Project co-financed by the European Regional Development Fund

TEESCHOOLS

Transferring Energy Efficiency in Mediterranean Schools

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

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

DELIVERABLE NUMBER: 5.3.3

TITLE OF DELIVERABLE: WP5 Renovation Plan for tested building
WP n. 5: CAPITALISING

ACTIVITY n. 5.3. WP Integration of results in the action plans

PARTNERS INVOLVED: Cyprus Energy Agency

2019

Contents

ABBREVIATIONS

NZEB	Nearly Zero Energy Building
CEA	Cyprus Energy Agency
MoECSY	Ministry of Education, Culture, Sports and Youth
ERDF	European Regional Development Fund
NPV	Net Present Value
NCF	Net Cash Flow
TFA	Treated Floor Area
HFA	Heated Floor Area
IES-VE	Integrated Environmental Solutions – Virtual Environment (Software)
RH	Relative Humidity
PV	Photovoltaic (System)
CFL	Compact Fluorescent Lamp
LED	Light-Emitting Diodes
EPC	Energy Performance Certificate
EAC	Electricity Authority of Cyprus
RAA	Regulatory Administrative Act
LCC	Life Cycle Cost

UNITS

1 kWh electricity	2.7 kWh (Primary)
1 kWh thermal (Heating Oil)	1.1 kWh (Primary)
1 kWh_{pr} electricity	0.794 $kgCO_2$
1 kWh_{pr} thermal (Heating Oil)	0.266 $kgCO_2$
1 kg Heating Oil	11.75 kWh
1 L Heating Oil	10.10 kWh

1. OBJECTIVE OF THE PLAN

The Cyprus Energy Agency in the framework of the implementation of the project "TEESCHOOLS", which is co-financed by the European Regional Development Fund, carried out Energy Audits at five selected public-primary school facilities. The Energy Audits were based on the EN 16247 standard and were implemented within the Work Package 3 of the TEESCHOOLS project, during the academic year 2017 - 2018.

The aim of the energy audits was the evaluation of the schools' current energy consumption and the establishment of actions and measures that will result in energy savings and exploitation of renewable energy sources. These measures were divided in two categories as follows: (a) viable individual interventions for energy performance upgrade and (b) upgrade of the school building to a Nearly Zero Energy Building (NZEB), as this is defined in the national legislation[1]. The NZEB scenario was the ultimate target of the TEESCHOOLS project, therefore the five pilots were evaluated based on the criteria set on the Decree of 2014 (RAA 366/2014).

The individual energy audit reports included the evaluation of the buildings' envelope and electromechanical equipment, as well as the feasibility analysis of the measures for the improvements of the schools' energy performance[2]. This report constitutes an aggregate renovation plan based on the pilot results from each of the Energy Audits.

The main objective of the renovation plan is to propose technical and financial solutions for the school buildings in order to reduce energy consumption and CO_2 emissions. The solutions provided for each school are based on technoeconomic analysis and in accordance with the identified needs of each building.

In brief, the plan is consisted of some general information of the regions of the pilot schools (Climatic Zones), as wells as the state-of-art of the buildings in terms of construction and energy systems characteristics, based on the energy audits that have been carried out. The main measures proposed for implementation and financing recommendations are also included. Finally, the benefits of the energy renovations to NZEB level are presented, in terms of primary energy consumption, carbon emissions and energy bills.

[1]The Regulation on the Energy Performance of Buildings (Requirements and technical characteristics that must be met by a nearly zero-energy building) Decree of 2014 (RAA 366/2014) sets out the requirements that must be met by a building in order to be classified as NZEB. More information provided in Annex 7.1.

[2] It is noted that during the implementation of the energy audits, specific Questionnaires were also created and distributed to the personnel of each school in order to evaluate their comfort levels and their willingness to change their behaviour to save energy. The results of the questionnaires were compared selectively with data collected from data loggers (for RH and Temperature), which were placed in specific classrooms. Nevertheless, those results are not included in this Plan as they were an extra action adopted by CEA in order to evaluate thermal comfort levels in the classrooms of typical primary school buildings, as an additional input.

2. GENERAL INFORMATION

2.1 Region

Three out of the five pilot schools are located in Lefkosia [Nicosia] the capital of Cyprus. The remaining two are located in Larnaka District. The areas were selected to represent the Climate Zones where the majority of school buildings are located [Figures 1 and 4]. Four of the schools are located in Municipalities, whereas one, the Voroklini primary school, is located in the community of Voroklini.

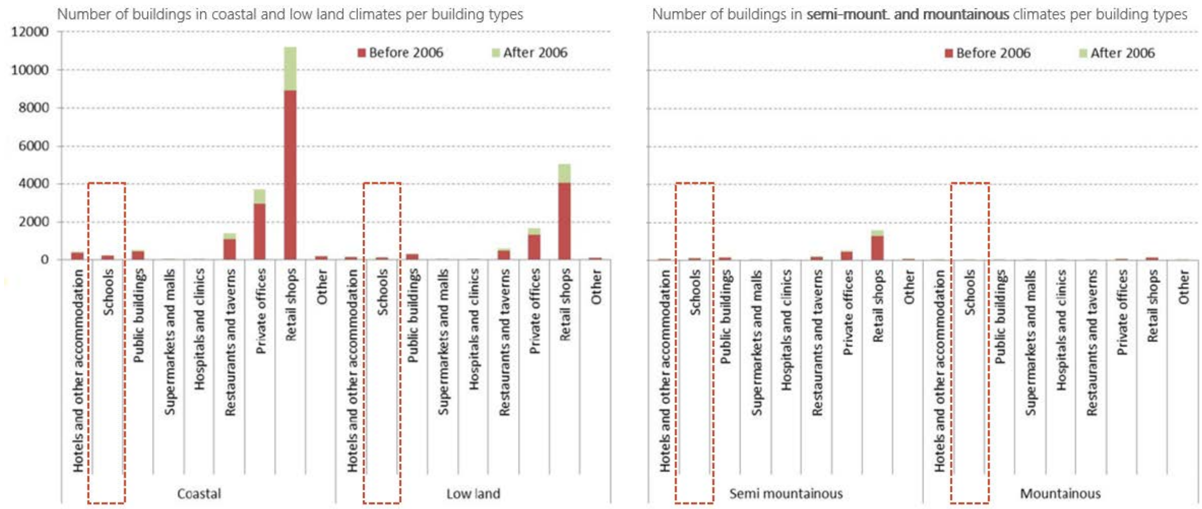


FIGURE 1: NUMBER OF SCHOOL BUILDINGS PER CLIMATIC ZONE. SOURCE: ECONOMIDOU M., ZANGHERI P., PACI D. JRC TECHNICAL REPORTS 'FINAL REPORT LONG-TERM STRATEGY FOR MOBILISING INVESTMENTS FOR RENOVATING CYPRUS NATIONAL BUILDING STOCK (D1.8)' - LIMITED DISTRIBUTION, 2017

Lefkosia, lies approximately at the geographic centre on the banks of the 'Pedieos' River, at around 130 m elevation, with latitude and longitude coordinates of 35° 11' 8.0376'' N and 33° 22' 56.1900'' E, respectively. Larnaca, is a coastal city located on the southern coast of Cyprus and the capital of the eponymous district. It is on an elevation of about 26 m, with latitude and longitude coordinates of 34° 55' N and 33° 38' E, respectively [Figure 2].

More specifically for the selected primary schools [Figure 3] the following apply:

- School 1 – CZ2: Hadjigeorgakis Kornesios Primary School, Aglantzia Municipality - is located in the mid-east perimeter of Greater Nicosia.
- School 2 – CZ2: Ayios Georgios 3rd Primary School, Lakatamia Municipality - is a suburb of Nicosia district, located in the Southwest perimeter of Greater Nicosia.
- School 3 – CZ2: Ayios Andreas Primary School [CA,CB], Nicosia Municipality - is located approximately in the mid of Greater Nicosia.
- School 4 – CZ1: Livadia Primary School, Livadia Municipality - is a suburb of Larnaca district, located approximately on the centre-east site of the district.
- School 5 – CZ1: Voroklini Primary School, Voroklini community - is a suburb of Larnaca district, located approximately on the centre-east site of the district.

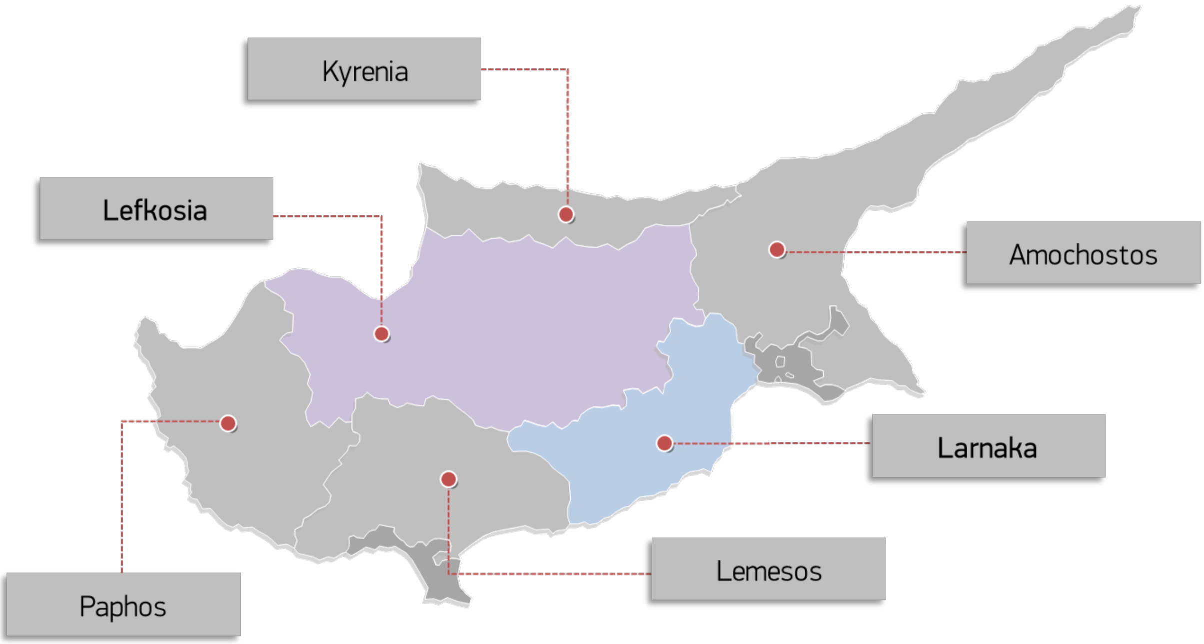


FIGURE 2: CYPRUS POLITICAL MAP - DISTRICTS

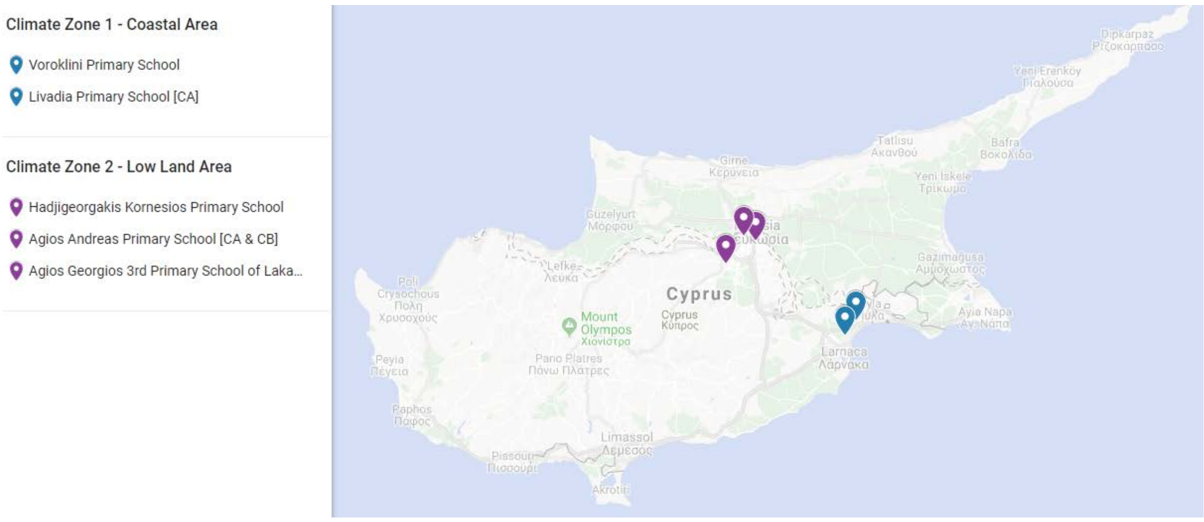


FIGURE 3: LOCATION OF PILOT SCHOOLS SELECTED FOR TEESCHOOLS PROJECT [3 IN LEFKOSIA DISTRICT - CZ2, AND 2 IN LARNAKA DISTRICT - CZ1]

2.2 CLIMATE

Cyprus' climate varies significantly between the coastal, the mountainous areas, and the areas in the interior of the island. Based on that, Cyprus is officially divided in 4 Climate Zones, as Figure 4 indicates. The school buildings under study, belong to Climate Zones 1 (Coastal Areas) and 2 (Low Land Areas) [CZ1 and CZ2], therefore an analysis is provided for the respective climates.

Three of the schools are located within CZ2, in Lefkosia District, which experiences long, hot, muggy and dry summers, and cool to mild winters, with most of the rainfall occurring between November and February. In general, July is the hottest month in Lefkosia with an average daily temperature of 29.7°C and the coldest is February at 10.5°C. The most daily sunshine is 13 hours and it occurs in July. Regarding the HDDs and CDDs, those have been calculated to 788 and 322, with base temperatures the 17°C and 28°C respectively[3]. The typical meteorological data for Nicosia, which also have been used for the energy simulations, are presented in Table (1).

Two of the schools are located within CZ1, in Larnaka District, which experiences long, hot, highly humid and very dry summers, and cool to mild winters with low rainfall. Most of this rainfall occurring between November and March. In general, August is the hottest month in Larnaca with an average daily temperature of 27.6°C and the coldest is February at 11.8°C. The most daily sunshine is 12.6 hours and it occurs in June. Regarding the HDDs and CDDs, those have been calculated to 544 and 161, also with base temperatures the 17°C and 28°C respectively. The typical meteorological data for Larnaca, which also have been used for the energy simulations, are presented in Table (2).

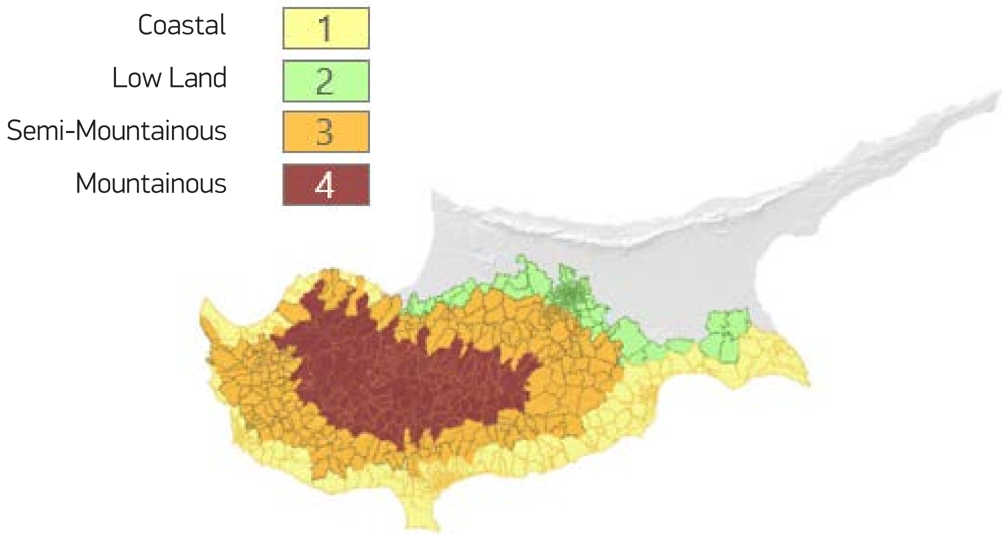


FIGURE 4: CLIMATIC CLASSIFICATION OF THE CYPRUS TERRITORY. SOURCE: ECONOMIDOU M., ZANGHERI P., PACI D. JRC TECHNICAL REPORTS 'FINAL REPORT LONG-TERM STRATEGY FOR MOBILISING INVESTMENTS FOR RENOVATING CYPRUS NATIONAL BUILDING STOCK (D1.8)' - LIMITED DISTRIBUTION, 2017

[3] The base temperature for HDD has been selected based on the fact that the main users of the school are children, whereas the base temperature for the CDD is based on the fact that natural ventilation and fans are usually used in the classrooms during the summer.

TABLE 1: CLIMATE DATA FOR ATHALASSA, NICOSIA, ELEVATION: 162 M (1991–2005)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Monthly Max. Temperature (°C)	22,2	22,9	30,5	36,7	41,5	42,9	43,4	43,2	41,1	38,0	30,8	23,8
Extreme Monthly Min. Temperature (°C)	-2,0	-2,9	-0,0	1,6	7,5	7,5	15,5	16,3	13,0	5,4	0,3 -	-0,7
Mean Daily Maximum Temperature (°C)	15.5	15.9	19.2	24.0	29.7	34.3	37.2	36.9	33.5	29.0	22.1	17.0
Mean Daily Temperature (°C)	10.6	10.5	13.1	17.1	22.3	26.9	29.7	29.4	26.2	22.3	16.3	12.0
Mean Daily Minimum Temperature (°C)	5.7	5.2	7.0	10.2	14.8	19.4	22.2	21.9	18.8	15.6	10.4	7.1
Mean Monthly Precipitation (mm)	54.7	41.6	28.3	19.9	23.5	17.6	5.8	1.3	11.7	17.4	54.6	65.8
Mean RH at 13:00 hrs LST (%)	58	54	46	40	34	30	27	29	30	36	48	59
Mean Daily Sunshine Duration (hrs && tenths)	5,9	6,9	7,7	8,9	10,7	12,3	12,5	11,8	10,4	8,9	7,1	5,5
Mean Daily Windrun at 2 m (km)	117	141	152	172	187	201	201	186	172	137	113	102

Data Extracted from: CMS, Cyprus' Meteorological Service - Monthly Climate Statistics for Lefkosia 2019 (CMS, 2019)

TABLE 2: CLIMATE DATA FOR LARNACA, ELEVATION: 1 M (1991–2005)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Monthly Max. Temperature (°C)	19,6	20,3	24,0	29,6	33,8	35,4	36,6	36,4	35,4	32,4	27,3	21,3
Extreme Monthly Min. Temperature (°C)	2,7	1,8	4,4	6,8	11,3	16,0	19,3	19,7	16,4	12,7	7,1	5,0
Mean Daily Maximum Temperature (°C)	16,8	16,8	19,1	22,5	26,5	30,3	32,4	32,7	30,9	28,1	22,6	18,3
Mean Daily Temperature (°C)	12,1	11,8	13,9	17,1	21,2	25,0	27,3	27,6	25,4	22,6	17,5	13,7
Mean Daily Minimum Temperature (°C)	7,5	6,9	8,7	11,7	16,0	19,8	22,2	22,6	19,9	17,1	12,5	9,2
Mean Monthly Precipitation (mm)	77,6	40,9	34,4	17,7	8,8	2,7	0,6	0,4	7,1	13,8	53,1	94,5
Mean RH at 13:00 hrs LST (%)	56	53	52	53	52	52	54	54	50	49	51	58
Mean Daily Sunshine Duration (hrs && tenths)	6,3	7,2	7,7	8,9	10,7	12,6	12,5	11,8	10,4	8,9	7,2	5,8
Mean Daily Windrun at 2 m (km)	184	204	216	234	240	253	275	260	222	182	187	174

Data Extracted from: (CMS, Cyprus' Meteorological Service - Monthly Climate Statistics for Larnaka 2019)

2.3 SCHOOLS

'Hadjigeorgakis Kornesios' Primary School in Aglantzia, Lefkosia

The school is located in the municipality of Aglantzia (36, Thessalias Street) in the district of Nicosia, next to the Akadimias Forest Park (coordinates 35.16 °N, 33.38 °E) – Figure 5. It is a public school for children aged 6-12. During the audit, it had a total of 250 people working and studying in the school during school hours: 221 pupils (20 per classroom on average), the principle, 23 teachers, 1 administrative officer, 3 cleaners, and 1 person operating the school canteen.

