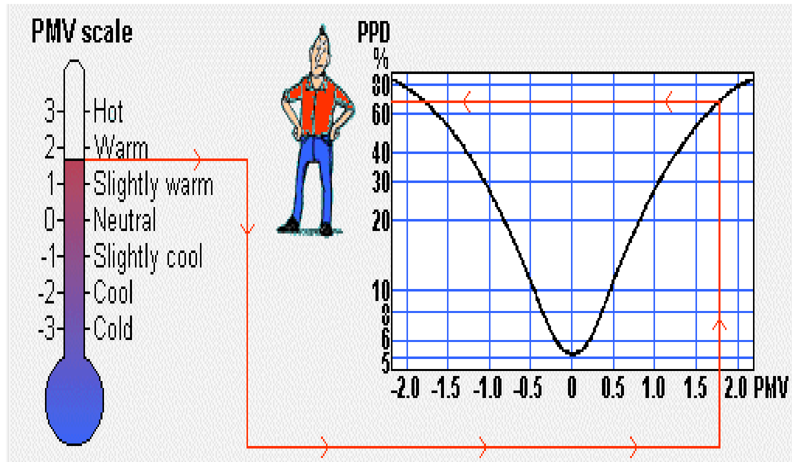
Using this recommendation, the Consultant has collected all data from questionnaires and calculated PPD's and PMV's for each interviewed person and as a total.

Value	Sensation
-3	Cold
-2	Cool
-1	Slightly cool
0	Neutral
1	Slightly warm
2	Warm
3	Hot

Questionnaires and respective results are presented as attachment. Calculations of PMV's and PPD's are made using appropriate thermal Comfort Spreadsheets and quick calculators.

As said above, the PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale used by the Consultant for anonymous interviews.

On the other hand, Predicted Percentage Dissatisfied (PPD) Index is a quantitative measure of the thermal comfort of a group of people at a particular thermal environment. Predicted Percentage of Dissatisfied (PPD) predicts the percentage of occupants that will be dissatisfied with the thermal conditions. It is a function of PMV, given that as PMV moves further from 0, or neutral, PPD increases. The maximum number of people dissatisfied with their comfort conditions is 100% and as you can never please all people, all of the time, the recommended acceptable PPD range for thermal comfort from ASHRAE 55 is less than 10% persons dissatisfied for an interior space.



Final results from comfort data analysis have shown that after implementation of EE measures all schools are in range of acceptable comfort conditions, respectively -0.7 to +0.7.

10. Financial Appraisal

The Equity Payback Period (EPP) for respective buildings is presented in Table no.6 and Chart 23. The EPP in schools is **7.26 years**.

The same table & chart indicate the comparison between investments in the upgrade of building envelope and improvement of other systems (mechanical, electrical, solar). The total investment for all schools is **9,922,616 €.** The financial analysis is presented in table no.6 with the total investment per activity.

Table 6: Financial Appraisal

Nr.	Elements	Energy saved [kWh/a]	Savings [EUR]	Investment [EUR]	NPV [EUR]	IRR [%]	SIR	PBP [years]
1	Electrical	1,387,875	152,666 €	1,697,874 €	695,831 €	9.04%	2.35	9.72
2	Mechanical	7,437,175	192,690 €	2,736,927 €	284,327 €	6.09%	1.84	12.05
3	Envelope	12,983,023	880,983 €	5,393,815 €	8,419,417 €	18.29%	4.28	5.63
4	Solar System	51,570	6,448 €	94,000 €	7,098 €	5.80%	1.80	12.32
5	**Grand total**	**21,420,899**	**1,232,788 €**	**9,922,616 €**	**9,406,682 €**	**13.61%**	**3.25**	**7.26**

Chart below presents the PBP for total investments only for EE Measures and it is 7.26 years.

