D.T3.3.2 ON-SITE ENERGY AUDITS – SPORT HALLS

Poland

Version 1

02 2019

I. Building #1 SP 61 (ul. Białobrzeska 27, 02-340 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built in 1956 and stays in unchanged form till today. Envelope is well preserved however it has not been modernized since original state, except windows and roof modernization in 1998. Furthermore in 2015 windows in the sport hall have been changed. External partitions are not thermally insulated, thus heat resistance is very low. Windows are in very bad condition thus modernization should be considered, possibly together with a thermal insulation of external walls. In 1998 heating system and electric system have been modernized. The building is heated with heat exchanger powered by district heating. The heating installation is in a good condition. Heat is distributed with plate water convectors equipped with thermostats. The building does not have any mechanical ventilation or other HVAC system except kitchen which has been equipped with exhaust fans. The lighting in almost the whole building is provided with 2x58 W fluorescent fittings, except small rooms such as toilets, storage rooms etc. The lighting is controlled manually by users. The building does not have any BMS system.

The general overview of the building allowed for giving a poor opinion about energy efficiency of the building. The measured final energy indicator for heating equals 235.36 kWh/m^{2}a, which is very high.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 61 in Warsaw, located in the central part of the city. The school occupies a middle-sized building with 3 floors above the ground including a ground floor with basement, of a total area of 2 450 m^2, while the area of rooms dedicated strictly for the educational purposes is 994 m^2. There are 22 classrooms, one sport hall of 238 m^2 area and one canteen in the building. The canteen kitchen belongs to school. The school is able to provide conditions for educational purposes for around 570 children. Children attending the school are around 6-14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control, thermostats control and windows closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/AN/A

2.3. Context of the energy audit - scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor is Ms. Ewa Szczeszek, who is an economic manager in the school, taking care of energy and other media management in the building. Ms. Ewa Szczeszek mentioned that the building has some thermal comfort issues.

The main problem is caused by leaky windows. Even though old windows have been replaced with new PCV windows in 1998, the installed windows were of a very poor quality, also they were mounted incorrectly in some places. As a result, the air leakage is high, and during heavy rains water might appear on a sill inside the rooms. This problem have been solved in the sport hall, where in 2015 new PCV windows were installed. According to Ms. Ewa Szczeszek it was very cold in the sport hall before 2015, and now thermal comfort in the sport hall is well preserved.

Another problem is not insulated roof, which strengthens heat loss during winter. It is also a reason of hard thermal conditions during sunny days, when it gets very hot on the second floor. Even though roof has been modernized in 1998, it has not been properly insulated.

Ms. Ewa Szczeszek was also concerned about the problem of vandalism and dirty southern elevation near the passage to the sport hall. In her opinion, there could be made a storage room in this place, which could solve two problems at once. Firstly no vandalism would happen again, as there would not be a niche where vandals can hide. Secondly, the sport hall needs a storage room as there is no place in the building where some sports equipment could be stored.

The first visit in the school was performed on 18.01.2019 and included a technical documentation analysis and digitalization, connected with the whole building the whole building inspection (classrooms, sport hall and canteen, technical rooms) and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and domestic hot water systems evaluation. The building is not equipped with any cooling systems. The only mechanical ventilation system is located in the canteen's kitchen.

The on-site visit of the building included also the lighting system analysis (power, number, location, type and control method investigation) in audited rooms: classrooms, sport hall, canteen, entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was built in 1956. It was partially modernized on 1998, when the heating system and electric system modernization was performed. Moreover, in 1998 the old wooden windows have been exchanged with new PCV windows, and roof has been modernized, however it was not insulated. The building has 4 floors including a basement and ground floor. Its total area equals 2,450 m^2, including classrooms – 993.95 m^2, sports hall - 237.9 m^2, and canteen - 108.8 m^2 (192.91 m^2 including a kitchen and other facilities).

Buildings external partitions are not insulated. The roof is made of reinforced concrete of about 10 cm thickness covered with black roofing paper. External walls are made of full brick (40 cm), covered with sandstone on the outside. PCV windows mounted in 1998 according to regulations at that time should have a heat transfer coefficient of 2.6 W/(m^2K). New windows in sports hall have declared heat transfer coefficient of 1.1 W/(m^2K). Both old and new windows are double glazed with a PCV frame.

The building is heated with traditional plate heaters. The whole building is ventilated with natural ventilation except a canteen kitchen which has a mechanical ventilation. There is no cooling system in the building. The lighting system is composed of mainly 2x58 W fluorescent fittings.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 1 Standards used during energy audit

	Applied version	English version
1	Norma PN-EN 16247-1 “Audity Energetyczne: Wymagania Ogólne”	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 “Audity Energetyczne Część 2: Budynki”	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 “Audity Energetyczne Część 3: Procesy”	EN 16247-3“Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego.”	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń.”	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków – Wymiana ciepła przez grunt – Metody obliczania.”	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach – Liniowy współczynnik przenikania ciepła – Metody uproszczone i wartości orientacyjne.”	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia.”	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling

9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania”	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system”	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 1 Regulations used during energy audit

	Applied version	**English version**
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) – raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting

	raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) – raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 61 in Warsaw started with on-site visit that took place on 18th of January 2019. It began with an interview with an economic manager of the school, Ms. Ewa Szczeszek. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis.

Ms. Ewa Szczeszek pointed out a few problems. In her opinion it is too cold in the building, which is mainly caused by leaky windows. Another problem are hard thermal conditions on the top floor. It is cold in winter and it gets very hot during warm days when sun is shining.