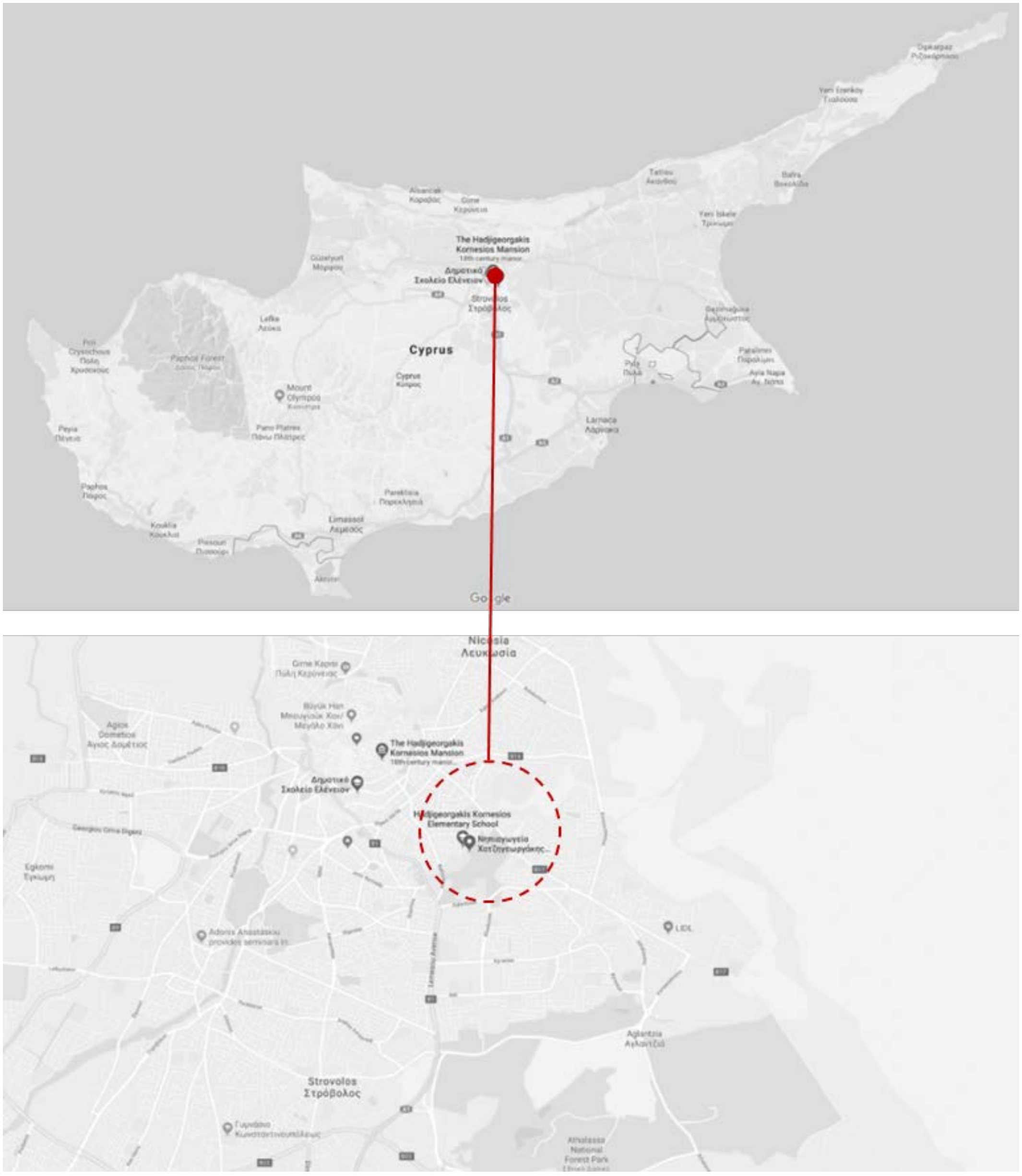


FIGURE 5: HADJIGEORGAKIS KORNESIOS PRIMARY SCHOOL – LOCATION

The school consists of 2 distinctive blocks and a small, prefabricated, addition. The main block [Figure 6] was constructed in 1968. It expands on the ground level hosts 4 classrooms, the principles and administration offices, the teachers' room, one room for special teaching, the canteen, the cleaning staff room, toilets, storage rooms, the boiler room and the multipurpose hall in the centre. The second block [Figure 7] has an 'L' shape, it was constructed at a later stage in order to house additional classrooms and labs for the increasing number of students. It was erected in 2 stages; the first part of this block was given for use in 2004 whereas the 2nd one was finished in 2014. Block B hosts 3 labs (currently used as regular classrooms), 5 classrooms, 2 classrooms for special education, the school's infirmary, lockers rooms, toilets and a storage room. It comprises a ground floor and first floor. The last block, which is prefabricated, hosts just 2 classrooms for periodical use, mainly as laboratories.

FIGURE 6: SCHOOL'S ENTRANCE - BLOCK A

The school's TFA is around 1,520 m^2, with a volume of 4,969 m^3 (HFA: 1,286 m^2). In specific, Block A has a TFA of 749 m^2 whereas Block B has a total TFA of 679 m^2, of which 339 m^2 are on the ground floor and the rest on the first floor. The prefabricated structure has an area of 97 m^2.

The total external surface consists of 1582.57 m^2 of masonry and bearing construction and 447.05 m^2 of openings (glazing). The average TFA of classrooms is close to 50 – 55 m^2 which is slightly lower compared to the design standards of the MoECSY's Technical Services, which define the suitable classroom for 25 people to be 65 m^2.

FIGURE 7: PART OF BLOCK B - NEWER ADDITION

'Ayios Georgios', 3rd Primary School of Lakatamia, Lefkosia

The school is located at the municipality of Lakatamia, a southwestern suburb in the province of Lefkosia, on 21/1 Georgiou Griva Digeni Street, in the parish of Ayia Paraskevi (coordinates: 35°06"N , 33°17"E) [Figure 8]. It is a public school for children aged 6-12. During the audit it had a total of 415 people working and studying in the school during school hours: 379 pupils (22 per classroom on average), the principle, 29 teachers, 2 administrative officers, 3 cleaners, and 1 person operating the school canteen.

FIGURE 8: 3RD PRIMARY SCHOOL OF AYIOS GEORGIOS – LOCATION

The school consists of 2 distinctive blocks and a small, prefabricated, addition. The main block [Figure 9] expands on a ground level and it hosts 3 classrooms, 2 labs, the principles and administration offices, the teachers' room, the canteen, the cleaning staff room, the school's infirmary, toilets, storage rooms, lockers room, the boiler room and the multipurpose hall in the centre. The second block, has an 'L' shape and it was constructed in 3 stages; the first part of this block was constructed at the same time with the main block (at 1986), whereas the second part (3 classrooms) was given for use at 2008 [Figure 10]. The third part, which was an extra classroom and storage space, was constructed at 2013. The second block hosts in total, 14 classrooms, 1 lab, 2 classrooms for special education, toilets and a storage room. It comprises a ground floor and first floor. The last block is prefabricated and hosts just 1 classroom for periodical use, mainly as an art laboratory. The prefabricated part originally was consisted of 2 classrooms, but after the additions on Block B, it was removed.

FIGURE 9: BLOCK A [LEFT] – OLDER BUILDINGS (1986)

The school's TFA is around 2,023 m^2, with a volume of 6,771 m^3 (HFA: 1,830 m^2). In specific Block A has a TFA of 1,151 m^2, Block B has a total TFA of 825 m^2, of which 418 m^2 are on the ground floor and the rest on the first floor. The Prefabricated classroom has an area of 47 m^2, and a respective height of 2.65 m.

The total external surface consists of 1,935.20 m^2 of masonry and bearing construction and 527.95 m^2 of openings (glazing). The average TFA of classrooms is 55 m^2 which is lower compared to the design standards of the Technical Services.

FIGURE 10: BLOCK B [RIGHT] – OLDER BUILDINGS (1986)

Ayios Andreas' Primary School in Lefkosia

The school is located at Lefkosia Municipality at Ayios Andreas, a historic parish of Lefkosia city, on Ayiou Pavlou Street (coordinates: 35°17''N ,33°34''E), as indicated in Figure 11. It is a public school for children aged 6-12. During the audit, it had a total of 279 people working and studying in the school during school hours: 249 pupils (20 per classroom on average), the principle, 24 teachers, 1 administrative officer, 4 cleaners, and 1 person operating the school canteen.

The school consists of 3 distinctive buildings and various smaller additions, which act as complementary for the school's operation. One of the main buildings is considered as a historical building. It was constructed in the mid-40s and operated in 1948. Today, it hosts all the activities of First (1st) Cycle [CA], which includes the 1st to 3rd grade of the primary school. The Second (2nd) Cycle [CB], includes the 4th to 6th grade. It uses two buildings, which were constructed later to serve the increased needs of the community.

The CA's building ('Block A'), comprises a floor and a pitched tiled roof [Figure 12]. It hosts 6 classrooms, the principles and administration offices (reception area), the teachers' room, multipurpose room, the cleaning staff room and two toilets for the staff. In 2 small adjacent buildings are hosted a special education classroom and the boiler room with 2 storage rooms and 2 toilet rooms. There are also separate buildings that are used as a storage spaces (2 of those are prefabricated). Lastly, there are 2 buildings that are used by the scouts[4]. The second building ('Block B'), was constructed in the 70s and operated in 1972. In its core is the multipurpose room, which is surrounded by administration spaces, classrooms (x3), labs, the school's infirmary, toilets, locker rooms and storage rooms. It only consists of a ground floor [Figure 13]. The third building ('Block C'), also operated for the first time in 1972. It also serves the 2nd Cycle and has in total 5 classrooms, 3 labs, 1 classroom for special education, 1 room used as library, 1 canteen, toilets, storage rooms and the boiler room. It comprises a ground floor and first floor [Figure 14].

[4]Their energy consumption it's not included in the consumption of the school buildings.

FIGURE 11: 'AYIOS ANDREAS' PRIMARY SCHOOL – LOCATION

The school's TFA is around 1,958 m^2, with a volume of 6,731.5 m^3 (HFA: 1,757 m^2). In specific Block A has a TFA of 582 m^2 (HFA: 571 m^2). The auxiliary buildings which are used for the needs of 1st Cycle but are not included in its HFA, are as follows: 20 m^2 for the special education classroom located in the northeast corner of Bock A, 50 m^2 storage space located in the southeast of Block A, 45 m^2 for the boiler room, 3 storage spaces and 2 toilets, located in front of the southeast corner of Block A and 32 m^2 for the prefabricated buildings which serve as storage space for the school's stationery, located in front of its southwest façade. Block B has a total TFA of 630 m^2 (HFA: 596 m^2), whereas Block C has a total TFA of 746 m^2 (HFA: 590 m^2), of which 389 m^2 are on the ground floor and the rest on the first floor.

FIGURE 12: BLOCK A, LISTED BUILDING– ENTRANCE (NORTHEAST FAÇADE)

Approximately half of the total external surface of the Block A is covered by openings, whereas for the South and North Façade of Block B and C the proportion is around 30%. East and west facades of Block B and C have the lowest proportion of openings, around 15% -20%. The average TFA of classrooms is 67 m^2, which is consisted with the design standards of the Technical services.

Figure 13: Block B (South Façade) – On the far left: Block C (East Facade)

Figure 14: Block C (North Façade) – On the far right: Block B (North Facade)

Livadia Primary School [CB] in Livadia, Larnaka

The school is located at the municipality of Livadia on Mesaorias Street, on the northern side of Larnaca and at a short distance from it (coordinates: 34°95"N ,33°62"E), as indicated in Figure 15. It is a public school for children aged 6-12. The 2nd Cycle (children aged 9–12 years old) has a total of 278 people working and studying in the school during school hours: 250 pupils (22 per classroom on average), the principle, 23 teachers, 1 administrative officer, 3 cleaners, and 1 person operating the school canteen.

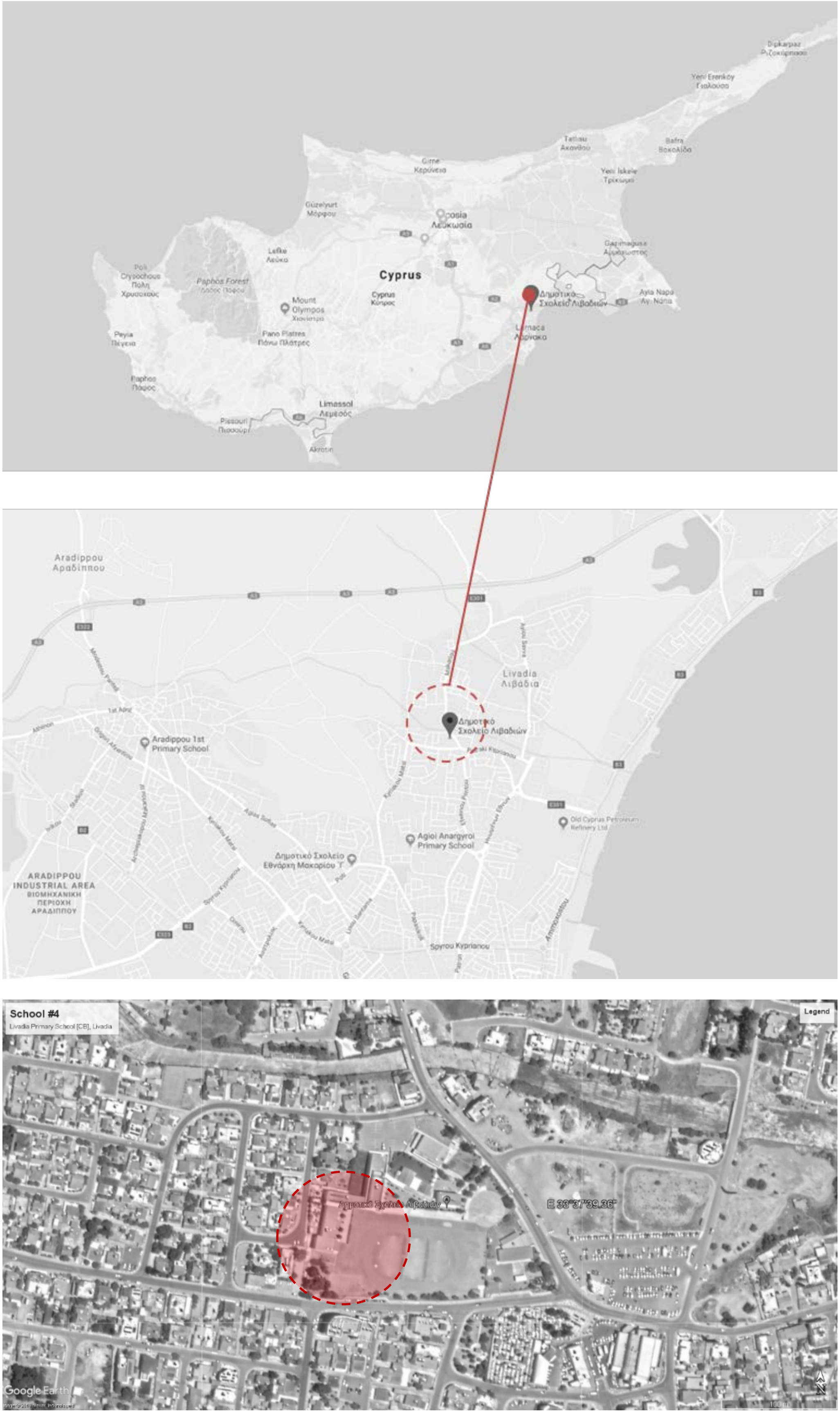


FIGURE 15: 'LIVADIA' PRIMARY SCHOOL, CB – LOCATION

The Second (2nd) Cycle [CB] which includes the 4th to 6th grade of the primary school, is the school under study. It consists of 1 building of a pi-shaped plan view. On the same plot, there are various other buildings (blocks) which are used for the needs of the First (1st) Cycle [CA]m and some for common lectures, nonetheless they have separate energy bills, so this energy audit only focuses on the building which hosts the CB.

The school/building acquired its first form on 1989, and it was consisted of a ground floor and a first floor. The school was undergone an anti-seismic upgrade on 2008 and some alterations took place at the same time. In specific, 4 new spaces were added on the first floor and a new staircase was added at the North-eastern part of the building. Currently, the ground floor hosts 2 classrooms, 1 special education classroom, 2 labs (Technology and Cooking Lab), the administrative offices, the teachers' room, the cleaning staffs' room, the canteen, toilets, storage spaces, and the boiler room˙ whereas the 1st floor hosts 7 classrooms, 1 classroom for special education and a storage space [Figures 16 & 17]. It's noted here that the CB uses also the ground floor of a newer building[5] which belongs to the CB (indicated in Figure 18), in order to host 2 more classrooms and 1 special education classroom. On the same floor it's also the music lab, the school's infirmary, the locker rooms, storage spaces and toilets which are shared among the 2 cycles.

FIGURE 16: BUILDING UNDER STUDY - PART OF EAST FAÇADE

The school's TFA is around 899 m^2 (HFA: 764 m^2), with a volume of 2,607.10 m^3. In specific, the ground floor has a TFA of approximately 488 m^2 and the remaining TFA is on the first floor.

Approximately 40% of the total external surface of the East Façade (main facade) is covered by openings, whereas for West façade (school's entrance), the proportion is around 20% which is the lowest. Openings on the North facades are about 30 % in total and on South facades 40%. The average TFA of classrooms is 55 m^2, which is lower compared to the design standards of the Technical Services.

[5] It's excluded from this energy audit as it is a separate building with separate energy bills.

FIGURE 17: BUILDING UNDER STUDY - PART OF EAST AND SOUTH FAÇADE

FIGURE 18: BUILDING USED MAINLY BY THE 1ST CYCLE - ON THE GROUND FLOOR, ACTIVITIES OF THE 2ND CYCLE ARE HOSTED

Voroklini Primary School in Voroklini, Larnaka

The school is located at the community of Voroklini on Pedias Street, about eight kilometres north-east of the city of Larnaca (coordinates: 34°98"N ,33°66"E), as indicated in Figure 19. It is a public school for children aged 6-12. During the audit it had a total of 438 people working and studying in the school during school hours: 400 pupils (25 per classroom on average), the principle, 33 teachers, 1 administrative officer, 3 cleaners, and 1 person operating the school canteen.

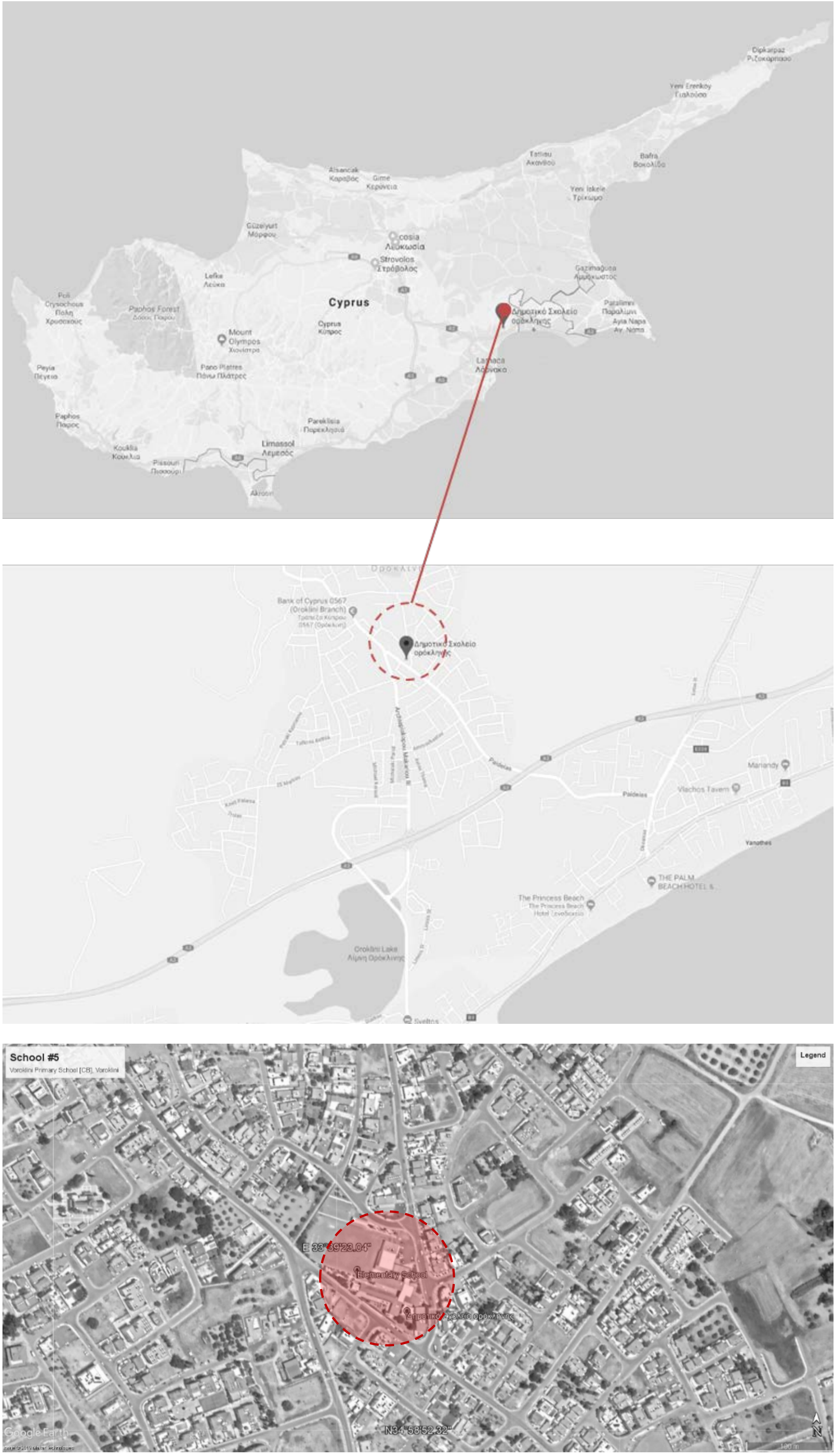


FIGURE 19: 'OROKLINI' PRIMARY SCHOOL – LOCATION

Voroklini Primary School is one of the biggest primary schools of Cyprus. The school consists of 6 distinctive blocks and during the time of the audit, another block which will host the Multipurpose Hall, was under construction on the north part of the school. Overall the school as a whole, it is a complex structure as each block was constructed in different periods and has different characteristics in terms of envelope properties and installations.