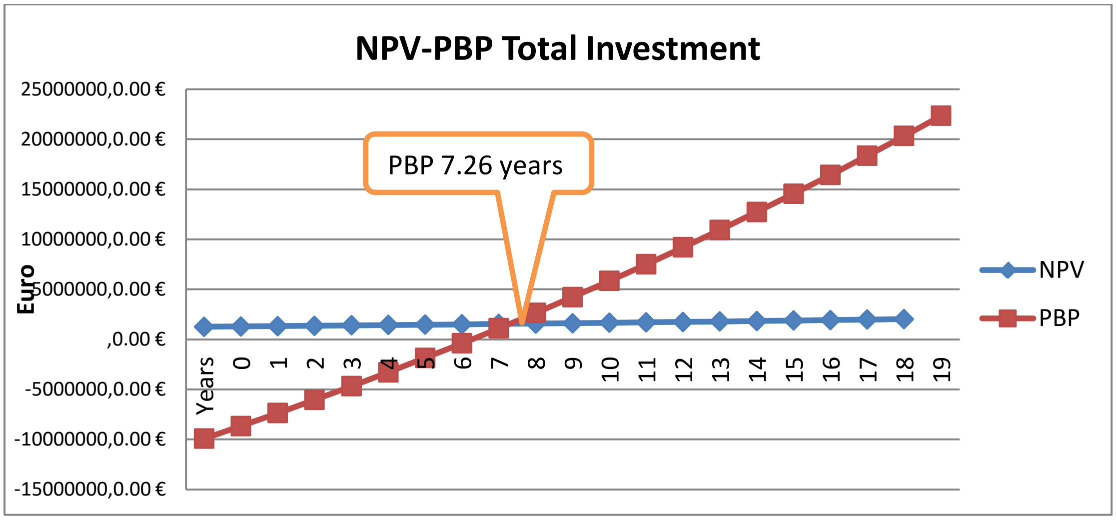


Chart 21: PBP total investment EE Measures

Chart below presents the PBP for total investments for all Measures, including Non-EE Measures and it is 8.46 years.

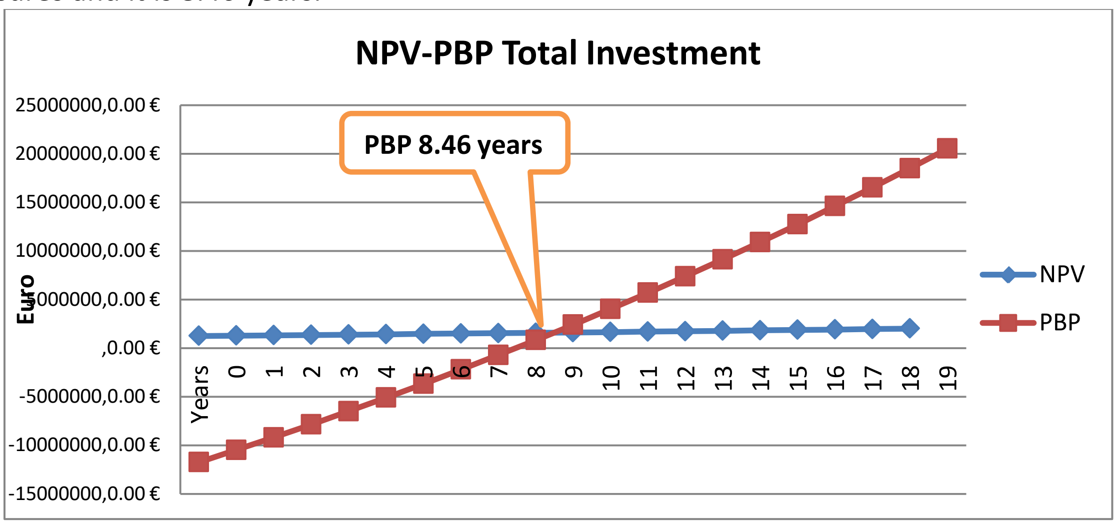


Chart 22: PBP Total investment

11. METHODOLOGY OF ENERGY EFFICIENCY MEASURES

Baseline data

Baseline data was gathered over a period of 36 months between 2010 to 2012 and 2011 to 2013, as follows:

- Monthly consumption of electricity and all other forms of fuel used for heating (e.g. oil, coal, wood, etc.), including further data on the calorific content of those fuels, as well as the bulk density of deliveries;
- Daily operation hours for each building and daily building occupancy levels (in terms of staff/students/patients), throughout the year, for the same months;
- Information on the illumination and internal temperatures used for each building during the heating season.