The 1st Block ('Block A'), was constructed 1964 and is the oldest one [Figure 20]. It has a long rectangular plan view and is the only one that has pitched, tiled roof. It consists of a ground floor and it hosts 3 classrooms, 1 lab (cooking lab), 1 classroom for special education, storage spaces, toiles and the school's infirmary.

FIGURE 20: BLOCK A - CONSTRUCTED IN 1964 (SOUTH FACADE)

The 2nd Block ('Block B'), was constructed in 1979, followed by the 3rd Block (Block C), few years later (in 1985). Both are consisting of a ground floor and together they formed an 'L' shape east of Block A [Figure 21]. Block B hosts 1 classroom, 1 lab (Art Lab) and 1 classroom for special education and other activities. Block C hosts mainly the administrative spaces, as it is on central spot. In specific, the principal's office, the assistants' principals office and the secretariat's room are on Block C. The cleaning staff's room, the computer's Lab and the boiler room are also hosted at Block C. The 4th Block ('Block D'), was constructed in 2 different phases [Figure 22]. By 1992 the first part was delivered, it included 2 classrooms and toilet rooms on the ground floor. By 2001 the 2nd part was delivered. It included 3 classrooms on the 1st floor. The construction of the 5th Block ('Block E'), was also delivered in 2 phases [Figure 23]. On 2005 the 1st part (ground floor) was delivered, whereas the 1st floor was completed in 2009. On the ground floor there are 2 classrooms, 1 classroom for special education, the teachers' room, the school's canteen, storage spaces and toilets. On the 1st floor there 4 classrooms and one classroom for special education. The last and newest -completed- addition was the 6th block ('Block F'), at the north site of the plot [Figure 24]. It was completed in 2015 and it hosts just 4 classrooms, 2 on the ground floor and 2 on the 1st floor. The Multipurpose Hall, which was currently under construction, will be located West of Block F.

It is noted that during 2008-2010, the school was undergone seismic upgrading where some alterations also took place. Nonetheless, those regard mainly the school's exterior space.

FIGURE 21: BLOCK B [LEFT] AND BLOCK C [RIGHT] - CONSTRUCTED IN 1979 AND 1985 (EAST AND SOUTH FAÇADE RESPECTIVELY)

FIGURE 22: BLOCK D - CONSTRUCTED IN 1992 AND 2001 (WEST FACADE)

FIGURE 23: BLOCK E - CONSTRUCTED IN 2005 AND 2009 (SOUTH FACADE)

FIGURE 24: BLOCK F - CONSTRUCTED IN 2015 (SOUTH AND EAST FACADE)

The school's TFA is around 1,663 m^2 (HFA: 1,534 m^2), with a volume of 4,245.75 m^3 . In specific Block A has a TFA of 275 m^2 (HFA: 257 m^2) all in a ground floor, Block B and Block C have TFAs of around 130 m^2 and 125 m^2 respectively, also only in ground floor. For Block C and Block B, all areas are heated, therefore their HFA is equal to the TFA. Block D, Block E and Block F consist of two levels and their respective areas are as follows: Block D has a total TFA of 548 m^2 (of which 277 m^2 are on ground floor), Block E has a TFA of 332 m^2 (166 m^2 on each floor) and Block F has a TFA of 267 m^2 (of which 137 are on ground floor). Their respective HFAs are 506 m^2 , 277 m^2 and 260 m^2.

Approximately 40% of the south façade and 20% of the north façade of Block A is covered by openings, whereas west and east facades do not have almost any windows. Block B has around 50% and 25% openings on its west and its east façade respectively. Block C has 50% openings on the south façade, 25% on the north façade and 40% on the west façade. About 50% of the west façade and 25% of the east façade of Block D consists of openings. Block E has its most openings facing south (approximately 50%) and the rest (around 25% of the surface) facing north. Lastly, the south façade of Block F is 50% openings. The remaining openings (around 25%) are on its north façade. Overall, as a common rule, all the Blocks are mainly exposed towards one orientation (usually towards south) and the opposite site has the remaining openings (around the half).

The average TFA of classrooms on Block B, D and E is around 55 m^2, on Block A around 60 m^2 whereas on Block F the respective area is around 65 m^2. The majority of classrooms are close to the design standards of the Technical Services.

Typical school schedule

Public primary schools operate from the beginning of September to end of June. Pupils start the academic year on the second Monday of September and finish on the second to last Wednesday of June each year. Operating hours are from 7:45 to 13:05 for all primary schools in Cyprus, excluding the 'all-day' schools. All schools remain close on the dates (annual holidays), indicated in the following Table.

TABLE 3: ANNUAL HOLIDAYS FOR PUBLIC PRIMARY SCHOOLS IN CYPRUS

Holiday	Type	Period
Christmas Holidays_1	Date Range	1st of January – 6th of January
Three Hierarchs Day	Fixed Day	30th of January
25th of March	Fixed Day	25th of March
1st of April	Fixed Day	1st of April
Easter	Moveable Date Range	2 weeks – Usually in April
1st of May	Fixed Day	1st of May
Cataclysm day	Moveable Date	50 days after the Easter Sunday
Saint Varnavas Day	Fixed Day	11th of June
Summer Holidays	Moveable Date Range	Second to last Friday of June to the first Monday of September
1st of October	Fixed Day	1st of October
28th of October	Fixed Day	28th of October
Archbishop's day	Fixed Day	13th of November
Christmas Holidays_2	Date Range	23rd of December – 31st of December

The selected pilot schools are also used for extracurricular activities and studying, based on different time schedules. Nonetheless, not all the school facilities are used for these activities. Annex 7.2 indicates the places which were used after the regular time for the academic year which the audits took place. Is noted that even if these activities vary between each academic year, there are no significant deferrizations from year to year, and therefore, the overall schedule could be considered as typical.

Bellow, are summarized all the basic data for the selected pilot schools:

TABLE 4: BASIC DATA OF PILOT SCHOOL BUILDINGS [AGGREGATE TABLE] FOR THE ACADEMIC YEAR 2017 – 2018

No.	Schools	TFA [m^2]	Construction Year*	Number of students	Basic Schedule [Additional Activities]	Installed RES	Annual Electrical Consumption** [kwh]	Annual Thermal Consumption** [kwh]	Primary Energy Consumption TFA [KWh$_{pr}$/m^2·year]	CO_2 Emissions [KgCO$_2$]	Average Energy Cost [€/year]
1	Hadjigeorgakis Kornesios	1,520	1968+	221	7:45 - 13:05 [YES]	NO	25,395	26,480	64,25	27,207	6,340
2	Ayios Georgios	2,024	1986+	379	7:45 - 13:05 [YES]	NO	29,080	63,510	73,30	39,980	9,390
3	Ayios Andreas	1,958	1948+	269	7:45 - 13:05 [YES]	YES [not for in-situ use]	44,260	102,900	118,85	62,515	15,525
4	Livadia	940	1989+	203	7:45 - 13:05 [YES]	YES [not for in-situ use]	16,595	17,180	67,80	17,745	4,435
5	Voroklini	1,663	1964+	400	7:45 - 13:05 [YES]	NO	24,425	18,945	52,20	24,435	6,305

** The symbol + indicates that major alterations/extensions took place after the indicated date*

*** Average of three years data collection [2015 – 2018]*

3. PREVIOUS ANALYSIS

3.1 Constructive building aspects

School buildings in Cyprus, and buildings in general, are mostly heavy weight structures and are made of reinforced concrete and masonry walls. Most of the schools consist of two floors, a ground floor and first floor. The older buildings usually have only a ground floor, stone walls and pitched roof whereas the new buildings have 2 levels, brick walls and flat roofs.

The first educational buildings in Cyprus were constructed in accordance to the style of the era (Ottoman and British rule) and to serve specific needs of the community. The majority of the schools constructed during the British era follow the neoclassic style. During the 1950 – 1974 most of the schools were constructed by representatives of the modern architecture movement in Cyprus, and even if they don't follow specific guidelines they are characterized by common characteristics. Since the establishment of the Technical Services of the Ministry of Education, Culture, Sports and Youth [mostly after 1974], schools are constructed based on specific Guidelines. They have a consistency in construction materials and typical floor plans and facades, usually with an 'L' or 'π' shape [Figure 25], expanded on the West-East Axis. Exceptions are the schools constructed as a result of architectural competitions. This kind of schools usually fall far from the typical forms [Figure 26].

Figure 25: Similarities in school buildings designed by the technical services [Pilot buildings – Ayios Georgios, Livadia, Voroklini]

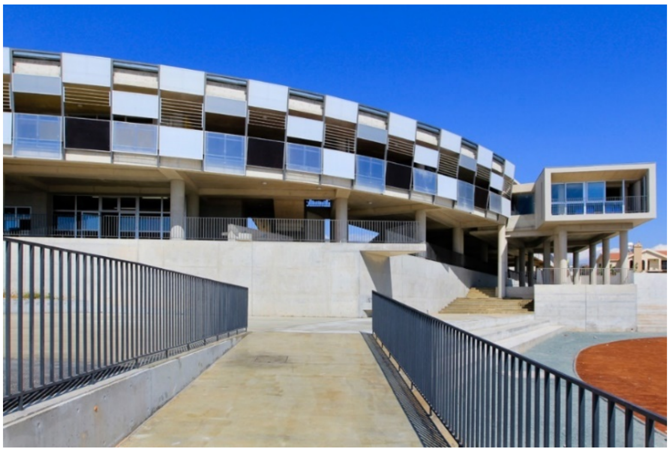


FIGURE 26: IPSONA'S PRIMARY SCHOOL, RESULT OF ARCHITECTURAL COMPETITION [2011]
ZENON SIEREPEKLIS ARCHITECTS. PHOTO RETRIEVED FROM WWW.CY-ARCH.COM

Cyprus' pilot schools fall within the majority of the public school building stock as they were constructed from the Technical Services. Exception is the listed building of Ayios Andreas which dates back to the British rule and the Block A of Voroklini primary school. These examples were selected to identify opportunities for energy savings and improved educational environment in historic buildings.

Based on the above, for all the schools except Ayios Andreas and partially Voroklini, columns and beams are made of concrete, reinforced with steel, walls are made of single or double bricks with plaster coating, and roofs are flat slabs. Mosaic tiles cover the majority of the floor (linoleum and laminate floors exist in some rooms). In some cases, prefabricated blocks, made up by sandwich panels with polyurethane foam, are used at school buildings constructions for -temporarily- covering needs. Such classrooms are met in 3 out of 5 pilot school buildings.

Openings of the school buildings made after mid 80s are of aluminium frame and single glazing. Double glazing windows are found in structures built in early-mid 90s. In older schools, windows were single-glazing with iron frame, nonetheless, many of those have been replaced by double-glazing aluminium frames. Doors are either glazed or opaque with metallic or a mixed frame, depending on the year and the overall architecture. Regardless the general typology, classrooms usually have a large glazing area on one of the external walls and smaller openings on the opposite side which can be either external or internal (facing to an internal corridor), to serve cross ventilation. For the most, windows are sliding and are equipped with interior light-coloured curtains or roll-up blinds to control solar penetration. Older buildings usually consist of windows which are opening towards inside, while others are stable. In recent renovations or maintenance works, external stable metallic shades are installed in many schools, as classrooms were overheated. Those cut off or allow the solar radiation to penetrate the building according to the season.

For the historic schools, walls are load bearing, constructed from local stone (limestone), whereas roofs are pitched with tiles. Windows are either wooden or iron single-glazed where doors are either glazed or opaque with wooden or a mixed frame.

The thermal properties of the main structural elements of the buildings are strongly dependent on the year of the construction. All buildings, or additions, constructed before 2007[6] have no insulation in any of

[6] It's noted here, that before 2007 there were no requirements for the energy efficiency of buildings and that the first regulation concerned the obligatory installation of thermal insulation on the buildings' elements. After that, the minimum requirements for the buildings readjusted several times reaching the todays levels.

their structural elements (walls, roofs, floors) unless added later. Whatever was built later, and up to 2017 usually has insulation at walls, beams, columns and roofs. Nonetheless, the placement of the insulation, the material and the width, might vary between the schools. In most of the times new spaces, added between 2010-2016, are partially insulated with 3-5 cm of polystyrene [Figure 27], whereas for additions from 2017 and onwards the width increases to 10cm to meet the minimum Energy Performance requirements [Annex 7.1]. For pitched roofs, other insulation materials, such as rockwool can be used.

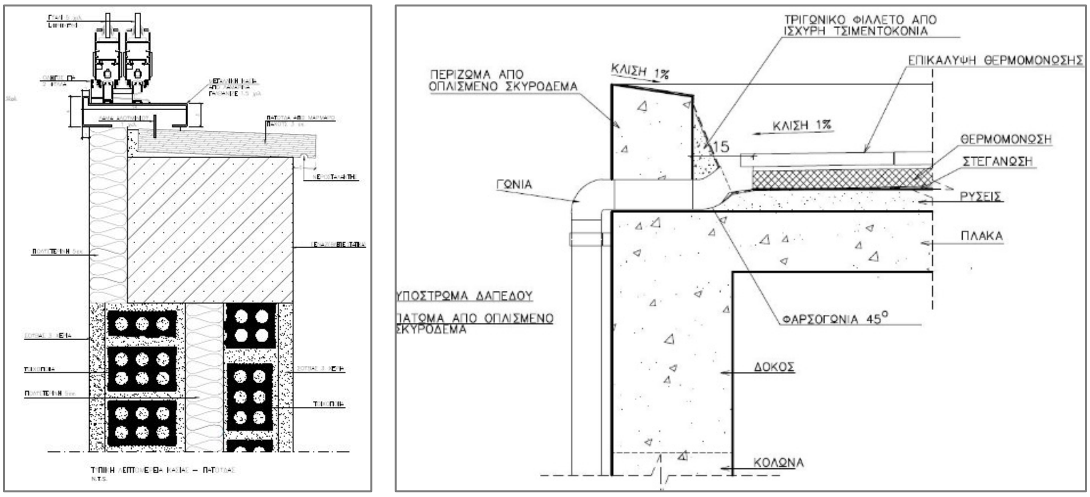


FIGURE 27: CONSTRUCTION DETAILS. LEFT: INSULATION OF THE WALLS OF NEW SPACE (ADDITION TO EXISTING BUILDING), VOROKLINI PRIMARY SCHOOL- SOURCE: TECHNICAL SERVICES OF THE MINISTRY OF EDUCATION AND CULTURE [2014], RIGHT : INSULATION OF THE ROOF OF NEW SPACE (ADDITION TO EXISTING BUILDING), LAKATAMIA PRIMARY SCHOOL - SOURCE: TECHNICAL SERVICES OF THE CYPRUS MINISTRY OF EDUCATION AND CULTURE [2013]

The same stands for window frames and glazing. The construction characteristics as well as the associated thermal characteristics of the windows follows the main trends of the construction period. For new additions or replacements of older windows, it is worth noticing that the thermophysical properties of the windows are similar to the current provisions of the energy performance regulations in Cyprus. Older buildings have metallic frames with single glass panes and poor air tightness while school buildings built after the mid 90's, are equipped with better sealing aluminium frames with double glazing. Overall, in many occasions, different types of glazing and level of insulation is met in the same school either due to partial renovation or due to different buildings or parts of buildings constructed in different year.

In the following Table [5], the analysis of the pilots' building envelopes is provided. Information has been collected by the Technical Services of the MoECSY, the buildings' users, the School Board, as well as by the on-the-spot check, to assess the performance of the building's envelope. This information has been analysed, in accordance with the Cypriot Thermal Insulation Guide[7], in order to acquire the respective U-Values for each structural element. It can be seen that the buildings at their biggest proportion do not meet the minimum requirements for energy performance[8], which is resulting to low performance and consequently, lack of thermal comfort conditions.

[7] Energy Service, Ministry of Energy, Commerce, Industry and Tourism (2010), *Thermal Insulation Guide - 2nd Edition*. Nicosia, Cyprus.

[8] Extensive analysis is provided in Annex 7.3.

TABLE 5: CALCULATED U-VALUES FOR ALL THE STRUCTURAL ELEMENTS OF THE PILOT SCHOOL BUILDINGS

School	Bearing Structure		External Walls		Roofs		Floors		Windows		Doors	
	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)	U value ($W \cdot m^{-2}K^{-1}$)	Thickness (mm)
#1	3.26	250	1.68	200	2.31	253	0.80	410	5.50	4	5.87	15
	3.04	300	1.18	300	3.21	235	0.76	460	4.96	6	3.85	40
	0.53	350	0.39	400	3.00	300	0.78	420	3.02	25	3.06	50
			0.27	100	0.48	320	0.74	455			2.48	30
					0.28	100	2.58	255				
							0.72	425				
							3.23	185				
#2	3.26	250	1.68	200	3.21	235	0.80	410	4.96	6	3.85	40
	0.80	280	1.18	300	3.00	300	2.58	255	3.02	25	3.06	50
			0.53	360	0.48	320	0.72	425			2.48	30
			2.90	300	6.18	10						
			0.27	100								
#3	3.26	250	1.39	250	2.31	253	0.80	410	5.50	4	5.87	15
	0.53	350	2.41	500	3.21	235	0.78	420	3.02	25	3.06	50
					2.19	-	0.72	425	4.38	6		
#4	3.26	250	1.68	200	0.52	310	0.80	410	4.96	6	3.85	40
			0.82	250								
#5	3.26	250	1.39	250	0.59	315	0.80	410	4.96	6	3.85	40
	2.85	350	0.39	400	0.33	350	0.76	460	3.02	25	3.06	50
	2.68	400			2.19	-	0.78	420				
	0.50	600					0.72	425				

3.2 AIRFLOW AND PATHOLOGIES

The air tightness of the building envelope was in adequate condition for the majority of the schools based on the optical inspection of the auditing team. Although, noticeable air leakiness occured in the junctions between window frames and envelope, especially in older buildings and window frames. Based on this, it was suggested to repair the junctions by sealing them using elastic-basis mortar, if replacing the windows is not an exigency.

In some of the school buildings [Lakatamia, Ayios Andreas, Voroklini], the auditing team also noticed that condensation problems occurred on some interior walls and roofs of various spaces of the schools, such as classrooms and storage rooms [Figure 28]. Those can compromise building occupants' health and comfort, damage interior finishes, and raise maintenance costs. The problems of condensation in most of the spaces are due to the existence of thermal bridges on the junctions between the wall and roof. Those can be addressed with the placement of thermal insulation across the hole building's envelope. This option, however, is only foreseen under the holistic upgrade scenario that leads building to a NZEB.

The second category of condensation and humidity problems derives from failures of the waterproofing sheet or technical installations. The first can be resolved with the inspection of the waterproofing in order to locate the failures and then, removal and re-fitting of the waterproofing sheet before the plastering and painting of the roof. In the case of the technical installations, caution should be taken in order to resolve the problem before deteriorates.

The last category of condensation problems, which mainly affect the structural elements (like walls), were found mainly on closed spaces, like the storage and locker rooms. Those concern cases of poor ventilation conditions, therefore, it is suggested by the energy auditors' team to regularly ventilate the spaces when and where possible.

FIGURE 28: CONDENSATION AND HUMIDITY PROBLEMS PRESENTED IN VARIOUS SPACES OF THE PILOT SCHOOLS

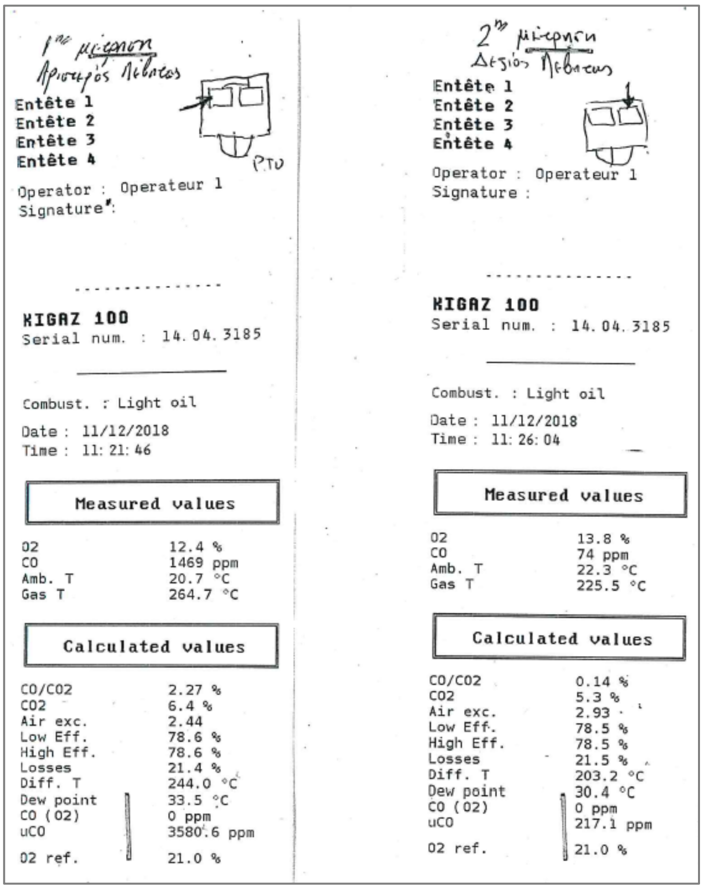
Lastly, in Livadia Primary school, it was observed that during the days with strong winds the spaces on the ground floor which face towards the yard/field were affected by dust particles, resulting in bad air quality or breathing problems. It was suggested by the auditors to examine this at a greater extend and provide solutions based on the most suitable model. Solutions can be provided either by changing the ground material of the field, or by reducing the wind's speed in the yard (tree planting).

3.3 ENERGY SYSTEMS

Analysis and determination of the boiler's energy performance

All pilot school buildings use oil boilers for covering their heating demand. The systems are used to heat the premises (classrooms, offices) of the building starting from late November or early December, until late March. The systems consist of a cast iron boiler (sometimes more than 1) in association with an oil-fired burner. Most of the boilers are more than 10 years old with efficiencies varying from 76% to 93%. The systems are usually maintained 1-2 times per academic period, nonetheless maintenance and service reports are not always available. The piping system feeding the terminal systems (radiators) with hot water is most of the times no insulated except within the boilers' rooms.

The heating system is usually on from 07:00 to 11:00 at 18ºC – 20 ºC. Higher set-temperatures, up to 24ºC are allowed for offices in accordance to the Design Standards of the Technical Services. In some cases, classrooms, labs and offices use split type A/C units for heating either when it is very cold, or when they operate after the typical schedule of the school.


Entête 1
Entête 2
Entête 3
Entête 4
Operator : Operateur 1
Signature :
KIGAZ 100
Serial num. : 14.04.3185
Combust. : Light oil
Date : 11/12/2018
Time : 11:21:46

Measured values	
O2	12.4 %
CO	1469 ppm
Amb. T	20.7 °C
Gas T	264.7 °C

Calculated values	
CO/CO2	2.27 %
CO2	6.4 %
Air exc.	2.44
Low Eff.	78.6 %
High Eff.	78.6 %
Losses	21.4 %
Diff. T	244.0 °C
Dew point	33.5 °C
CO (O2)	0 ppm
uCO	3580.6 ppm
O2 ref.	21.0 %

Entête 1
Entête 2
Entête 3
Entête 4
Operator : Operateur 1
Signature :
KIGAZ 100
Serial num. : 14.04.3185
Combust. : Light oil
Date : 11/12/2018
Time : 11:26:04

Measured values	
O2	13.8 %
CO	74 ppm
Amb. T	22.3 °C
Gas T	225.5 °C

Calculated values	
CO/CO2	0.14 %
CO2	5.3 %
Air exc.	2.93
Low Eff.	78.5 %
High Eff.	78.5 %
Losses	21.5 %
Diff. T	203.2 °C
Dew point	30.4 °C
CO (O2)	0 ppm
uCO	217.1 ppm
O2 ref.	21.0 %

FIGURE 29: EXAMPLE OF BOILER PERFORMANCE METRICS [AYIOS ANDREAS PRIMARY SCHOOL]

For the inspection of the heating systems and in order to evaluate the actual performance of the heating apparatus, the concentration of CO_2 and O_2 in the flue gas, and the associate flue gas temperature and boiler-room temperature were measured during the in-situ visit of the auditing team. The device was tested, and its performance determined by the exhaust gas analysis.

An exhaust gas analyser of KIMO INSTRUMENTS, type KIGAZ 100, was used for exhaust gas analysis [Figure 29]. The analyser calibrated according to the manufacturer's instructions [Annex 7.4]. The same device was also used to measure the temperature of the air supplied to the burner and the temperature of the exhaust gas. The results of measurements of the exhaust gas contents in CO_2, O_2 as well as the exhaust gas and air temperatures are shown in Table 6.

The determination of the efficiency of the boiler-burner systems was based on the methodology presented in CYS EN 15316-4-1:2017[9] [Equation 1]. The rate of losses from the boilers' body $f_{gen,env}$, was extracted directly from the standard because there are no exact elements for the heat insulation of the boilers. Based on the data acquired from the measurements and by using the methodology mentioned before, the efficiency of the boilers was calculated. Is noted that the efficiencies are compared to the minimum required by the European Standard CYS EN 303-2:1999, which is 88.5%.

EQUATION 1: DETERMINATION OF THE EFFICIENCY OF THE BOILER-BURNER SYSTEM BASED ON THE METHODOLOGY PRESENTED IN CYS EN 15316-4-1:2017

$$n_{gen,pn} = \frac{c_1 + c_2 \cdot \log P_n}{100} = \frac{P_{gen,del} - P_{gen,ls,ch,on} - P_{gen,ls,env}}{P_{gen,del}}$$

$$n_{gen,pn} = 1 - f_{ch,on} - f_{gen,env}$$

[9] Energy performance of buildings. Method for calculation of system energy requirements and system efficiencies. Space heating and DHW generation systems, combustion systems (boilers, biomass)

TABLE 6: SUMMARISED TABLE OF BOILERS' INSPECTION

School	Measured efficiency of boiler(s)	Efficiency after adjustments	Notes & Recommendations
1	94.5%	92.5% due to the imperfect thermal insulation of the boiler	To clean the boiler's surfaces and adjust the operation of the burner as during the visual inspection of the combustion chamber revealed soot deposits in the flame chamber and, a high combustion air ratio was found [2.04 instead of 1.22]. Inadequate low flue gas temperature [98.5°C instead of 160°C-180°C] was also found indicating the inefficient operation of the burner. Based on the above the working conditions of the boiler and burner was found **inefficient calling for immediately corrective actions**.
2	80.74% [-]	78.7% due to the imperfect thermal insulation of the boiler	It was observed that one of the two boilers was highly destroyed from the emitted heating and was out of the operation for the last years. The auditing team **consider for inspection only the boiler that was in operation.** There was inadequate inspection and maintenance of the boiler, and the burner's operating conditions need adjustments. **Extensive cleaning of the heat transfer surfaces** is also needed, as the combustion chamber has soot deposits. A high combustion air ratio was found [3.10 instead of 1.22]. Moreover, high oxygen content on the flue gas was measured [14,2% instead of 3%-5%]. Based on the above, the working conditions of the boiler and burner was found **inefficient calling for immediately corrective actions**.
3*	83.2% [A] 79.1% [B] 78.6% [C]	80.26% Weighted efficiency as there is common energy bill	**Boiler A [CA]:** It is needed to **clean and adjust the combustion of the device** because there are soot deposits at the base of the chimney. The chimney of Boiler-A has a very small length, which results to rainwater penetration and the exhaust gases do not flow upwards, causing oxidation at various points, even inside the combustion chamber. It is recommended to **replace the chimney.** In addition, most of the pipes in the boiler room (A) are very rusty and partly insulated, so it is recommended to replace them with new ones that will be insulated externally. **Boiler B [CB]:** There is need **to clean and regulate combustion of the device**. Additionally, it is observed an increased exhaust temperature of about 15°C (265°C) with respect to the maximum allowable temperature of 250°C. **Boiler C [CB]:** There is need to clean and regulate combustion of the device. In addition, based on optical inspection, it is recommended to **insulate the pipes which are directed to and from the pumps of Boiler-B and C** which do not have insulation.
4*	93.3%	-	**In this case there are questions on both the validity of the readings of the gas analyser and the settings of the boiler-chimney system** as according to the manufacturer the maximum rated efficiency, at full load does not exceed 90.7%. The boiler was left to reach steady state for more than 35 minutes before the first reading was taken and a further 10 minutes when a second one was taken, which verified steady state conditions. Furthermore, the CO/CO_2 ratio was found null as was the CO levels. Even though the readings may be erroneous, **corrective actions and professional maintenance** as per manufacturer's recommendations should be carried out. Based on findings of the optical inspection the auditors suggest **replacing the old insulation with new and thicker** as most of the pipes in the boiler room were partly insulated. It is also recommended to **remove the objects that cover the heating panels** and prevented the air circulation which reduces their performance.
5*	77.4%	-	There is a need to **clean and adjust the combustion of the device** (burner settings). **Further adjustment** as to the temperature settings and the chimney duct sizing and/or damping **should be considered since the combustion air ratio was measured to be equal to 2.73 [instead of 1.22]**. The flue gas water temperature exceeds the rated (labelled) temperature, of 200°C by 65°C, which ultimately deems the **performance of the boiler system poor.** Furthermore, the CO/CO_2 ratio was found null as was the CO levels. Even though the readings may be erroneous, **corrective actions and professional maintenance** as per the manufacturer's recommendations should be carried out. In addition, based on findings of the optical inspection the auditors observed that most of the pipes in the boiler room were partly insulated, so it is recommended to **replace the old insulation with new and thicker**.
** During the first visit for the energy audit boilers were out of operation due to fair weather conditions causing absence of heating demand, therefore a second visit was arranged for measurements within 2018-2019.*			

Except the boilers' inspection, an analysis and determination of the heat losses of the heating distribution network took place for each pilot school.

The existing heating distribution network in all pilots consists of two sections. The first section includes the hot water pipelines between the hot water boiler and the collectors. In this section the water circulates at an average temperature of 80 °C and is therefore classified as a high temperature part. The second section of the network includes the hot water distribution pipelines from the collectors to the heating panels (radiators). In the second section the average water temperature is again at 80 °C and hence this section is also characterized as a high temperature.

More specifically, the high temperature section of the installation is subdivided for morphological and computational purposes into three subnets. The first subnet (SN-1) includes the part of the installation from the collectors to the heating panels in the heated rooms. The second subnet (SN-2) includes the part of the installation from the hot water boiler up to the entry shaft on the ground next to the boiler room. The third subnet (SN-3) includes the part of the installation that goes into the ground and ends up in the collectors. The determination of the thermal losses of the high temperature network was based on the methodology of CYS EN 15316-2:2017[10] on a monthly basis, for the subnets 1, 2 respectively, as for the third subnet it was not possible to determine its characteristics.

EQUATION 2: DETERMINATION OF THE THERMAL LOSSES OF THE HIGH TEMPERATURE NETWORK BASED ON THE METHODOLOGY OF CYS EN 15316-2:2017

$$Q_{HCW,dis,ls} = \frac{1}{1000} \sum_{0}^{t_{HCW,op}} \sum_{j} \Psi_j \cdot \left(\vartheta_{HCW,mean} - \vartheta_{HCW,amb,j}\right) \cdot \left(L + L_{equi}\right) \cdot t_{ci}$$

Based on the acquired data and by applying the above methodology, shown in Equation 2, the losses of the high temperature heat distribution system were calculated for each school. The results vary for each school, with the highest losses located at the Ayios Georgios 3rd Primary School at 13,755 kWh/year or 1,363 L/year.

[10] CYS EN 15316-2:2017 (2017). Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems.

FIGURE 30: INDICATIVE OIL BOILERS LOCATED AT PILOT SCHOOLS. UP LEFT: DESTROYED BOILER AT AYIOS GEORGIOS SCHOOL. DOWN LEFT: LIVADIA [CB] BOILER. RIGHT AYIOS ANDREAS [CA] BOILER.

Analysis of the cooling system

Pilot school buildings use occasionally local air conditioning systems (split type units) in order to cover cooling loads in warm periods. It is noted that the installation of active cooling in classrooms is contrary to the school's design standards[11] but few of the pilot buildings have cooling installed in some specific classrooms that are generally warmer due to type of use, orientation and floor. Overall, split A/C units are usually located in offices and administration spaces and occasionally in labs and special education classrooms. Prefabricated spaces also have installed A/C units for cooling and heating purposes.

Active cooling is usually used between late May to late June and then from September to mid-October, for about 2 to 4 hours per day, however, their usage factor includes high uncertainty. In July and August their use is limited to just few administrative spaces which are occupied.

[11] In accordance with the Guide "Primary school - Design standards" (2011), which is published form the Technical Services of the MoECSY, active cooling should be avoided, and cooling should only be achieved with cross ventilation.

TABLE 7: SUMMARISED TABLE OF A/C INSPECTION

School	Number of A/C units installed	Total installed power [kW]	Efficiency [EER]
1	12	69.5	2.8 - 3.3
2	8	38.5	3.0 - 3.2
3	15	104.0	2.7 - 3.2
4	4	16.7	3.0 - 3.4
5	8	44.0	2.9 - 3.2

It is worth noticing that during the optical inspection of the heat pumps, the auditing team did not notice any significant misoperation or evident indicating poor maintenance in any of the pilot buildings. Based on these, the operation of the cooling system is acceptable, and the auditors suggest only to maintaining the existing maintenance scheme until the split units need replacement. In this case, it is pointed that for the installation of new split units, the Technical Services of the MoECSY, have adopted some standards where the seasonal efficiency of the units in "average climate" conditions should be:

- When used for cooling: SEER ≥ 5.6 and A+ class
- When used for heating: SCOP ≥ 4.0 and A+ class

Analysis of the ventilation system

Pilot school buildings use for the most fans, both for cooling and ventilation purposes. Fans are usually installed in classrooms as A/C units should be avoided. On average, every classroom is equipped with 4 wall mounted fans. According to the auditing findings, during the cooling period [May – Early October] the fans are in operation between 3 to 5 hours per day based on the orientation and the daily occupation schedule of each classroom, whereas in other months they can be used for ventilation when the classroom is overheated. Moreover, the equipment is of similar efficiency compared to the new equipment provided now in the market, and well maintained. Based on this, the auditors suggest maintaining the operation of the ventilation system in current standards.

TABLE 8: SUMMARISED TABLE OF VENTILATION INSPECTION

School	Number of fans installed	Total installed power [kW]
1	31	2.48
2	17	1.42
3	58	4.64
4	30	2.40
5	45	3.60

Analysis of the Lighting System

Lighting was the major electricity consumer for all the pilot buildings [Section 3.3.1]. The lighting of the facilities can be divided into two sub-systems, indoor lighting and outdoors lighting. The indoor lighting is mainly used during the day in the classrooms and the offices of the building. The outdoor lighting is used for safety purposes at night. For all the schools, it was considered that the lighting in occupied spaces is used for about 2-3 hours in summer month, 4-5 hours in winter months and 3-4 hours for the rest of the period.

In general, the lighting system of the selected schools [Table 9] consists of fluorescence tubes, CFL and incandescent lighting that it is of lower efficiency compared to the existing LED lighting technology indicating that an intervention in the existing system is of high importance.

TABLE 9: SUMMARISED TABLE OF LIGHTING SYSTEM INSPECTION

School	LED	Incandescent	CFL	Fluorescent [4ft]	Fluorescent [2ft]	Floodlights (small)	Floodlights (large)	Total installed power [kW]
1	4	9	54	166	48	6	5	17.37
2	4	3	1+3	152+10	48	3	3	12.90
3	8+20	-	26	190	452	16	-	26.86
4	-	-	57	138	-	19	-	14.35
5	2+6	-	5+13+7	143+39	164	20	-	22.64

Overall, the most common indoor lighting used is 120 cm fluorescence tubes with a rated power including the ballast of 69 W, installed in double lighting fixtures. This lighting fixtures are found in all the classrooms, as well as the multipurpose rooms of the schools. The administration offices usually have 60 x 60 cm fluorescence lighting fixture containing four 60 cm fluorescence tubes with a rated power of 21 W each. Other areas in the building with a lower use, such as the staircase, the toilets, storage rooms and the outer corridors, have CFL and incandescent lighting installed. The incandescent lighting bulbs are no longer available for purchase and therefore it is expected that when the lighting fixtures stop working, they will be replaced with CFL or LED lights.

The outdoors lighting is mostly divided into two sub-systems, the daily safety lighting and the corridor, staircase and peripheral lighting. The corridor and staircase lighting it usually consists of CFL lights whereas the safety sub-system consists of small floodlights and occasionally large floodlights. The safety lighting is turned on for approximately 5 and 7 hours at night depending on summer or winter time respectively.

Analysis of the ICT equipment

Office equipment was the second or third largest electricity consumer of the schools. The typical equipment found in every classroom includes PC's, LCD displays, video-projectors, speakers and in a few classes, printers and smartboards. Other equipment may include CD players and TVs. It is worth noticing that there are significant opportunities for energy efficiency improvement in ICT but taking into consideration that the majority of the office and classroom equipment are under massive procurement schemes centrally controlled by the Ministry administrative, it's quite difficult for the school to apply its own strategy. Based on this, the auditors underline only this opportunity, but no other suggestions are provided.

TABLE 10: SUMMARISED TABLE OF ICT EQUIPMENT INSPECTION

School	Total installed power [kW]
1	16
2	34
3	28
4	15
5	19

Analysis of Kitchen Equipment

Kitchen equipment is also a large electricity consumer at the audited schools. The equipment found includes water coolers, fridges and freezers, toasters, electric stoves and heaters, coffee makers, kettles, hot water thermal heaters and microwaves. As with the ICT equipment, there are significant opportunities for energy efficiency improvement in kitchen equipment but taking into consideration that the majority of the kitchen equipment are under massive procurement schemes centrally controlled by the Ministry administrative, it's quite difficult for the school to apply its own strategy. Based on this, the auditors underline only this opportunity, but no other suggestions are provided.

TABLE 11: SUMMARISED TABLE OF KITCHEN EQUIPMENT INSPECTION

School	Total installed power [kW]
1	10
2	23
3	11
4	13
5	13

Analysis of Photovoltaic Systems

Two of the pilot schools, Ayios Andreas and Livadia, were equipped with Photovoltaic System of 1 kW_p and 7 kW_p respectively. The PV Systems were correspondingly placed on 2007 and 2012 with an initiative of the Technical Services of the MoECSY. In accordance to their electricity production, the school board is getting bimonthly payments after a contractual agreement with the Electricity Authority of Cyprus. In this way, the school premises do not use the produced electricity for on-site consumption, however the school board has an extra income which can be used to cover the energy bills. The remaining schools do not use any kind of RES.

3.3 Energy Consumption

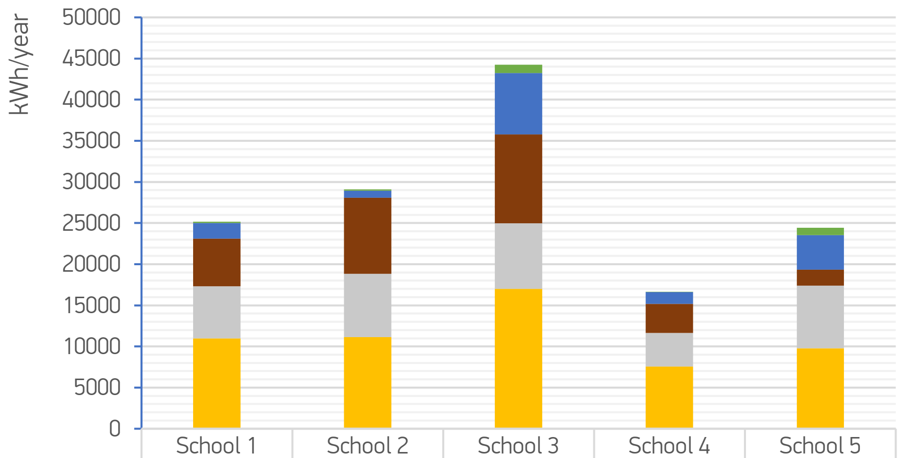
All the facilities use electricity to cover their lighting and cooling needs and for the use of the electrical appliances and equipment. For heating purposes, the schools use heating oil, whereas hot water is not provided in the schools except for some rare uses [i.e. For the infirmary or the kitchens]. The schools do not use directly any type of RES. The following average annual energy consumption and energy costs have emerged from the review of electricity invoices and oil bills between 2015 and 2018.

Electricity Consumption and Mix

Due to the way energy provider is measuring the consumption, monthly consumptions are not always available. Nonetheless, from the analysis of the collected bimonthly electricity invoices for 3 years, the annual electricity consumptions were estimated for each school. Those were used to form the baseline consumption and to establish a seasonal profile.

For every school, an electricity breakdown for all different uses has been produced given the data, measurements[12], schedules and profiles gathered from the visits. The detailed data considered were:

- the electricity consuming equipment (lighting, computers etc) recorded on site,
- the school's basic schedule
- specific daily usage of equipment
- verbal information given by the school staff about the use of interior and exterior lights, cooling and heating with the split units, ICT equipment and other devices.
- information from the manufacturers were available



	School 1	School 2	School 3	School 4	School 5
Other	180	155	1016	0	885
Cooling [AC & Fans]	1896	850	7462	1412	4204
Kitchen Equipment	5793	9243	10819	3557	1951
Office Equipment	6332	7702	7956	4071	7598
Lighting	10973	11128	17010	7559	9787

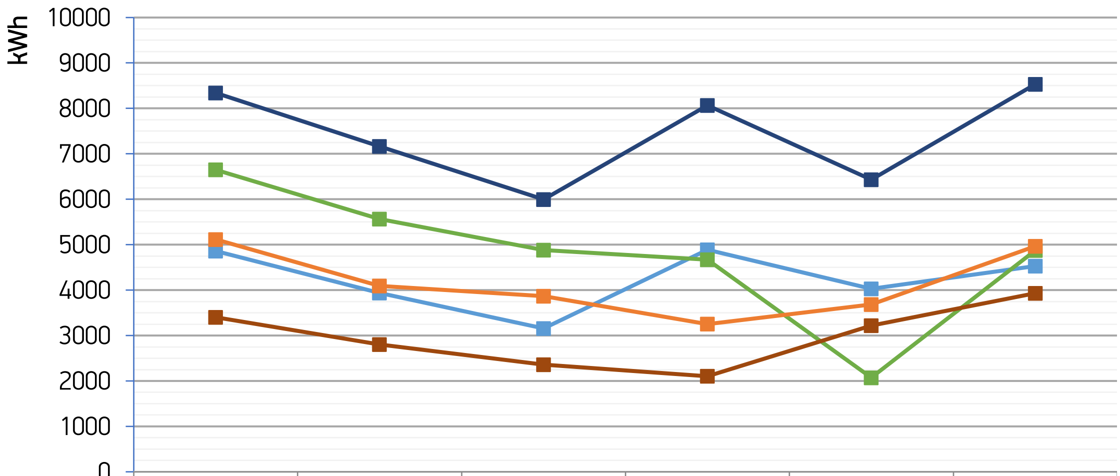
Graph 1: Electricity consumption breakdown of the facilities

The electricity consumption of the facilities can be broken down into five categories as presented in [Graph 1] for all pilot buildings. The four main categories include lighting that is responsible for the biggest

[12] A power analyser was installed for 2-3 weeks in every school in order to establish the actual consumptions and calibrate the Energy Model.

proportion of the total electricity consumption, including both indoor and outdoor lighting. The remaining 3 categories [office equipment, kitchen equipment, Cooling] vary among the schools as they are based on the usage patterns, the installed capacity of the equipment and the number of users. The last category 'other', includes special equipment for some classes and the boiler pumps.