All Energy Efficiency potentials and CO_2 reduction per used measure have been identified and the data is presented in table and graph format.

EE Measures approach

The results of the measurements performance for both "pre" and ‘post’ retrofit stages of the buildings were analyzed on a comparative basis presented through tables, charts and percentages, which have included the following activities:

- Gathering of general data
- Selection equipment for testing on site
- Detailed data collection and site measurements for before and after implementation of retrofit measures
- Analysis of data
- Preparation of MVE report

The final product has produced the technical report that includes:

- Quantified energy savings of the retrofitted public buildings;
- Assessment of improvement in air quality through reduction in emission of local air pollutants and greenhouse gases produced by boilers using duty fuels;
- Assessment on increased end-user satisfaction measured through improvement in indoor air quality, indoor temperature and perception surveys of improvement in comfort of students.

National Laws, Regulations and relevant documents were consulted for assessments, calculations and specifications in this project.

Measuring Procedures

Preparatory works
All visits were coordinated with school directors. Municipal representatives were informed, too.

Required preparatory works were carried out by consultant's team of experts, in terms of planning, location and number of schools to be visited. Forms, tables, questionnaires and other relevant documents for collection of all requested information for future analysis were duly prepared in advance. All measuring equipment's were checked regarding their performance.

Collection of information

Relevant above-mentioned documents were utilized for:

- Building General Data (type, name, location, year of construction, occupancy),
- Building Envelope Description (external walls, windows, roof and floor structures/components),
- Heating System (type of system in operation, type & number of radiators, distribution pipeline),
- Electrical Installation (lighting illumination, cabling, distribution boards, boiler room installation);
- Energy consumption of electricity and fuel used for heating, cooling, (e.g. oil, LPG, coal, wood).

Indoor Air Quality

The survey, through respective questionnaires, has assessed the occupants' perception of the internal environment in terms of: thermal comfort, CO_2 parameters and indoor parameters (temperature, lighting levels, air velocity, HVAC, hot sanitary water installation).

Measurements

Measurements carried out in all school buildings for the phase before EEM are: temperature measurement, air humidity, illumination and exhaust gas measurements. Exhaust gas measurements included: O_2 concentration level in percentage, CO levels in ppm, CO_2 concentration level in percentage, fuel gas temperature, ambient temperature in the boiler room, excessive air in percentage and efficiency.

Measuring equipment

Measuring equipment used in the phases before and after listed below:

- Thermo-graphic camera (for determination of thermal losses in building envelope),
- Fuel gas analyzer (to measure the percentage of oxygen, carbon monoxide and carbon dioxide and the temperature of the fuel gas and ambient temperature as well, including boiler efficiency),
- Multi-function measuring instrument (indoor air parameters of CO_2, relative humidity and room temperature),
- Thermal flux (measurement of building structure U-value)
- Light Meter (measurement of luminance),
- Multi-meter (measurement of electrical parameters).
- Laser distance measure instrument.

Analysis

The baseline scenario for energy consumption was the calculated scenario for comfort conditions. Detailed analysis, energy and financial, before and after energy efficiency measures were implemented and presented through **RET Screen International - Clean Energy Project Analysis Software**, as well as energy savings per year.

Monitoring, Verification and Evaluation (MVE) of EEM

The monitoring, verification and evaluation of the impact of the implemented energy efficiency measures was analyzed for the measured performance of 'pre' and 'post' retrofit stage of implemented EEM in buildings. The results for each building subject to this report are presented through tables, charts and percentages.

The findings of the MVE, including properly calculated energy and cost savings, investment payback period, as well as CO_2 emission reductions per building, are presented based on:

1. Survey Report (Description Before EEM)
2. Detailed Report (Before & After EEM)
3. Summary Report for 53 buildings
4. Tables, charts, photos, thermal images, detailed calculations

12. COEFFICENTS OF TRANSMISSION THROUGH BUILDING ENVELOPE

U-values of main Building's Envelope Elements (before & after)

This chapter contains a brief description of U-values of the main existing building elements, such as walls, roof, windows, doors and floors, **before & after** implementation of Energy efficiency measures.