A seasonal profile was not easy to be acquired for all the schools as the consumption did not range significantly through the various seasons. Nonetheless, for schools #4, #5 a seasonal profile was acquired as the consumption through all the years of gathered data, followed the same trend. For most schools, the lowest consumption is observed during the period mid-July – early September, as the schools are closed for most of the time. However, the consumption is not negligible, as some school premises are used for summer activities, the administrative and technical staff can be present at the school, and there is also operating equipment and external safety lighting in use [Graph 2].



	Dec -Jan	Feb - Mar	Apr - May	Jun - Jul	Aug - Sep	Oct - Nov
School 1	4858	3940	3157	4888	4028	4526
School 2	6648	5567	4879	4669	2073	4874
School 3	8341	7167	5996	8069	6431	8533
School 4	3404	2801	2358	2103	3222	3932
School 5	5117	4093	3864	3251	3686	4966

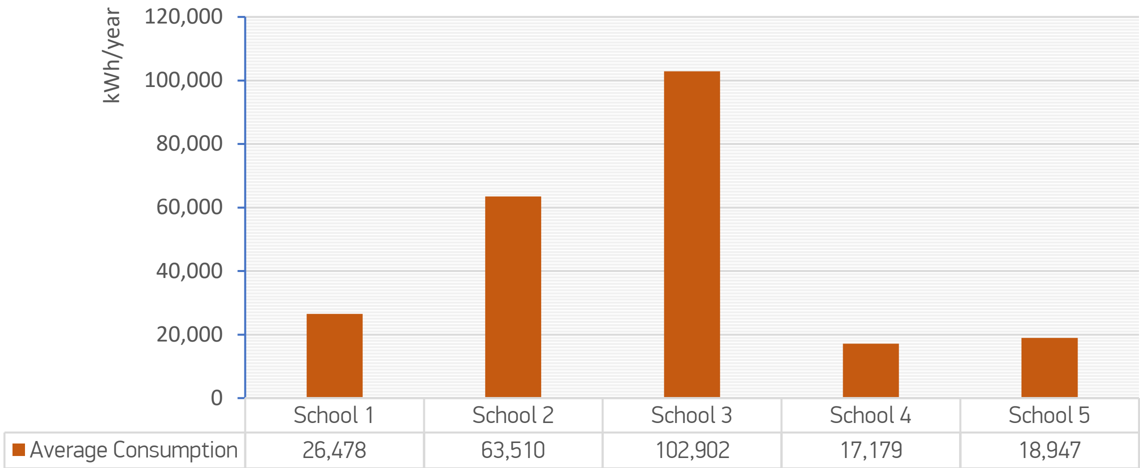
GRAPH 2: AVERAGE ANNUAL ELECTRICITY CONSUMPTION (PROFILE) FOR THE PILOT SCHOOLS [BASED ON THE YEARS 2016-2017, WHICH WERE COMPLETED FOR ALL SCHOOLS]

It is also noted that between April and May, the climatological conditions in Cyprus are usually comfortable to warm and the daylight duration is longer, therefore schools are free-running, which justifies the lower consumptions. On the other hand, the high consumptions which were observed during the winter months in some cases, seem to be highly connected with the extended use of artificial lighting.

Overall, it seems that the electricity the consumption is highly connected to the external conditions and the usage of the building. Generally, the annual consumption, for the most part, follows the same trend, which is highly expected as the use profile remains almost stable at each year (lighting use, equipment use). Moreover, as the schools do not usually use active cooling in the classrooms and use oil for heating, the variations due to the climatological data can be seen mainly in terms of primary energy.

Oil Consumption

School buildings are equipped with typical oil boilers for covering their heating as described in Section 3.2. The consumptions were given in 'litres of oil' that were purchased in various times for at least three academic years. Those were converted to kWh for comparison purposes, in accordance to the factors provided by the Energy Service [see at the beginning of the document]. It is noted that the heating demand was calculated based on the systems' efficiencies and the annual consumption for each school. In Graph 3, the average consumption of heating oil per school is provided.



GRAPH 3: HEATING OIL CONSUMPTION BREAKDOWN OF THE FACILITIES

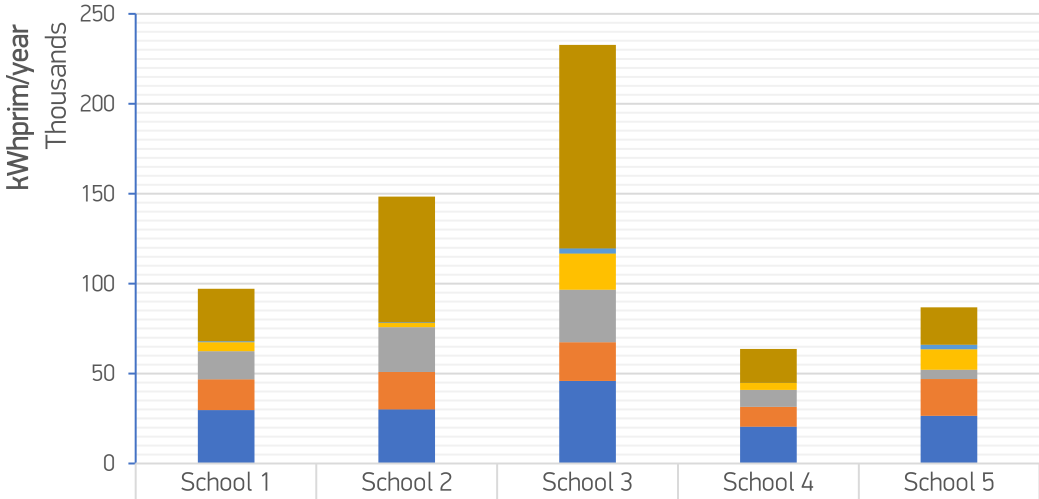
It was observed that the oil refills for each season (academic year), are usually taking place in early autumn[13], nonetheless some schools prefer to make 3 or more refills per year based on their needs. Over a period of 3 years it seems that the demand for heating remained more or less stable for the majority of schools. This is justified due to the fact that the operating profile of the heating systems and the systems themselves remained the same over these years and the schools' premises or the number of users did not change significantly. It is noted that, even if there were differences among the climatological conditions during the years of the collected data, it seems that it didn't affect the schools at a great extent.

Primary Energy Consumption and CO_2 Emissions

From the baseline consumption for electricity and heating oil, the primary energy consumption occurs, which displays how much energy is needed to be consumed in total in order for the final energy to be delivered at schools [Graph 4]. Electricity has a high factor when converted to primary energy terms because it is produced on an isolated grid and mostly by burning fossil fuels. The factors used for the calculations have been adapted from the *Energy Service, Ministry of Energy, Commerce, Industry and Tourism (2015), Building Energy Performance Calculation Methodology – Part C, Nicosia, Cyprus,* and those are as follows:

- Conversion factor for primary energy and CO_2 Emissions for electricity: 2.7 and 0.794 respectively.
- Conversion factor for primary energy and CO_2 Emissions for Heating Oil: 1.1 and 0.266 respectively.
    - o Lower Calorific value of heating oil: 10.11 kWh/L.

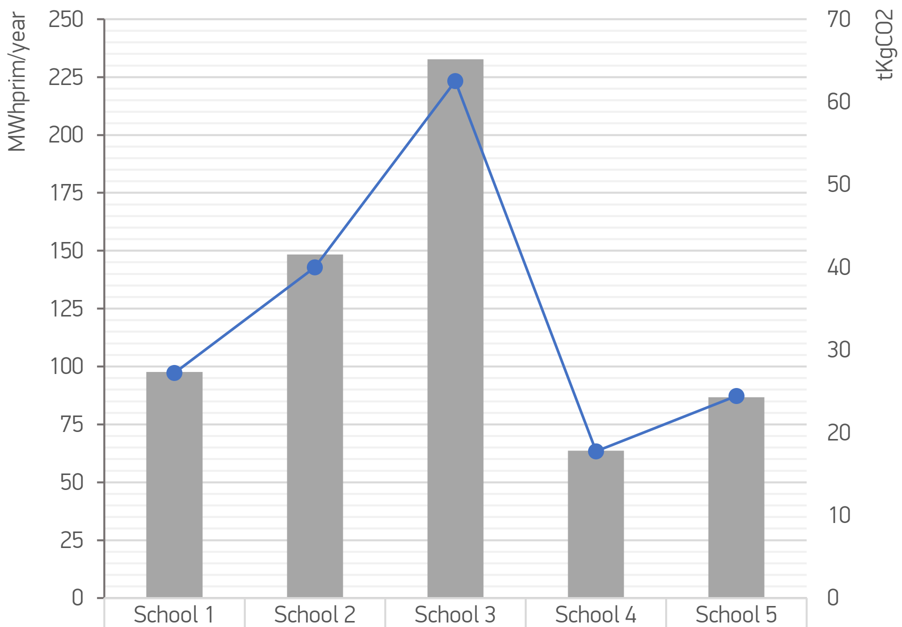
[13] According to the school boards, the refills of heating oil for each winter (November - March) are taking place once per year, however it is possible for more refills to take place later on if necessary.



	School 1	School 2	School 3	School 4	School 5
Heating Oil	29126	69861	113193	18896	20842
Other [Electricity]	486	419	2742	1	2390
Cooling [AC & Fans]	5119	2294	20148	3812	11349
Kitchen Equipment	15641	24956	29210	9604	5266
Office Equipment	17096	20797	21480	10991	20514
Lighting	29628	30045	45926	20409	26426

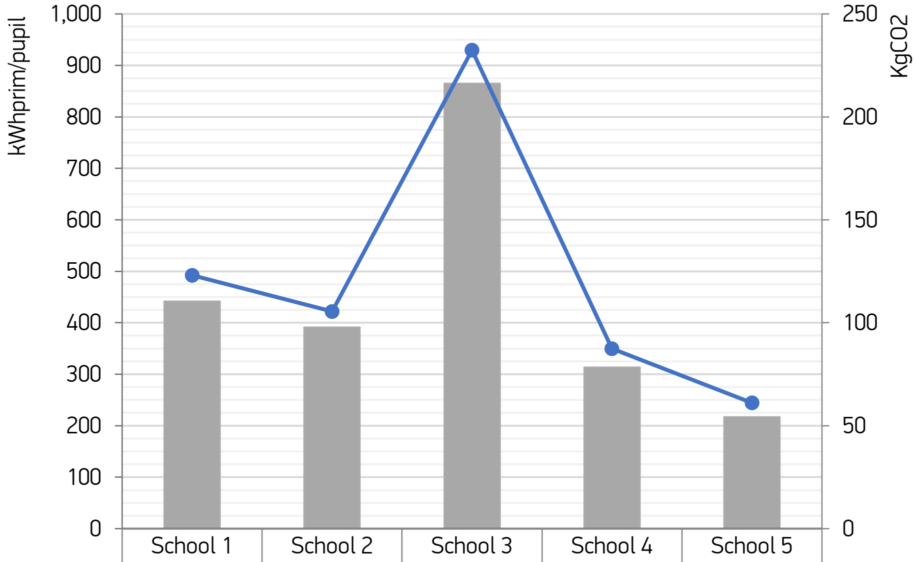
GRAPH 4: PRIMARY ENERGY CONSUMPTION BREAKDOWN [KWH$_{PRIM}$/YEAR]

The primary energy consumption and the corresponding CO_2 emissions of the schools are presented in Graph 5, whereas Graph 6 indicates the primary energy consumption and the corresponding CO_2 emissions per pupil in order to provide an apparent correlation.



	School 1	School 2	School 3	School 4	School 5
Primary Energy Consumption [kWhprim/year]	97,694.17	148,371.55	232,700.12	63,701.15	86,788.88
CO2 Emissions [KgCO2]	27,207.30	39,981.58	62,516.08	17,745.41	24,433.27

GRAPH 5: AVERAGE ANNUAL PRIMARY ENERGY CONSUMPTION AND CORRESPONDING CO2 EMISSIONS OF THE PILOT SCHOOLS



	School 1	School 2	School 3	School 4	School 5
Primary Energy Consumption per pupil [kWhpr/pupil·a]	442.06	391.48	865.06	313.80	216.97
Carbon emissions per pupil [KgCO2/student·year]	123.11	105.49	232.40	87.42	61.08

GRAPH 6: AVERAGE ANNUAL PRIMARY ENERGY CONSUMPTION AND CORRESPONDING CO2 EMISSIONS PER PUPIL, FOR EACH OF THE PILOT SCHOOLS

The values of the primary energy consumption of the schools, except from the School #3 (Agios Andreas) are not significantly high, due to the fact the schools operate for limited hours each day, within the daylight, they remain close for long periods and do not use active cooling, except in some occasions. However, to reach NZEB levels, which is the general target set in TEESCHOOLS project, other requirements should be met. This means that the building shell and the systems should satisfy specific requirements as set in the relevant legislation [Decree 366/2014]. At the same time, renewable energy generation should take place on site. For this reason, specific measures for implementation have been proposed for each school, both to reach the NZEB level and to save energy from individual interventions. Those are provided in the next chapter.

4. INTERVENTION PROPOSAL AND RECOMMENDATIONS

4.1 ENERGY DEMAND REDUCTION

The reduction of the energy demand is the starting point when planning an energy conservation strategy. For a building to reduce its heating and cooling demand means mostly better thermal performance of its envelope. Other measures like increase or reduction of the solar and other internal gains, can also reduce heating demand but usually it is not as effectively as insulation and they are also depended on users' behaviour.

Envelope

In Cyprus, the existence of insulation on the buildings' envelope strongly depends on the year of construction. All pilot schools were constructed prior to 2007 when the first insulation regulation was issued. This means, that the majority of building elements of the schools under study are totally without insulation (Section 2.3), while the existing calculated thermal transmittances do not meet the minimum requirements. Three of the schools (#1, #2, #5) have spaces that were constructed after 2007 which are equipped with insulation, nonetheless, their total surface is very low compared to the overall building's surface.

The higher proportion of the heat loss during the winter and vice versa for summer, is happening from the roof and the walls. For this reason, the first intervention of the renovation plan is to insulate the roofs[14] of the buildings which do not have insulation. In specific, for this scenario, extruded polystyrene of 10 cm width and λ equal to 0.032 W/(m·K) is selected for most of the cases. This selection is based due to the fact that extruded or expanded polystyrene is the most common material used for thermal insulation for flat roofs in Cyprus, there is also high technical expertise for its installation, and it's one of the most efficient insulation in terms of efficiency and initial cost. For metal roofs and inclined roofs different materials are proposed [Table 12].

This measure will reduce the building's demands, mainly for heating as active cooling is not used at a great extent, achieving energy savings. It is also expected that the internal conditions will be improved, and the operating time of the heating system will be reduced. It should be pointed out that for schools, the savings achieved are not enough to ensure the financial viability of the interventions.

In the table below all the U-values of the roofs in current condition, the proposed ones, as well as the insulating material thickness needed are presented accordingly with the primary energy savings.

[14] It is noted that the insulation of the external walls as an individual measure is not examined due to its high capital cost [negative cumulative cash flows], nevertheless, within the NZEB scenario, the insulation of the walls is included. The same applies for roofs that are already insulated with more than 500 mm thickness of insulation material.

TABLE 12: PILOT BUILDINGS - ROOF INSULATION PROPOSAL

School	Existing Roofs U-Values (W/m²K)	Insulation thickness (mm)	Roofs New U-Values (W/m²K)	Total area of roof insulation surface (m²)	Primary Energy Reduction [kWh/year]
1	2.31	80	0.28	952	-14,207 [15%]
	3.21	100	0.28		
	3.00	100	0.28		
	0.48	-	-	-	
	0.28	-	-	-	
2	3.21	100	0.28	1,116	-8,824 [6%]
	3.00	100	0.28		
	0.48	-		-	
	6.18	50 [polyurethane foam]	0.40	330	
3	2.31	100	0.27	1,186	-16,398 [7%]
	3.21	100	0.29		
	2.19	100 [rockwool]	0.32	792	
4	0.52	-	-	-	-
5	0.59	-	-	-	-400-600[15] [1%]
	0.33	-	-	-	
	2.19	100 [rockwool]	0.32	388	

Windows

Windows and openings in general are responsible for a significant amount of heat loss, not only by transmittance but also due to infiltration. The selected school buildings have a high proportion of windows that were installed when the buildings were initially constructed. However, during the last years, there have been some interventions in some of the schools where the windows were replaced.

For the purposes of the energy audits, the auditor's team deemed that the replacement of the windows should not be examined as an individual measure since it has a very high capital cost [negative cumulative cash flows] and each opening requires a separate check [for leaks, malfunctions, erosion etc]. Their replacement is only suggested by the auditors in the cases that the windows are irreversibly damaged or have obvious leaks[16]. Nevertheless, within the NZEB scenario, the replacement of the windows is taken into consideration to satisfy the minimum energy performance requirements for windows [ANNEX 7.1].

It is noted that the reduction in heating and cooling demand that will be achieved by adding insulation to the building envelope is estimated using a building simulation model, developed in the environment of IES-VE[17] software.

[15] This measure is not examined in terms of techno-economic analysis, as insulation will be placed in Block A which equals to around 17% of the total HFA and therefore the estimated savings range from 350 – 550 kWh of heating oil per year, which translates to just 30 € to 40 €. It's only proposed by the energy auditors for thermal comfort improvement.

[16] The proposed replacements concern double glazing, aluminium frames with thermal breaks which is more compatible with the standards of the Technical Services.

[17] The IES Virtual Environment (VE) is a suite of building performance analysis applications. It can be used by to test different options, identify passive solutions, compare low-carbon & renewable technologies, and draw conclusions on energy use, CO_2 emissions and occupant comfort.

Other strategies

In some of the pilot schools were the in-situ visit showed that there is room for improvement, the auditors proposed the use of passive strategies in order to reduce the heating or cooling demand and to improve thermal comfort levels. Strategies which maximize the utilization of sun penetration in winter and they cut it off during summer, like the correct use of internal curtains, were suggested. In addition, it was also proposed to reduce internal gains from equipment and lighting during summer when possible. The cross ventilation was introduced for the warm periods, whereas for winter period, the seal of windows' leakage was proposed. It is noted nevertheless that it is not easy to measure the impact of these measures.

4.2 Energy Systems

Lighting systems

As it can be observed from the Graph 1, lighting holds the biggest proportion of electricity consumption in all the pilot school buildings, despite the fact that schools are occupied and operate mainly during the daytime. External lighting also holds a big proportion of electricity consumption. Therefore, it is the first energy system which is proposed for an upgrade as it can lead to significant energy savings.

The auditors suggested the replacement of all the lighting fixtures of older technology, with LED lighting fixtures [Table 13]. It is important to underline that it was suggested to replace the fixtures and not just the lamps, with LED fixtures. The most common LED fixture is the LED panel. It is also noted that the lighting profile (operating hours) were kept the same for the evaluation of this scenario.

The luminance level after the intervention should be in the range of the acceptable levels, defined by the national regulations. Specifically, it is 300 lux for classrooms/offices and 500 lux for labs, at desk level. To achieve that, a full lighting study should take place for each space. However, for the purposes of the energy audit typical values were considered, in order to estimate the installed power of the proposed LED systems that would be necessary to cover the relative demand. In the next table the expected electricity savings due to LED systems and automated control are summarized for all pilot schools.

TABLE 13: LIGHTING SYSTEM REPLACEMENT PROPOSAL [SEE IN COMPARISON WITH TABLE 9]

School	Dominant Lighting fixtures and lamp type	Dominant External lighting	Total installed power [kW]	Total installed power [kW] - LED	Primary Energy Reduction [kWh/year]
1	Fluorescent [4ft]	Floodlights (small) Floodlights (large)	17.37	5.3	**-21,276 [22%]**
2	Fluorescent [4ft]	Floodlights (small) Floodlights (large)	12.90	4.65	**-19,931 [13%]**
3	Fluorescent [4ft] Fluorescent [2ft]	Floodlights (small)	26.86	8.54	**-30,937 [14%]**
4	Fluorescent [4ft]	Floodlights (small)	14.35	4.27	**-14,094 [22%]**
5	Fluorescent [4ft] Fluorescent [2ft]	Floodlights (small)	22.64	6.32	**-18,757 [21%]**

Apart from the LED fixtures, automation systems[18] for classrooms and offices that have adequate daylight are proposed for installation. Such a system is designed to dim, or to turn on and off the lights, or part of the lights, automatically when there is adequate daylight. In addition, for circulation spaces, it is suggested to install a presence sensor, in order to be activated only when there are people. This will be needed mainly for the premises that are used for afternoon activities.

Heating system

In terms of final energy consumption[19], heating consumption is higher than electricity in all pilot buildings. The efficiency of converting the energy of the fuel to thermal energy and transferring it into the conditioned spaces is the most crucial factor when in pursuit for energy savings. The majority of oil boilers of the pilot schools are not adequate maintained or operated at efficient way [see section 3.2], whereas the piping systems are inadequately insulated due to damaged or lack of insulation. Moreover, the controls of the systems are manual for the whole building, making the overall system inefficient. Thermal comfort is also an issue because there is no possibility in controlling each space separately.