12.1 External walls

U-values for external walls depend on the wall layer composition and construction period.

For the 25 schools with solid brick walls constructed within the period 1950-1980 the U-value **before** EE Measures varies from 1.12 W/m^2K , with only a few schools with thickness of external walls 50cm to 1.37 W/m^2K and at most of the schools with thickness of 38cm. The improved U-values for these external walls **after** are 0.31 – 0.33 W/m^2K.

The U-value **before** EE Measures for the 26 schools with hollow brick walls of 25cm thickness, constructed without thermal insulation within the period 1980-2004, varies from 1.80 W/m^2K to 1.92 W/m^2K . The improved U-value for the external walls **after** implementation of EEM is mostly 0.35 W/m^2K.

U-value for the 2 schools with already installed thermal insulation is 0.35 W/m^{2}K.
There is no big difference between the U-values **after** EEM for the walls of 50cm compared to those of 38cm thickness or 25cm (0.31 – 0.35 W/m^{2}K) due to the installation of same thickness of thermal insulation, which is 8.0cm. This highlights the impact of thermal insulation versus wall thickness. In order to achieve the improved U-values after the implementation of Energy Efficiency Measures it is of great importance to avoid the thermal bridges. This is achieved through the entire thermal insulation of vertical facade, including projections of columns and beams, windows and door reveals/soffits and lintel areas, all canopies, balconies, cantilevers, overhangs and overhang eaves. High attention should be dedicated to the transition zone of facade with roof.

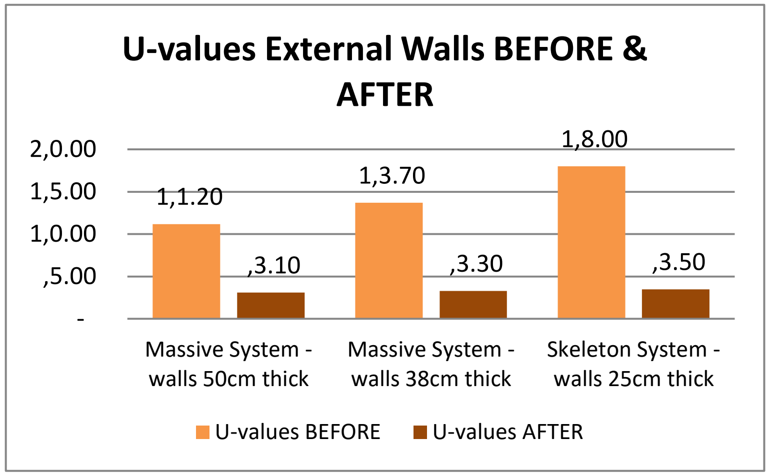


Chart 23 U-values External Walls BEFORE & AFTER

12.2 Roofs

U-values for roofs depend on the composition of roof slab layers. U-value for the 2 schools with already installed thermal insulation is 0.5 & 0.6 W/m^{2}K.

The U-value of roofs **before** EE Measures varies from 1.1 W/m^{2}K with roof slab system "Avramenko", 2.04 W/m^{2}K 1.1 with roof slab system "Monta" and 3.3–4.0 W/m^{2}K with roof concrete slabs in situ; where for the average of schools is 2.6 W/m^{2}K. The U-value of roofs **after** the implementation of EE Measures at most of the schools is 0.2 W/m^{2}K.

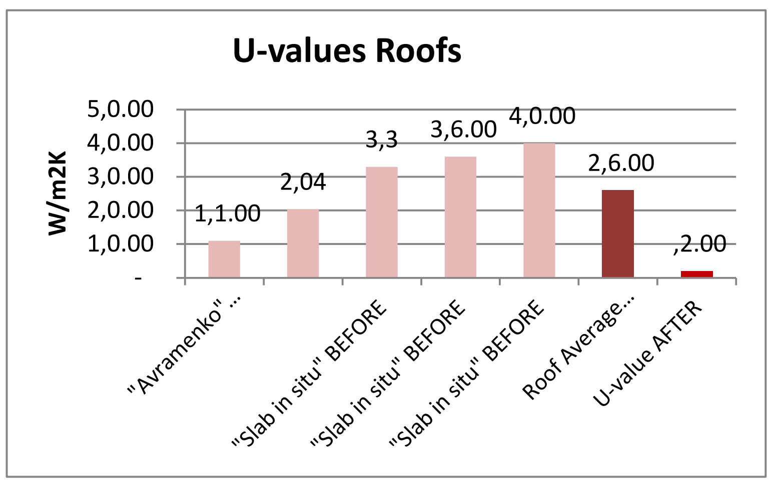


Chart 24 Roof U-values Roof, Before & After

12.3 Windows

U-values for windows depend on the frame, glazing characteristics and their current condition.

The U-value of windows **before** EE Measures varies from 2.5 – 5.2 W/m^2K; where at 2 schools it is 2.5 W/m^2K, at 4 schools it is 2.8 W/m^2K, at 28 schools it is 3.5 W/m^2K, at 6 schools it is 3.8 W/m^2K, at 7 schools it is 4.0 W/m^2K, at 3 schools it is 4.5 W/m^2K, and at 4 schools it is 5.2 W/m^2K.

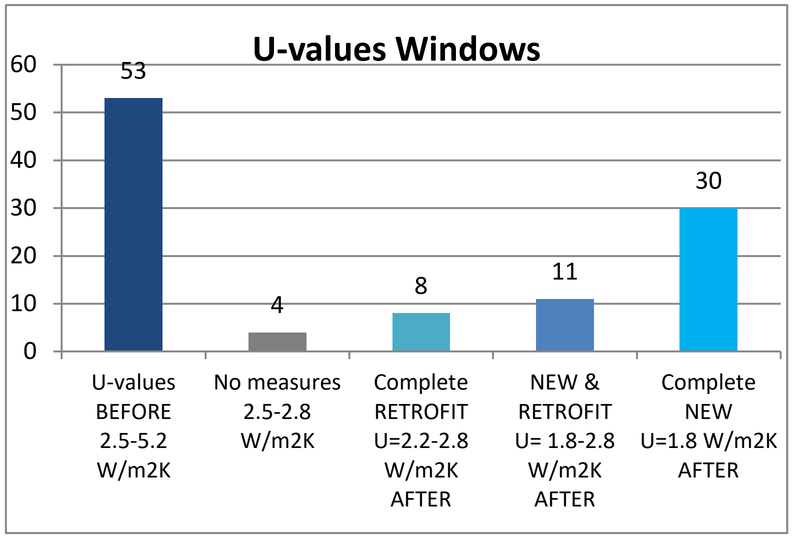


Chart 25: U-values WINDOWS, Before & After

The U-value of windows **after** EE Measures varies from 1.8 – 2.8 W/m^2K; where at 30 schools with completely new windows and 11 schools with partially new windows is 1.8 W/m^2K, at 8 schools with complete retrofitting and 11 schools with partial retrofitting is 2.2-2.8 W/m^2K and at 4 schools with no EE measures is 2.5-2.8 W/m^2K.

12.4 External doors

U-values for doors depend on the frame, glazing characteristics and their current condition.

The U-value of doors **before** EE Measures varies from 2.8 – 5.2 W/m^2K; where at 9 schools it is 2.8 W/m^2K, at 23 schools it is 3.5 W/m^2K, at 6 schools it is 3.8 W/m^2K, at 7 schools it is 4.0 W/m^2K, at 6 schools it is 5.0 W/m^2K, and at 2 schools it is 5.2 W/m^2K.