The auditors do not propose the replacement of the boilers except in one case which the boiler is damaged and out of operation (Ayios Georgios, School#2), nonetheless, since the school is covering its needs from the other boiler, the scenario for the LCC concerns only the boiler which is in operation. For this reason, the proposed measures for heating, concern 2 scenarios, (a) the extensive maintenance and adjustments of the boiler and burner, and (b) the thermal insulation of the heating distribution pipelines [Table 14]. It is also suggested to install thermostatic valves to each space for better control of the indoor conditions.

For (a) it was proposed to clean the heat transfer surfaces of the boiler and proper adjust the operation conditions of the burner in order to fulfil the operational requirements of the national regulation for maintenance and adjustment of the boiler systems. For (b) it is proposed to install or to replace (depends on the case) the existing insulation of the hot distribution pipes with 25 mm and 40 mm Armaflex foam insulation for the subnets, with a factor thermal treatment of maximum 0,041 W/(m·K) at 50 °C and outer coating of elastomeric material, or metal or plastic foil. In any case, the new foamed insulating material must be fitted with a water vapor barrier to prevent moisture dissipation during non-operation of the network through insulation, resulting in condensation on the surface of the steel pipe.

TABLE 14: MEASURES FOR REDUCING ENERGY CONSUMPTION FOR HEATING

School	Boiler maintenance and adjustments	Thermal insulation of heating distribution pipelines	Primary Energy Reduction [kWh/year]
1	-	✓	-1,613 [2%]
2	✓	✓	-22,610 [15%]
3	✓	✓	-14,700 [7%]
4	-	✓	-383 [1%]
5	✓	✓	-3,091 [4%]

[18] With automations, the consumption of a lighting system installed in schools decreases by approximately 30-40%.
[19] Final energy consumption is the amount of energy that is consumed in the building for its needs. In the case of heating, it is the amount of oil that is burnt in the boiler to produce heat.

Cooling system

As it was described in Section 3.2, active cooling is limited in most of the pilot schools and applied locally with split type A/C units. These are installed in administrative offices, labs, special education classroom and classrooms that have more overheating problems due to their use and orientation. During the inspection, the auditing team did not notice any significant misoperation or evident indicating poor maintenance in any of the pilot buildings. Based on these, the operation of the cooling system is acceptable, and the auditors suggest only to maintaining the existing maintenance scheme. The same applies for fans which are installed in the majority of the pilot schools.

It is also pointed that for the installation of new split units or fans, the Technical Services of the Ministry have adopted specific energy standards and they are already upgrading them, therefore no other measures are suggested on this. Replacement of A/Cs that are malfunctioning should be examined at individual level.

4.3 Renewable Energy Sources

According to the current Energy Performance of Buildings legislation, a certain amount of the energy consumed at a building must be generated on site by a renewable source system. In this scenario, the RES installation is examined as an individual scenario.

The most common system that generates renewable energy in Cyprus and can be installed in urban environment is the photovoltaic system (PV) that converts solar radiation to electricity. At the same time, schools have a lot of free roof space that is the most ideal place for installing PV systems. The fact that the schools are in use at the peak of PV production is also very important.

The use of solar energy in Cyprus is very promising due to the fact that all regions of Cyprus have a long duration of sunshine. In the lowlands, the average number of hours of sunshine for the whole year is 75% of the hours the sun is above the horizon. Throughout summer, sunshine averages 11 - 12 hours a day, while in December and January that have the most clouds, the duration of sunshine decreases only at 5-6 hours a day. The average daily solar radiation in a horizontal plane in Cyprus is estimated at 5.4 kWh/m^2.

Photovoltaic panels can be installed both in flat roofs or inclined ones unless they are partially or fully shaded. The PV systems that are proposed will be connect to the grid with the "net-metering" scheme[20] which is available in Cyprus for up to 10 kWp since 2018. This means that generated electricity on site by the PV system of the school building is withdrawn from the electricity the building consumed from the grid on a bimonthly period. If more electricity is generated than consumed from the grid, then it can be transfer for up to March of each year, but further to that, no compensation can be claimed. Thus, the size of the system has to be chosen in order to at least cover the yearly electricity demand of the school.

The software PVSYST v.6.40 was used to calculate the electricity generated by the photovoltaic system, based on the following features:

- Interconnected with the net-metering scheme;
- Frame angle at 33°-34°;

[20] The Net-billing scheme, for bigger systems, is also available for non-residential consumers, nonetheless, the audit team is not proposing a system larger than 10 kWp for any of the schools therefore only the net-metering scheme is examined. Furthermore, during the initiation of the energy audits, net-billing was not available.

- PV module: Si-poly;
- Panel surface 1.6 m^2;
- Number of PV modules, in-series: 10 modules, in-parallel: 2 strings;
- Total number of modules: 20 with a power of 260 W_p each;
- Local climate data.

For the evaluation of energy production of the PV array the following assumptions are used.

- Thermal loss factors Uc (constant) at 20 W/(m^2·K) and Uv (wind) at 0 W/(m^2·K);
- Wiring ohmic loss, Global array res. 60 mOhm, loss faction 0.8% at STC;
- Module quality loss, loss fraction 0.8%;
- Module mismatch losses, loss fraction 1.0% at MPP;
- Incidence effect, ASHRAE parametrization, IAM = 1 - bo·(1/cos i – 1), bo param. 0.05.

TABLE 15: PV SYSTEMS PROPOSAL

School	Total number of PV panels	Total power installed (kWp)	Inclination/ Orientation	Annual electricity generation (kWh)
1	20	5.2	34°/ 194° SSE	**8,500**
2	20	5.2	34°/ 180° S	**8,300**
3[21]	40	10.4	34°/ 194° SSE	**17,800**
4	20	5.2	33° / SE ® 0°	**9,230**
5	30	7.8	33°/ 162° SSE	**13,800**

4.4 Total renovation scheme - Energy Upgrade to NZEB

The energy upgrade of the building to NZEB is one of the basic objectives of TEESCHOOLS project. Through this assessment, new opportunities for funding schemes and renovation plans may arise. In addition, thermal comfort conditions in this type of school buildings can be examined setting the benchmark.

More specifically, this scenario concerns the energy upgrade of the School Buildings to a NZEB as this is defined in the relative law (Regulatory Administrative Act 366/2014[22]). A building to be defined as NZEB, it needs to consume less than 100 kWh_{pr}/m^2•year but also to achieve an energy class of A on the Energy performance Certificate. It also needs to have construction elements of low thermal conductivity and to cover at least 25% of its needs from RES [See Annex 7.1]. For this reason, the following scenarios [Table 16] include measures for the improvement of the envelopes' energy performance and of the schools' systems. They also include a scenario for RES installation, in order to reach at least 25% of the estimated primary energy consumption.

[21] This scenario concerns only the case in which a sperate electricity meter is installed in the school. Currently there is a PV system installed in the school in contractual agreement with the Electricity Authority of Cyprus. The same applies for School #4.
[22] MECIT (2014), *"Requirements and technical characteristics to be met by the Nearly Zero Energy Building - RAA 366/2014"*

It is noted that when combined with the insulation of the building envelope, the heating systems will have to be of smaller capacity in comparison with the existing ones as they will have to cover less heating demand. Nonetheless, for the purposes of these scenarios, the boilers considered to be the same.

TABLE 16: UPGRADE TO NZEB LEVEL – MEASURES TAKEN

Measures	Schools	Comments
Installation of thermal Insulation on the exterior of the walls [U-Value ≤ 0.4 W/(m²·K)]	1, 2, 3[23], 4, 5[24]	Extruded polystyrene 100 mm with, λ equal to 0.032 W/(m·K)
Installation of thermal Insulation on the roofs [U-Value ≤ 0.4 W/(m²·K)]	1, 2, 3, 4, 5	Extruded polystyrene 100 mm, with λ equal to 0.032 W/(m·K)
Installation of thermal Insulation on the roofs [U-Value ≤ 0.4 W/(m²·K)]	2	Sandwich panel with 50 mm polyurethane foam, with λ equal to 0.022 W/(m·K)
Installation of thermal Insulation on the roofs [U-Value ≤ 0.4 W/(m²·K)]	3, 5	Rockwool 100 mm, with λ equal to 0.037 W/(m·K)
Replacement of the doors and windows [U-Value ≤ 2.25 W/(m²·K)]	1, 2, 3, 4, 5	Double-glazing windows, aluminium frame with thermal break and shades where necessary
Replacement of the existing lighting system with LED lighting	1, 2, 3, 4, 5	See Section 4.2
Maintenance and adjustment of the boiler and burner [Efficiency ≥ 88%]	2, 3, 5	See Section 4.2
Thermal insulation of the heating distribution pipelines of the heating system	1, 2, 3, 4, 5	See Section 4.2
Installation of PV system: with the net-metering method[25] [Capacity ≤ 10 kWp]	1 , 2, 3, 4, 5	Sch. 1, 4: 5.2 kWp Sch.2, 5: 7.8 kWp Sch.3: 10.4 kWp

[23] Only for CB building.
[24] Not for the older building [Block A].
[25] It is noted that the price for a PV system is significantly lower in 2019 compare to 2017-2018, when the audits took place.

4.5 Improvement actions: The web tool

In the framework of TEESCHOOLS project, a web tool was developed that is able to provide a simplified energy evaluation and feedback for school buildings that are located in the project partners' countries. Key actors who have access in some basic information and energy consumption data about their school, can get an idea of its energy performance. The tool gives also the possibility to select some basic renovation options and evaluate the results.

4.6 Financial solutions

Current Status

Financial mechanisms, for energy efficiency renovations in buildings should have a central role in national long-term renovation strategies and be actively promoted. In the case of public school buildings in Cyprus this is even more crucial, as energy efficiency projects are not a priority. The main reasons for proceeding to buildings' renovation are the seismic upgrade, the emergency works and the expansions due to increasing needs. There is also low confidence on investment projects related to energy efficiency in schools, as schools have a complicated management structure and in general, have low energy consumption and low occupancy rates, therefore any measure taken is seen as risky and fragmented. Furthermore, there are limited available energy and operations' data, which becomes a barrier in the establishment of a typical energy profile for school buildings. Furthermore, no relative benchmarks are available at national level.

Overall, schools' budgets are managed by the Local Authorities [School Boards or Community Councils], which are responsible for the financial and overall management of the school building. However, the buildings belong to the central government, under the responsibility of the Ministry of Education, Culture, Sports and Youth, which is the body that decides whether a big-scale intervention on the building will take place. The Ministry is responsible for the school's annual budget and grants given to the schools, as well as for meeting the schools' annual financial obligations. The annual budget and the application for a big-scale or emergency projects, is submitted by the School Board in cooperation with the School Advisory Committee which consists of the Principle and other members. At the same time, the Technical Services of the Ministry is the responsible department for the improvement of the school buildings, taking into account any education or technical requirements.

In regards the implementation of energy renovation projects, even if is not directly assessed, the main responsible for making decisions is the MoECSY, through the Technical Services. Nonetheless, the School Advisory Committee, in advance, has to declare and sufficiently substantiated the needs of the school. In cooperation with the School Board, the School Advisory Committee, can apply for works needed and if/when the MoECSY approves them, the Technical Services are responsible for their implementation.

It is noted that the responsible Department for the implementation of energy renovation in public buildings, and the implementation of the EPBD in Cyprus in general, is the Energy Service of the Ministry of Energy, Commerce and Industry. In Cyprus emphasis is given to stricter energy efficiency standards and investments for public buildings to reach their obligations and more specifically, in buildings with the lowest energy efficiency[26].

[26] Article 7, directive 2010/31/EE – Adapted in: Cyprus' 'Long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private'.

Over the last decade, financial support for investments in energy efficiency and renewable energy technologies has been made available to Cypriot households, commercial companies and public sector through various government-supported schemes, nonetheless, schools are not included in these, except for an initiative for installing 5 MW of Photovoltaic systems in school buildings[27].

An allocated budget for Energy Efficiency projects in public school buildings is not directly available, but the Technical Services of the MoECSY have a budget for maintaining the schools at a good state.

Proposals based on the TEESCHOOLS project

By using the results from the energy audits of the schools, potential ways of financing Energy Upgrades of public school buildings, have been identified. Those will be used for the establishments of decisions at political level:

a. **Own Funding:** Use a proportion of the annual State Budget provided to the Schools Boards specifically for Energy Efficiency projects. The Ministry of Agriculture, Rural Development and Environment, and the Ministry of Energy, Commerce and Industry can also be involved in this.

b. **Local Funding:** Use a proportion of the annual budget of the Local Authority [Municipality or Community], where the school is located, to improve the energy efficiency of the schools.

c. **From Subsides or Incentives:** Those can be derived from relevant Incentives or Schemes, i.e. Provided by the Ministry of Energy, Commerce and Industry. At local level, these Subsides are usually deriving from the Structural Funds[28] or from the Special Fund[29] for Renewable Energy and Energy Conservation.

d. **From ESCOs (Private Money)[30]:** Through Energy Performance Contracts and based on the most cost-effective scenarios. Combined measures for energy upgrades of more than one building are necessary to make this investment attractive as currently the majority of the energy upgrades scenarios for school buildings [low consumptions and limited operation], have limited potential for energy savings.

e. **From Financing Institutions:** Available targeted schemes to cover big-scale projects in the form of favourable loans. Those can be designed on the basis of the Energy-Audits results[31].

[27] Specific details are not available yet.
[28] The budget of the relevant Axis of the current Programming Period is closed.
[29] The Fund is financed through the implementation of an energy fee equal to EUR 0.01 cent per kWh on electricity consumption for all final consumers [green taxation]. The Fund is managed by the Special Fund Managing Committee.
[30] The relevant law for ESCOs was adapted in Cyprus in 2014 and until today, only few ESCOs are officially registered, with no available projects for demonstration and validation.
[31] The Corporate Social Responsibility can be another option for funding – further assessment is needed.

4.7 Training and Behavioural

The critical issue of global warming creates the need to develop and implement behavioural changes in our daily life. Europe is adopting and implementing policies in order to reduce the emission of CO_2 into the atmosphere. However, all sectors of society have a key role to ensure the reduction of energy consumption, and to achieve the goals of a sustainable environment. Policymaking and human behaviour are the fundamentals factor for the reduction in energy consumption.

Several approaches proposed for achieving environmentally sustainable behaviour. Behavioural models implemented to understand what users do, and why they do so. It is very significant to analyse users' behaviour and develop a framework with their energy efficiency behaviour.

In general, raising the environmental awareness of children must begin early at school, where children are socialized, shaping viewpoints and behaviours, setting the foundation for their future life. The role of the teacher and any authority figure in this effort is paramount. Teachers can influence their students and contribute to more suitable behaviour of the younger generation regarding energy and the environment. Education is an apparent key in boosting young children behaviour, and it's essential to ensuring embodied the ecological values into their behaviour.

By educating students in the classroom about the right decisions, it is making their ability much higher by reducing brain cycles. If the knowledge is on the front of their mind, an individual will not have to think as hard about what is right. This reduction in complex thought also saves time. By creating more environmental classes and increasing participation from each student, it pushes sustainability into the realm of a social norm.

In the frame of the TEESCHOOLS project, a set of open lessons will be realized in selected schools in order to promote energy saving philosophy in schools and in buildings in general. Apart from the costly interventions, behaviour change from a building's users can lead to energy saving and has negligible cost. The trainings in schools are expected to increase students' and teachers' awareness on saving energy and reducing the environmental impact.

5. IMPACT OF THE RENOVATION PLAN

5.1 ESTIMATED ENERGY CONSUMPTION AFTER THE INTERVENTIONS

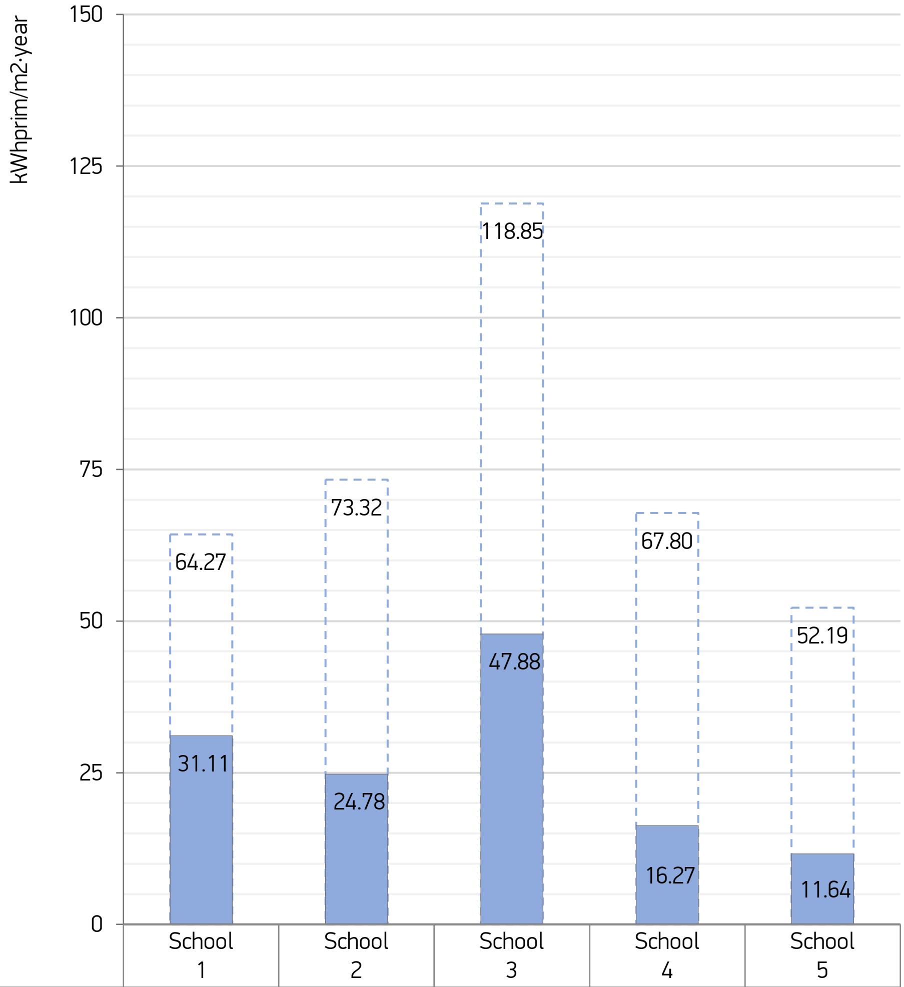
It is important to underline that the present renovation plan is referred to the combination of several interventions for each school in order to reach the NZEB level. In the above chapters individual scenarios which have been evaluated were presented. Nonetheless, in this Section, only the NZEB scenario is analysed, as it was the ultimate target of TEESCHOOLS project.

It should be also noted that by adding energy savings from single interventions does not give the same savings as when all interventions are applied together especially in the cases which regard both, heating oil and electricity consumption. Another significant point has to do with the renewable energy according to the proposed installation of the photovoltaic panels. By reducing the school's energy demand, the RES installation within the NZEB scenarios can vary significantly.

The primary energy consumption after the renovation refers to the estimated consumption of the building, subtracting the electricity generated from the PV systems. The CO_2 emissions refer to the net annual energy consumption, and thus they include emissions deriving from all sources of energy, the electricity and oil consumption. The primary energy consumption for the current and post-renovation scenario, are provided in Graph 6, whereas a more comprehensive analysis for the energy savings and respective indicators for the NZEB scenario are provided in Table 17. Schools #4 and #5, have the highest difference between the before and after scenario, with more than 75% reductions in primary energy consumption. Nonetheless, the most crucial impact of the NZEB scenario, is on the Ayios Andreas Primary School, since it was the one with the highest consumption to start with.

On average, the estimated savings of the primary energy consumption for the five pilot schools[32] are about 66% (or 80,685 kWh/year). It can be also seen that the NZEB scenario has a significant environmental performance, as it achieves a reduction of around 22,450 kg·CO_2/a, equivalent to 67% decrease, compared to the baseline scenarios. Nonetheless, when proceeding with the implementation of measures aiming to improve the energy performance of the building and its internal conditions, the carbon footprint of the whole procedure should be taken into account (from the materials' production, till their recycling or their withdrawal from the site).

[32] More detailed results on energy savings and environmental performances are included in the reports of the individual energy audits (deliverable 3.3.1 of the TEESCHOOLS project).



	School 1	School 2	School 3	School 4	School 5
Primary Energy Consumption [kWhprim/m2·year]	64.27	73.32	118.85	67.80	52.19
Primary Energy Consumption for NZEB [kWhprim/m2·year]	31.11	24.78	47.88	16.27	11.64

GRAPH 7: ANNUAL PRIMARY ENERGY CONSUMPTION PER SQ.M. FOR CURRENT AND NZEB SCENARIOS [IN ACCORDANCE TO THE CURRENT REGULATION A NON-RESIDENTIAL BUILDING TO BE NZEB, NEEDS TO CONSUME LESS THAN 125 KWH/M2•YEAR]

NB: The NZEB requirement for a primary energy consumption of less than 125 kWh/m^2·year, it is based on the EPC indication. In the above cases [Graph 7], the consumptions concern the actual data based on the analysis of the energy bills and the calibrated Energy Model; therefore it is estimated that in the case which an EPC will be issued, the results will show increased consumption as the usage profile will be different (typical). Nonetheless, the proportional reductions between the current situation and the NZEB scenario, are estimated to follow the same trends.