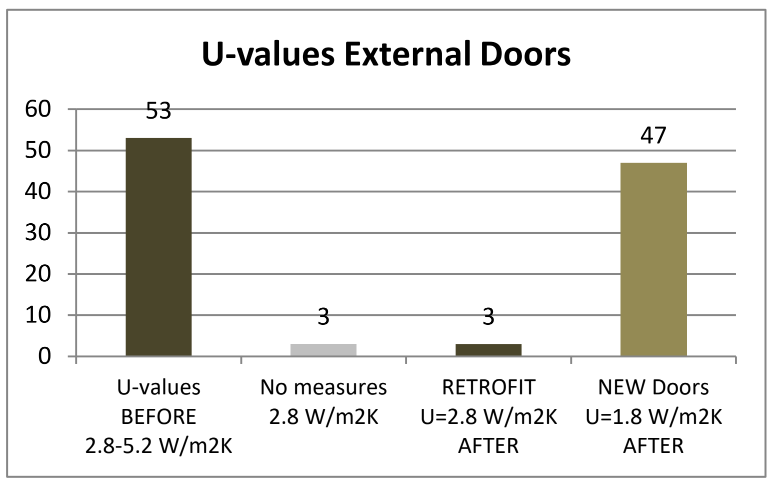


Chart 26: U-values External Doors, BEFORE & AFTER

The U-value of doors **after** EE Measures varies from 1.8 – 2.8 W/m^2K; where at 47 schools with new external doors it is 1.8 W/m^2K, at 3 schools with retrofit measures is 2.8 W/m^2K and at 3 schools without EE Measures it is 2.8 W/m^2K, same as before.

12.5 Floors

In the 53 schools subject to this report, the U-value of floors **before** EE Measures varies from 1.0 – 2.3 W/m^{2}K, depending on the composition of floor layers. New PVC flooring was installed in 25 schools out of which thermal insulation was installed in 12 schools. The U-value of the floors at these 12 schools before EEM was 1.72 - 2.3 W/m^{2}K, while **after** the implementation of EE Measures the U-value varies from 0.93 - 0.96 W/m^{2}K.

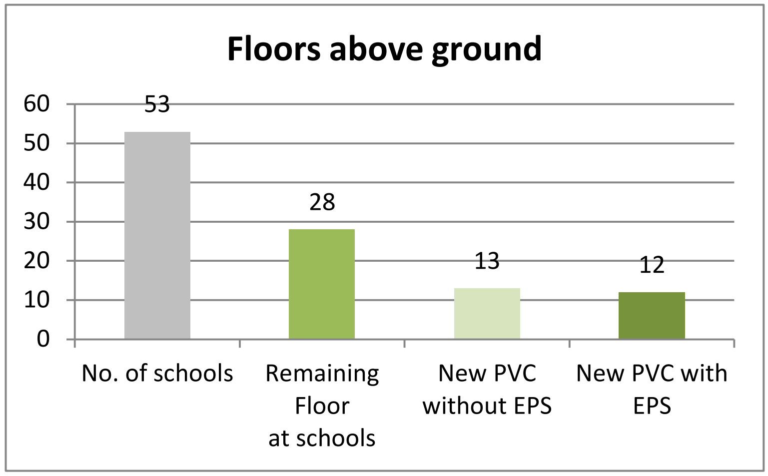


Chart 27 Floors above ground, BEFORE & AFTER

13. Conclusions

Significant energy consumption savings have been achieved for all refurbished buildings with annual savings of an average of **62**% which amounts to **21,420,899** kWh/year for the analyzed **53 schools**. Difference in average annual specific CO_2 emissions reduction follows the same pattern as energy consumption, which is 62% in total or **8703 t/a**. The Equity Payback Period (EPP) for EE Measures is **7.26 years**, while the EPP for total investments is **8.46 years**.

By this report, it is presented the breakdown of schools with respect to Municipality, age, area, total and specific energy consumption (before, after and savings), investment costs, net savings, payback period, CO_2 emissions reduction and specific investment. Total investment costs are **11,740,251 €**, while the costs regarding EE Measures are **9,922,616 €** and for non EE Measures - **1,817,635 €**. Average specific investment per school building is **97.12 €.**

The breakdown with respect to total and specific energy consumption (before, after and savings) is presented in table 7 below:

Table 7: Total and specific energy consumption

Description	Unit	Before	After	Savings
Total Energy Consumption	[kWh/a]	34,391,716	12,970,817	21,420,899
Average Specific Energy Consumption	[kWh/m2,a]	284	107	177