TABLE 17: INDICATORS FOR BEFORE AND POST RENOVATION [NZEB]

Schools	Baseline Annual Consumption			Total cost for the energy renovation to NZEB [€] [Section 5.2]	Post Renovation estimated Consumption – NZEB level		
	Primary Energy [$kWh_{prim}/m^2 \cdot year$]	Carbon emissions [$kgCO^2/year$]	Average Energy Cost [€/year]		Primary Energy [$kWh_{prim}/m^2 \cdot year$]	Carbon emissions [$kgCO^2/year$]	Average Energy Cost [€/year]
1	64,25	27,207	6,3340	288,915	31.10 [-52%]	13,215 [-51%]	3.075
2	73,30	39,980	9,390	346,515	24.80 [-66%]	13,205 [-67%]	3,145
3	118,85	62,515	15,525	336,470	47.90 [-60%]	24,254 [-61%]	6,240
4	67,80	17,745	4,435	181,231	16.25 [-76%]	3,950 [-78%]	1,025
5	52,20	24,435	6,305	414,554	11.65 [-78%]	4,995 [-80%]	1,395

5.2 ECONOMIC EVALUATION

The suggestions indicated in Section 4.5 for the buildings to reach the NZEB level as this is defined in the relevant legislation, were analysed both in technical and economic terms. The results of the economic evaluation of the NZEB renovation plan for the pilot schools are presented in this chapter. It is noted here that this evaluation took place also for all the individual measures suggested per school for energy savings, nonetheless, for the purposes of the aggregate renovation plan, only the NZEB scenario is presented in detail.

More specifically, the criteria for the evaluation of the suggested measures included the reduction of the energy consumption, the Life Cycle Cost (LCC) and the Net Cash Flow (NCF) of each measure, and the achievement of better thermal comfort conditions in a quantify matter. It is understood that the energy consumption and energy costs will continue to exist to meet the requirements in lighting, heating and electrical appliances/equipment. The values presented under the LCC index correspond to cash flow under: (a) the implementation scenario (LCC_A) and (b) non-implementation action (LCC_B). In addition, the NCF index is the comparison (discrepancy) between the LCC_A and LCC_B.

The Life Cycle Cost index has been calculated from the following equation:

$$\boldsymbol{LCC = -C_{in} + \sum_{i=1}^{n} \frac{EC_i \cdot C_{el,i}}{(1+i)^n} + \sum_{i=1}^{n} \frac{MC_i}{(1+i)^n} + \frac{SV_n}{(1+i)^n}}$$

where:

C_{in} → Initial investment cost

EC_i → Electricity consumption in year i

$C_{el,i}$ → Electricity cost in year i

MC_i → Maintenance cost in year i

SV_n → Savage value in year n

n → Economic lifetime of the investment

i → Annual discount rate

SV_n → Residual value of the investment

The assumptions taken into account in the economic evaluation of the proposals are as follows:

- Life-Cycle Cost Analysis: 20 years
- Current Cost of electricity: 0.18 €/kWh [based on the acquired energy bills]
- Current Cost of heating oil: 0.07 €/kWh [based on the acquired energy bills]
- Discount rate: 6%
- Annual rate of increase in energy prices: 2%
- Fixed debit where applicable

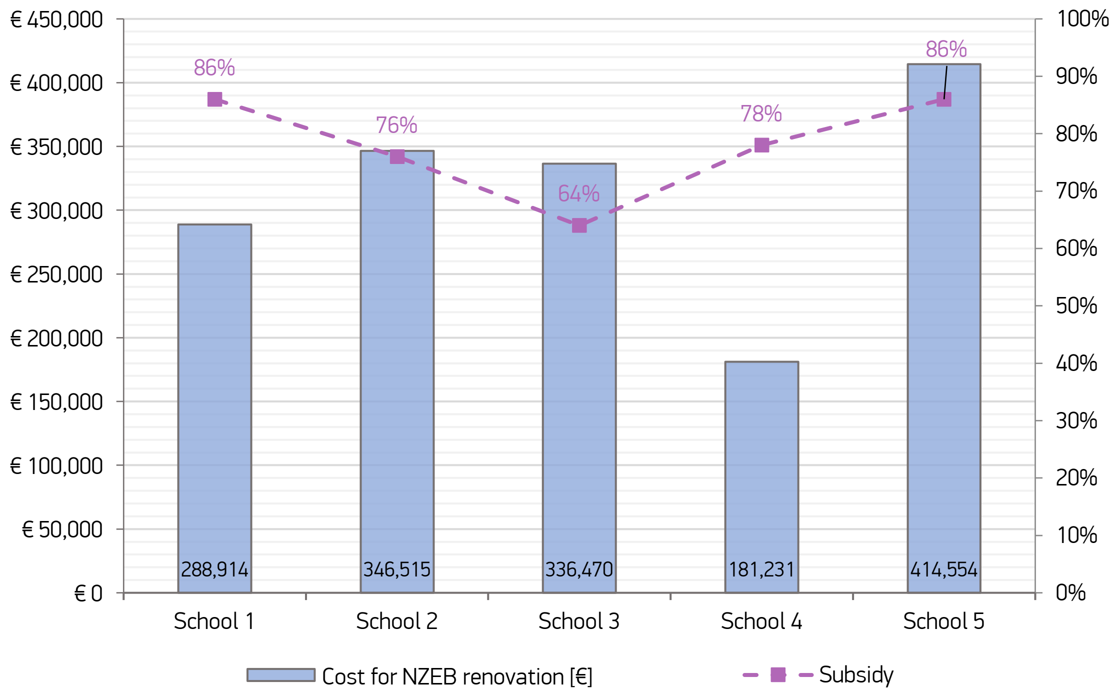
A sensitivity analysis also took place for the above assumptions. The costs indicated in Table 18 are indicative and include labour cost for installing new equipment and removing the old one where needed. They include also the VAT, and in general all costs related to the renovation activity and they are based on the market prices between 2017-2018.

TABLE 18: COST OF ENERGY SAVING MEASURES TO REACH NZEB LEVEL [TO BE READ IN ACCORDANCE WITH TABLE X]

Measures	Schools	Cost [€]
Installation of thermal Insulation on the exterior of the walls	1, 2, 3[33], 4, 5[34]	Extruded polystyrene Average Price in the market: 45 € /m^2
Installation of thermal Insulation on the roofs	1, 2, 3, 4, 5	Extruded polystyrene Average Price in the market: 35 € /m^2
Installation of thermal Insulation on the roofs	2	Sandwich panel Average Price in the market: 25 € /m^2
Installation of thermal Insulation on the roofs	3, 5	Rockwool Average Price in the market: 30 € /m^2
Replacement of the doors and windows: Double-glazing windows, aluminium frame with thermal break and shades where necessary	1, 2, 3, 4, 5	Average Price in the market: 300-400 €/m^2 (mean average cost depends on the size, the previous installation and extra features)
Replacement of the existing lighting system with LED lighting [as 4.2]	1, 2, 3, 4, 5	Sch.1: 4,351 € Sch.2: 3,319 € Sch.3: 7,642 € Sch.4: 4,093 € Sch.5: 6,037 €
Maintenance and adjustment of the boiler and burner [as 4.2]	2, 3, 5	Average Price: 100 € - 150 € per boiler
Thermal insulation of the heating distribution pipelines of the heating system [as 4.2]	1, 2, 3, 4, 5	Armaflex Average Price in the market: for 25 mm: 1.5 €/m, for 40 mm: 7 €/m
Installation of PV system: with the net-metering method[35]	1 , 2, 3, 4, 5	Sch. 1, 4: 5.2 kWp Cost: 7,975 € including the purchasing and installing the photovoltaic system Sch.2, 5: 7.8 kWp - Cost: 11,400 € including the purchasing and installing the photovoltaic system Sch.3: 10.4 kWp - Cost: 14,830 € including the purchasing and installing the photovoltaic system

[33] Only for CB building. Interior insulation can be used for CA, but it was not suggested due to humidity problems detected on the walls of the school during the in-situ visit.
[34] Not for the older building [Block A].
[35] It is noted that the price for a PV system is significantly lower in 2019 compare to 2017-2018, when the audits took place.

The total renovation cost for the pilot buildings to reach the NZEB level, is presented in the following Graph [also indicated in Table 17], versus the corresponding subsidy needed to result in positive cash flows (for the investment to be consider as having a positive impact). It can be seen that the average cost for each school to be upgraded to NZEB level is approximately 313,500.00 € and a subsidy of around 78% is needed to make the investment accessible and affordable[36].



GRAPH 8: COST FOR NZEB RENOVATION AND SUBSIDY NEEDED IN ORDER FOR THE INVESTMENT TO HAVE POSITIVE NCFS

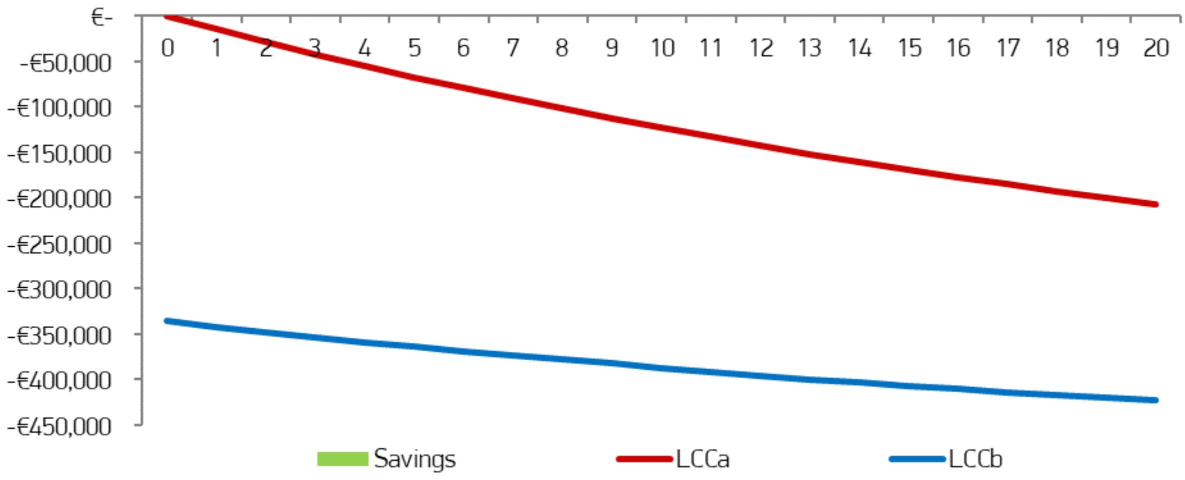
The results of the assessment for the Ayios Andreas School [School #3], which seems to have the higher feasibility, are presented below - with and without subsidy respectively. The following table provides the LCC for the baseline and the suggested scenario, and the respective NCFs.

TABLE 19: INDEXES FOR THE ECONOMIC EVALUATION OF NZEB SCENARIO FOR SCHOOL#3

Index	Value [€]
LCC_A	- 207,609
LCC_B	- 423,201
NCF	- 215,592

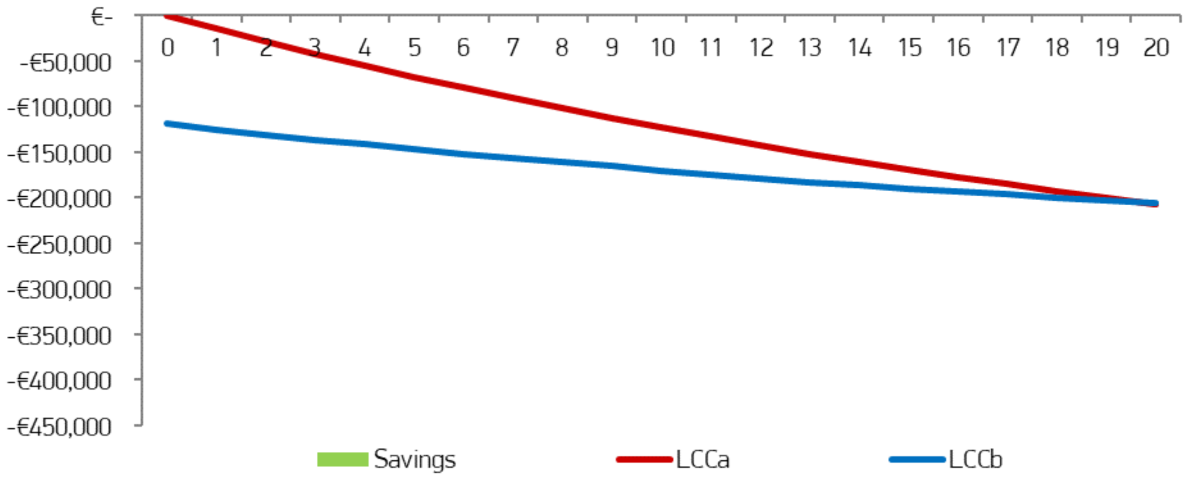
From the above LCCs, it is obvious that NZEB Scenario is considered as economically unsustainable, however it can significantly contribute to achieving better thermal conditions and reduce at a great extent its environmental impact and its operating cost, protecting it from the fluctuations on energy prices. Graph 9 presents the cumulative cash flows of this scenario (shown as negative cash flows expressed in present values), for the consumptions at the school with and without the implementation of the NZEB Scenario.

[36] Section 4.5 is providing some indications about the financing mechanisms that can be activated to cover the subsidy.

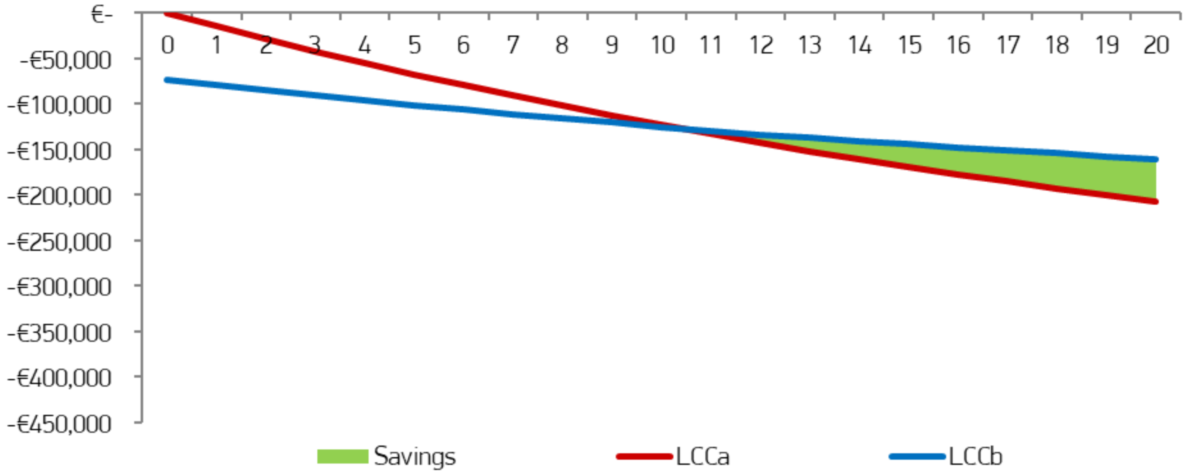


GRAPH 9: CUMULATIVE CASH FLOWS FOR THE IMPLEMENTATION OF THE NZEB FOR SCHOOL #3 (COMPARISON OF LCC_A AND LCC_B)

The minimum state subsidy needed to make the proposal of NZEB economically viable equals to -217,025€, or 64.5% of the initial investment, which will result to equal LCCs or zero NCF (Graph 10). A validation also took place for the case of which a subsidy of 78%, as the average subsidy needed for all the five pilot schools. The results are provided in Graph 11.



GRAPH 10: CUMULATIVE CASH FLOWS FOR THE IMPLEMENTATION OF THE NZEB FOR SCHOOL #3 -INCLUDING THE STATE SUBSIDY OF 64.5% (COMPARISON OF LCC_A AND LCC_B)



GRAPH 11: CUMULATIVE CASH FLOWS FOR THE IMPLEMENTATION OF THE NZEB FOR SCHOOL #3 -INCLUDING A STATE SUBSIDY OF 78% - AVERAGE SUBSIDY NEEDED FOR THE 5 PILOT SCHOOLS (COMPARISON OF LCC_A AND LCC_B)

6. CONCLUSIONS

The Cyprus Energy Agency in the framework of the implementation of the project “TEESCHOOLS”, which is co-financed by the European Regional Development Fund, carried out five Energy Audits at selected school buildings.

The aim of the energy audits was the evaluation of the schools’ current energy use and consumption and the proposal of actions and measures that will result in energy savings and exploitation of renewable energy sources. These measures were divided in 2 categories as follows: the first concerns viable individual interventions for energy performance upgrade, and the second concerns an integrated approach, the upgrade of the school building to a Nearly Zero Energy Building (NZEB), as this defined in the national law, requirement set by the ‘TEESCHOOLS’ project.

All the facilities use electricity to cover the lighting and cooling needs and for the use of the electrical appliances and the equipment. For heating purposes, the schools use heating oil, whereas hot water is not provided in the schools except in some specific spaces, which is rarely used. The schools have an average annual energy consumption of 27,950 kWh electricity and 45,803 kWh of heating oil (125.85 MWh primary energy) and energy costs of about 8,400 €. Those results emerged from the review of previous energy bills of at least a 3 years period.

The energy audit reports included also the evaluation of the buildings’ envelope and electromechanical equipment in terms of energy performance, as well as the energy and the economic feasibility analysis of the measures for the improvements of the schools’ energy performance. For all the schools, the implementations which are proposed based on the needs of the users (educational staff, administrative staff and pupils), who set as a priority the improvement of thermal comfort conditions, thermal insulation of the roofs is proposed. Nevertheless, based on the priorities of the School Boards, which are responsible for the payment of the bills and the implementation of the maintenance programme, the replacement of the existing lighting systems and the installation of PV systems, are prioritised as they lead to a significant operation cost reduction. The other scenarios, regarding the adjustments of the heating boilers and the thermal insulation of the boilers, can also easily implemented, providing immediate results but with less impact.

The NZEB scenario, which has the highest environmental and energy impact with reductions reaching up to 67% and 66% respectively, it is considered as "unsustainable" in terms of the techno-economic analysis. It is worth noticing that generally the energy upgrade interventions which contribute also to the establishment of thermal comfort, have limited potential for energy savings and therefore they are not proposed to be implemented by an Energy Performance Contract (EPC). Therefore, the NZEB scenario is proposed for implementation only if a concrete financial mechanism is in place. The solution to involve private funding for measures which have high energy saving potentials (lighting and RES) and national or local funding for measures that have low energy savings potential but affect users’ thermal comfort (insulation), should be further examined.

7. ANNEXES:

7.1 Minimum energy performance requirements at national level

Table 20: Legal framework for non-residential buildings

	Minimum Energy Efficiency Requirements					NZEB
	21.12.2007 - 31.12.2010	1.1.2010 - 10.12.2013	11.12.2013 - 29.10.2015	30.10.2015 - 31.12.2016	1.1.2017 - 31.12.2020	1.1.2019 (Public Buildings)
	Decree 568/2007	Decree 446/2009	Decree 432/2013	Decree 359/2015	Decree 119/2016	Decree 366/2014
Ranking - Class	-	≥ B	≥ B	≥ B	≥ B	A
U-value – Walls [W/m²K]	≤ 0.85	≤ 0.85	≤ 0.72	≤ 0.72	≤ 0.40	≤ 0.40
U-value – Horizontal structural elements [W/m²K]	≤ 0.75	≤ 0.75	≤ 0.63	≤ 0.63	≤ 0.40	≤ 0.40
U-value of a ground (over non - heated spaces) [W/m²K]	≤ 2.00	≤ 2.00	≤ 2.00	≤ 2.00	-	-
U-value of the windows [W/m²K]	≤ 3.80	≤ 3.80	≤ 3.23	≤ 3.23	≤ 2.90	≤ 2.25
U-value – Mean (Walls & Windows) [W/m²K]	-	≤1.80	≤1.80	≤1.80	-	-
Maximum consumption of primary energy kWh/m²	-	-	-	-	-	125
Maximum energy demand for heating kWh/m²	-	-	-	-	-	-
Maximum window shading coefficient	-	-	0.63	0.63	0.63	0.63
Maximum power of lighting installations at office buildings [W/m²]	-	-	-	-	10	10
Primary Energy from RES [%]	-	PVs Providence	3% + PVs Providence	3% + PVs Providence	7%	25%

7.2 Extra operation hours for each pilot school

Table 21: Use of Hadjigeorgakis Kornesios premises after the regular timetable for 2017-2018

Nº	Space	Days Used	Hours Used	Purpose	Nº of people
1	3 Classrooms [Codes: B_A1, B_A2, B_A3]	Monday - Friday	13:45 – 16:00	Extracurricular activities and studying	Around 13 per classroom
2	Multipurpose Hall	Monday – Friday Tuesday, Wednesday & Friday Saturday	13:05 – 13:45 13:15 – 14:15 20:30 - 21:30	Lunch Sports for All Sports for All	40 people 15 people 15 people

Table 22: Use of Ayios Georgios 3rd Primary school premises after the regular timetable for 2017-2018

Nº	Space	Days Used	Hours Used	Purpose	Nº of people
1	6 Classrooms [Codes: A3, A4, A5, A6, A11, Cook. Lab]	Monday - Friday	13:45 – 16:00	Extracurricular activities and studying	Around 10 per classroom
2	Multipurpose Hall	Monday – Friday Monday – Thursday Tuesday Thursday Saturday	13:05 – 13:45 17:30 - 21:30 20:30 - 21:30 20:15 - 22:30 10:00 - 13:30	Lunch Training courses Folklore group Folklore group Folklore group	60 people 15 people 20 people 20 people 20 people
3	Computers Lab	Wednesday	18:00 – 19:30	Training courses for adults	Around 10 people
4	Cooking Lab	Monday & Thursday Wednesday	09:30 – 11:00 19:00 – 20:30	Training courses for adults	Around 10 people
5	Classroom [Code: A3]	Friday	16:00 – 19:00	Training courses for adults	Around 10 people

TABLE 23: USE OF AYIOS ANDREAS PRIMARY SCHOOL PREMISES AFTER THE REGULAR TIMETABLE FOR 2017-2018

Nº	Space	Days Used	Hours Used	Purpose	Nº of people
1	4 Classrooms [Codes: C_A3, A5, A6, Art Lab]	Monday - Friday	13:45 – 16:00	Extracurricular activities and studying	Around 11 per classroom
2	Cooking Lab	Monday Thursday Monday – Friday [October-May] Monday-Friday [June-August]	18:30 – 20:00 17:30 - 19:00 13:05 – 13:45 13:05 – 13:45	Training courses Training courses Lunch Lunch	10 people 10 people 45 people 40 people
3	Multipurpose Hall [Block B]	Monday & Wednesday Thursday Monday-Friday [June-August]	18:15 – 19:00 19:00 – 20:30 17:30 - 21:30 07:30 – 16:00	Training courses Training courses Summer School	15 people 15 people 40 people
4	Art Lab [Code: C_A1]	Monday Wednesday & Thursday	17:30 – 20:30 16:30 – 18:00	Training courses Training courses	10 people 10 people
5	Computer Lab	Monday & Thursday	17:45 – 19:15	Training courses	8 people
6	Classroom [Code: B_A11]	Tuesday Wednesday	18:00 – 19:30 16:30 – 19:30	Training courses Training courses	10 people 8 people
7	Classroom [Code: B_A12]	Wednesday	18:30 – 20:00	Training courses	12 people
8	Multipurpose Hall [Block A]	Tuesday Wednesday & Thursday	18:30 – 20:00 19:00 – 21:00	Training courses Other activities	15 people 20 people

TABLE 24: USE OF LIVADIA PRIMARY SCHOOL PREMISES AFTER THE REGULAR TIMETABLE FOR 2017-2018

Nº	Space	Days Used	Hours Used	Purpose	Nº of people
1	5 Classrooms [Codes: A1 (Cooking Lab), A2, A5, A6, A7]	Monday - Friday	13:45 – 16:00	Extracurricular activities and studying	Around 12 per classroom
2	4 Classrooms [Codes: A2, A5, A6, A7]	Monday, Tuesday & Thursday - Friday	16:00 – 17:30	DRA.S.E. Programme	Around 12 per classroom
3	Cooking Lab [Code: A1]	Monday Thursday	18:30 – 20:00 19:00 – 20:30	Training courses Training courses	15 people 15 people

TABLE 25: USE OF VOROKLINI PRIMARY SCHOOL PREMISES AFTER THE REGULAR TIMETABLE FOR 2017-2018

Nº	Space	Days Used	Hours Used	Purpose	Nº of people
1	7 Classrooms [Codes: B_A4, A_A5, A_A6, A_A7, A_A8, E_A15 and E_A16]	Monday – Friday [October-May]	13:45 – 16:00	Extracurricular activities and studying	Around 12 per classroom
2	Cooking Lab [Code: A_A5]	Monday – Friday [October-May]	13:05 – 13:45	Lunch	85 people [not simultaneously]
3	1 Classroom [Code: F_A23]	Wednesday & Thursday [October-May] Tuesday	13:05 – 14:35 16:00 – 19:00	Studying Training courses	9 people Around 10 people
4	1 Classroom [Code: F_A25]	Wednesday [October-May]	16:30 – 19:30	Training courses	Around 10 people
5	1 Classroom [Code: F_A26]	Friday [October-May]	18:00 – 21:00	Training courses	Around 10 people
6	7 Classrooms [Codes: C_A1, B_A2, A_A6, A_A7, D_A10, E_A15 and E_A16]	Monday – Friday [June-August]	07:90 – 13:30 [intermittent use]	Summer school	Around 14 per classroom

7.3 THERMAL PROPERTIES OF BUILDING ELEMENTS [ANALYSIS]

School	Construction Year	Type	Description	Thickness (mm)	U value ($W{\cdot}m^{2}K^{-1}$)	Comparison with today' s standards
#1 #2 #3 #4 #5	1968 1987 1970 1989 1964	Bearing Structure	Reinforced Concrete	250	3.26	
#1	2004	Bearing Structure	Reinforced Concrete	300	3.04	
#2	2014	Bearing Structure	Reinforced Concrete_ Insulated	280	0.80	
#1 #3	2014 2010	Bearing Structure	Reinforced Concrete_ Insulated	350	0.53	
#5	1979 1985	Bearing Structure	Reinforced Concrete	350	2.85	
#5	1991 | 2001 2005 | 2009	Bearing Structure	Reinforced Concrete	400	2.68	
#5	2015	Bearing Structure	Reinforced Concrete_ Insulated	600	0.50	
#1 #2 #4	1968 1987 1989	External Wall	Single Perforated Brick _ Plaster	200	1.68	
#3 #5	1970 2010 1964 1979 1985 1985 | 2001 2005 | 2009	External Wall	Single Perforated Brick _ Plaster	250	1.39	
#4	2008	External Wall	Single Perforated Brick _ Th. Plaster	250	0.82	
#1 #2	2004 2008	External Wall	Double Perforated Brick _ Plaster	300	1.18	
#1 #5	2014 2015	External Wall	Double Perforated Brick _ Insulation 50 mm_ Plaster	400	0.39	
#2	2014	External Wall	Thermal Insulating Bricks_ Plaster	360	0.53	
#3	1946	External Wall _ Bearing Structure	Limestone Wall _ Plaster	500	2.41	
#2	2013	External Wall	Concrete Wall	300	2.90	
#1 #2	2015 2013	External Wall _ Bearing Structure	Wall 'Sandwich' Panels	100	0.27	Temporary construction
#1 #3	1968 1970	Roof	Un-Insulated Roof _ Concrete Slab _ False Ceiling	253	2.61	

#1 #2 #3	1968 1987 1970	Roof	Un-Insulated Roof _ Concrete Slab	235	3.21	
#1 #2	2004 1987 | 2008	Roof	Un-Insulated Roof _ Concrete Slab	300	3.00	
#1 #2	2014 2014	Roof	Insulated Roof _ Insulation 50 mm_ Concrete Slab	320	0.48	
#5	1979 → 2012 1985 → 2012 2009 → 2012 2001 → 2012 1989 → 2013	Roof	Insulated Roof _ Concrete Slab	315	0.59	
#4	2008	Roof	Insulated Roof _ Concrete Slab _ 2	310	0.52	
#5	2015	Roof	Insulated Roof _ Concrete Slab	350	0.33	
#2	1987	Roof	Un-Insulated Metal Roof (Zinc)	10	6.18	
#3 #5	1946 1964	Roof	Pitched Roof _ False Ceiling	-	2.19	
#1 #2	2015 2013	Roof	Roof 'Sandwich' Panels	100	0.28	Temporary construction
#1 #2 #3 #4 #5	1968 1970 1987 1946 1989 1964 1979 1985	Ground Floor	Un-Insulated Floor _ Tiles Finish	410	0.80	N/A
#1 #5	2004 2005 2015	Ground Floor	Un-Insulated Floor _ Tiles Finish _ New	460	0.76	N/A
#1 #3 #5	1968 1970 1964 2005	Ground Floor	Un-Insulated Floor _ Linoleum Finish	420	0.78	N/A
#1	2004	Ground Floor	Un-Insulated Floor _ Linoleum Finish _ New	455	0.74	N/A
#1 #2	2015 2013	Ground Floor	Concrete Base _ Linoleum Finish	255	2.58	Temporary construction
#1 #2 #3 #5	1968 1987 1970 1979	Ground Floor	Un-Insulated Floor _ Laminate Finish	425	0.72	N/A
#1	2004	Exposed Floor	Un-Insulated Exposed Floor_Concrete Slab_ Tiles	185	3.23	
#1 #3	1968 1946 1970	Window	Single Glazed_ Iron Frame	4	5.50	
#1 #2 #4 #5	2004 1987 2008 1989 →2008 1964 → 2008 1979 → 2008	Window	Single Glazed_ Aluminium Frame	6	4.96	

	1985 → 2008 1985 | 2001 → 2008 2005 | 2009					
#1 #2 #3 #5	2014 2014 2010 2015	Window	Double Glazed _ Aluminium Frame	25	3.02	
#3	2017	Window	Single Glazed_ Wooden Frame _ 2	6	4.38	
#1 #2	2015 2013	Window	Single Glazed_ Aluminium Frame	6	4.92	Temporary construction
#1 #3	1968 1946 1970	Entrance Door	External Doors _ Iron	15	5.87	
#1 #2 #4 #5	2004 1987 2013 1989 →2008 2008 1964 → 2008 1979 → 2008 1985 → 2008 1985 | 2001 → 2008 2005 | 2009	Entrance Door	External Doors _ Aluminium	40	3.85	
#1 #2 #3 #5	2014 2014 2010 2015	Entrance Door	External Doors _ Aluminium_2	50	3.06	
#1 #2	2015 2013	Entrance Door	External Doors _ Aluminium	30	2.48	Temporary construction

7.4 Calibration of exhaust gas analyser KIMO KIGAZ 100

CNE TECHNOLOGY CENTER

CERTIFICATE OF CALIBRATION
Πιστοποιητικό Διακρίβωσης

Issued by / *Εκδόθηκε από:*
CNE Technology Ltd
Calibration Laboratory, PO Box 16104, Nicosia 2086, Cyprus
Εργαστήριο Διακριβώσεων, ΤΘ 16104, Λευκωσία 2086, Κύπρος
Tel/Τηλ: +357 22624090 Fax: +357 22624092
www.cnetechnology.com info@cnetechnology.com

Certificate No:
Αριθμός Πιστοποιητικού:
R02.108383

Customer / *Πελάτης*	:	ΕΝΕΡΓΕΙΑΚΟ ΓΡΑΦΕΙΟ ΚΥΠΡΙΩΝ ΠΟΛΙΤΩΝ
Address / *Διεύθυνση*	:	ΟΔΟΣ ΛΕΥΚΩΝΟΣ 10-12 ΛΕΥΚΩΣΙΑ 1011, ΚΥΠΡΟΣ
Item Description / *Περιγραφή Αντικειμένου*	:	Combustion Gas Analyser
Manufacturer / *Κατασκευαστής*	:	KIMO INSTRUMENTS
Model / *Τύπος*	:	KIGAZ 100
Serial No / *Αριθμός Σειράς*	:	14043185
Item Code / *Κωδικός Αντικειμένου*	:	14043185
Purchase Order No / *Αριθμός Παραγγελίας*	:	
Date Received / *Ημερομηνία Παραλαβής*	:	04/07/2017
Work Order No / *Αριθμός Εντολής Εργασίας*	:	21107
Date of Calibration / *Ημερομηνία Διακρίβωσης*	:	07/07/2017
Place of Calibration / *Τοποθεσία Διακρίβωσης*	:	CNE - Calibration Laboratory
Calibrated by / *Διακριβώθηκε από*	:	Loukas Psimolophitis

Seal *Σφραγίδα*	Date of Issue *Ημερομηνία Έκδοσης*	Signature *Υπογραφή*
CAL LAB CNE TECHNOLOGY ΕΡΓΑΣΤΗΡΙΟ ΔΙΑΚΡΙΒΩΣΕΩΝ	07/07/2017	Head Calibration Lab Dr Elias Psimolophitis

This certificate is issued in accordance with the Quality Management System of the issuing laboratory. It provides traceability of measurements to recognised national or international standards of the International System of Units (SI). The reported expanded uncertainty of measurement is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a confidence level of 95%.
This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory. Calibration Certificates without seal and signature are not valid. A copy of this certificate is kept by the issuing laboratory for a period of at least five years. The results of this certificate concern only the calibrated item(s).

Το πιστοποιητικό αυτό εκδίδεται σύμφωνα με τις πρόνοιες του Συστήματος Διασφάλισης Ποιότητας του εργαστηρίου. Παρέχει ιχνηλασιμότητα μετρήσεων σε αναγνωρισμένα εθνικά και διεθνή πρότυπα του Διεθνούς Συστήματος Μονάδων (SI). Η διευρυμένη αβεβαιότητα μετρήσεων που αναφέρεται είναι το γινόμενο της τυπικής αβεβαιότητας με τον συντελεστή κάλυψης k = 2 και παρέχει επίπεδο εμπιστοσύνης 95%.
Δεν επιτρέπεται η αναπαραγωγή του πιστοποιητικού αυτού παρά μόνο καθ' ολοκληρία, εκτός αν δοθεί γραπτή έγκριση από εργαστήριο που το εκδίδει. Πιστοποιητικά διακρίβωσης μη φέροντα σφραγίδα και υπογραφή δεν έχουν ισχύ. Αντίγραφο του παρόντος πιστοποιητικού θα διατηρηθεί στο εργαστήριο που το εκδίδει για μία περίοδο τουλάχιστο πέντε ετών. Τα αποτελέσματα του παρόν πιστοποιητικού αφορούν μόνο τα αντικείμενα που έχουν διακριβωθεί.

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CERTIFICATE OF CALIBRATION

Πιστοποιητικό Διακρίβωσης

Issued by / *Εκδόθηκε από*: CNE Technology Ltd - Calibration Laboratory

Certificate No / *Αρ. Πιστοποιητικού:*

R02.108383

Calibration procedure / *Διαδικασία διακρίβωσης*

The calibration was carried out using reference gas mixtures in accordance with the laboratory technical procedure CP-N86.

Standard instruments / *Πρότυπα όργανα*

Description	Lab Ref No.	Serial No.	Cal. Cert. No.	Traceability
Block Calibrator, +35/600°C	ER.367	A44154	R02.101620	CYSAB NO L068
Standard Gas Mixture	ER.407.01	11711/1616	18207A/JB	NMI-NPL (UK)
Standard Gas Mixture	ER.407.03	12692	S69010-1	NMI-NPL (UK)
Standard Gas Mixture	ER.407.04	007888	16674D/JB	NMI-NPL (UK)
Standard Gas Mixture	ER.407.06	005721	S44276-1	NMI-NPL (UK)

Environmental conditions / *Περιβαλλοντικές συνθήκες*

Temperature [°C]	Relative Humidity [% r.h.]	Barometric Pressure [hPa]
23 ± 1,0	45 ± 5,0	975 ± 0,5

Calibration results / *Αποτελέσματα διακρίβωσης*

Flue Gases

Type of Gas	O2	O2	CO	CO	CO
Units	% vol	% vol	ppm	ppm	ppm
Range	0 ... 21	0 ... 21	0 ... 8000	0 ... 8000	0 ... 8000
Resolution	0,1	0,1	1	1	1
Reference Value	5,0	18,0	50,0	100,0	500,0
Displayed Value	8,5	20,3	41	82	418
Deviation	3,5	2,3	-9,0	-18,0	-82,0
Uncertainty	0,2	0,5	1,6	3,1	15,0

When the Displayed Value is marked with 'X', the measurement is outside the tolerance limits or the specific sensor is faulty.

Flue Gas Temperature

Reference Readings	Instrument Readings	Deviation	Uncertainty
[°C]	[°C]	[°C]	[°C]
150,0	150,3	0,3	0,5
250,0	249,7	-0,3	0,5
350,0	349,2	-0,8	0,5

CNE TECHNOLOGY CENTER

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Πιστοποιητικό Διακρίβωσης

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www.cnetechnology.com info@cnetechnology.com

Certificate No:
Αριθμός Πιστοποιητικού:
R02.116400

Customer / *Πελάτης*	:	ΕΝΕΡΓΕΙΑΚΟ ΓΡΑΦΕΙΟ ΚΥΠΡΙΩΝ ΠΟΛΙΤΩΝ
Address / *Διεύθυνση*	:	ΟΔΟΣ ΛΕΥΚΩΝΟΣ 10-12 ΛΕΥΚΩΣΙΑ 1011, ΚΥΠΡΟΣ
Item Description / *Περιγραφή Αντικειμένου*	:	Combustion Gas Analyser
Manufacturer / *Κατασκευαστής*	:	KIMO INSTRUMENTS
Model / *Τύπος*	:	KIGAZ 100
Serial No / *Αριθμός Σειράς*	:	14043185
Item Code / *Κωδικός Αντικειμένου*	:	14043185
Purchase Order No / *Αριθμός Παραγγελίας*	:	
Date Received / *Ημερομηνία Παραλαβής*	:	07/08/2018
Work Order No / *Αριθμός Εντολής Εργασίας*	:	22252
Date of Calibration / *Ημερομηνία Διακρίβωσης*	:	09/08/2018
Place of Calibration / *Τοποθεσία Διακρίβωσης*	:	CNE - Calibration Laboratory
Calibrated by / *Διακριβώθηκε από*	:	Loukas Psimolophitis

Seal *Σφραγίδα*	Date of Issue *Ημερομηνία Έκδοσης*	Signature *Υπογραφή*
CAL LAB CNE TECHNOLOGY ΕΡΓΑΣΤΗΡΙΟ ΔΙΑΚΡΙΒΩΣΕΩΝ	09/08/2018	Head - Calibration Lab Dr Elias Psimolophitis

CERTIFICATE OF CALIBRATION

Πιστοποιητικό Διακρίβωσης

Issued by / *Εκδόθηκε από*: CNE Technology Ltd - Calibration Laboratory

Certificate No / *Αρ. Πιστοποιητικού:*

R02.116400

Calibration procedure / *Διαδικασία διακρίβωσης*

The calibration was carried out using reference gas mixtures in accordance with the laboratory technical procedure CP-N86.

Standard instruments / *Πρότυπα όργανα*

Description	Lab Ref No.	Serial No.	Cal. Cert. No.	Traceability
Block Calibrator	ER.367	A44154	R02.112429	CYSAB NO L068
Standard Gas Mixture	ER.407.01	11711/1616	18207A/JB	NMI-NPL (UK)
Standard Gas Mixture	ER.407.03	12692	S69010-1	NMI-NPL (UK)
Standard Gas Mixture	ER.407.04	007888	16674D/JB	NMI-NPL (UK)
Standard Gas Mixture	ER.407.06	005721	S44276-1	NMI-NPL (UK)

Environmental conditions / *Περιβαλλοντικές συνθήκες*

Temperature [°C]	Relative Humidity [% r.h.]	Barometric Pressure [hPa]
23 ± 1,0	45 ± 5,0	970 ± 2,5

Calibration results / *Αποτελέσματα διακρίβωσης*

Gas Measurements

Type of Gas	O2	O2	CO	CO	CO
Units	% vol	% vol	ppm	ppm	ppm
Range	0 ... 21	0 ... 21	0 ... 8000	0 ... 8000	0 ... 8000
Resolution	0,1	0,1	1	1	1
Reference Value	20,9	5,0	50,0	100,0	500,0
Displayed Value	20,9	5,6	49	98	495
Deviation	0,0	0,6	-1,0	-2,0	-5,0
Uncertainty	0,6	0,2	1,6	3,1	15,0

When the Displayed Value is marked with 'X', the measurement is outside the tolerance limits or the specific sensor is faulty.

Temperature Measurements

Reference Readings	Instrument Readings	Deviation	Uncertainty
[°C]	[°C]	[°C]	[°C]
150,0	149,8	-0,2	0,5
250,0	249,6	-0,4	0,5
350,0	349,1	-0,9	0,5

Comments - Remarks / *Σχόλια - Παρατηρήσεις*

- The results reported are after adjustment.
- O2 Sensor replaced.

End of Calibration Certificate

Τέλος Πιστοποιητικού Διακρίβωσης

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8. INDEX OF FIGURES

9. INDEX OF TABLES

10. INDEX OF GRAPHS

11. INFORMATION ABOUT AUTHORS

Full Name	Specialty	Task
Maria Achilleos	Architectural Engineer, Certified specialist on NZEB and qualified expert on building certification	Preparation of the Energy Reports; Building shell analysis; Dynamic Energy analysis of buildings; In-situ visits; Techno-economic analysis.
Savvas Vlachos	Environmental Engineer, Energy Auditor - category A & B, according to the provisions of KDP 184/2012, registry number: ABXX003EE and qualified expert on building certification	Technical advisor and coordinator of the energy audits.
Apostolos K. Michopoulos	Dr. Mechanical Engineer, certified energy instructor for energy auditors of A & B category - according to the provisions of KDP 184/2012, by the Cypriot Energy Service, with years of experience in energy audits of residential and industrial installations.	External: Technical and scientific advisor of the audits.
Marios Petrakkas	Electrical Engineer, Energy Auditor - category A & B, according to the provisions of ΚΔΠ 184/2012	Analysis of electrical systems; Measurement of electrical and lighting loads; Recording of electrical devices and features. In-situ visits;
Orestis Kyriakou	Electrical Engineer, Energy Auditor - category A & B, according to the provisions of ΚΔΠ 184/2012	External: Analysis of electrical systems;
Giannis Kanaris	Mechanical Engineer, Certified Passivhaus Designer	Conducting performance measuring of heating / air conditioning systems In-situ visits;
Myrto Skouroupathi	Environmental Engineer	Contacts with the schools; Data collection. In-situ visits;

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