After the interview, there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through audit the auditor continued an interview, gaining information about schedules of occupation of building, as well as, as well as light and heating schedules.

The mechanical exhaust ventilation in the kitchen is used only when needed. In almost the whole building there is fluorescent light bulbs with traditional manual control lighting applied. In small rooms like storage rooms, toilettes etc. there are CFLs installed. Most of the data concerning HVAC and electric systems could be gained during the walk-through audit. Data about the envelope of the building was gained from the technical documentation of the building that was available during the on-site visit.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator equal wi=3.0 for electricity, and applying the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 61 w Warszawie
Street, number, city and postcode	Białobrzeska 27, 02-340 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°][1]	*52.22*
Latitude [DD.dd°]	20.97
Height above the see level [m]	*113*
Year of construction	*1956*
Useful area - the whole building the whole building [m^2]	*2 450*
Useful area - audited part [m^2]	*Classrooms: 993.95 m^2* *Sport hall: 237.9 m^2* *Canteen: 192.91 m^2 (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 5,400 kWh/month, with total yearly consumption of 64,938 kWh in 2017. The maximum ordered power is 50 kW on one electric connection.

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels for heating purposes, as it is connected to the district heating grid powered mainly by two CHP plants: Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The maximum heat power ordered for the central heating is 345 kW and for domestic hot water is 58 kW. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2017 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water.

[1] http://www.mapcoordinates.net/en

Table 2 Heat consumption in 2017

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	407.28	113.13	-3.7
II	289.70	80.47	-0.8
III	242.00	67.22	6.1
IV	232.50	64.58	7.7
V	171.30	47.58	14.6
VI	26.50	7.36	18.5
VII	19.20	5.33	18.9
VIII	20.20	5.61	19.7
IX	10.10	2.81	14.0
X	137.10	38.08	10.0
XI	251.90	69.97	4.9
XII	268.10	74.47	2.5
TOTAL	2 075.88	576.63	

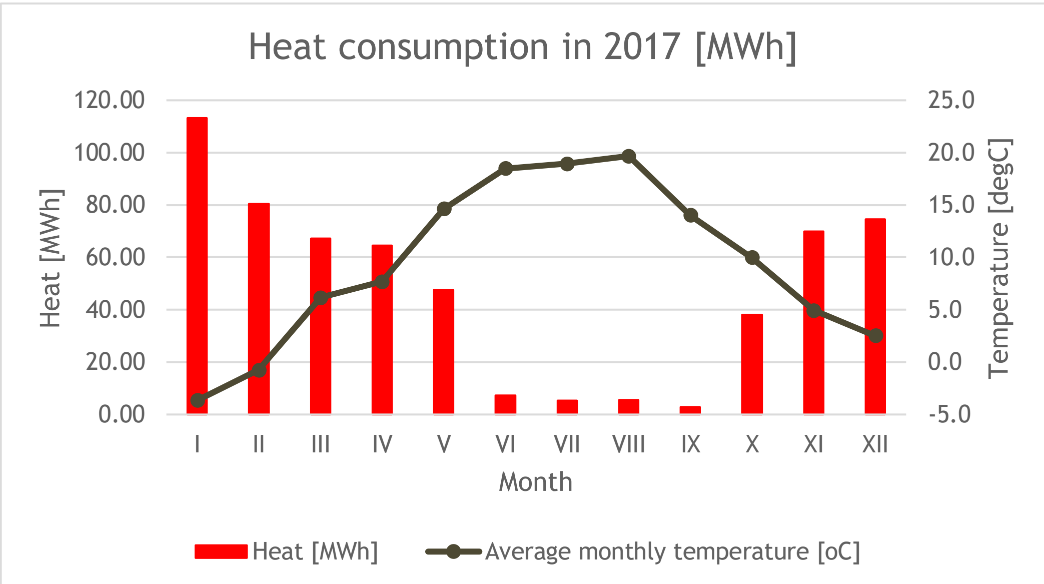

Figure 1 Heat consumption in 2017

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied.

Table 3 Energy consumption and emissions

Parameter	**Heat**	**Electricity**	**Total**
Final energy consumption [kWh/a]	576,633.06	64,938.00	641,571.06
Final energy consumption indicator [kWh/m^{2}a]	235.36	26.51	261.87
The non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	501,670.76	194,814.00	696,484.76
Primary energy consumption indicator [kWh/m^{2}a]	204.76	79.52	284.28
CO_2 emissions [tCO_2/a]	191.60	46.63	238.23

3.3. Building exploitation, maintenance and management

The school is used between around 7.30 AM – 4.30 PM Monday-Friday. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

The heating and domestic hot water preparation systems work with no pre-defined breaks. Lighting in the corridors and rooms is switched on only when needed. Corridors are well illuminated with natural light due to many windows along the corridors, thus lighting in corridors is not used very often.

4. Existing state of building energy systems

The building was built in 1956. The total floor area equals 2450 square meters. It contains 22 classrooms, the sport hall and the canteen. The building has been modernized in 1998. The modernization included heating system and electric system modernization together with exchange of windows into double glazed PCV framed windows and modernization of roof (but without a thermal insulation).

4.1. Heating system

The heating source in the building is an insulated heat exchanger with weather control. The designed heating load for the building according to documentation is 0.291 GJ/h (0.338 MW), however the currently ordered power is set to 0.345 MW for the heating and 0.058 MW for the domestic hot water. Water is the working medium in the system. Water is the heating factor in the installation.The heat exchanger station powered by the district heating is insulated, so according to [1] its efficiency equals 99%.

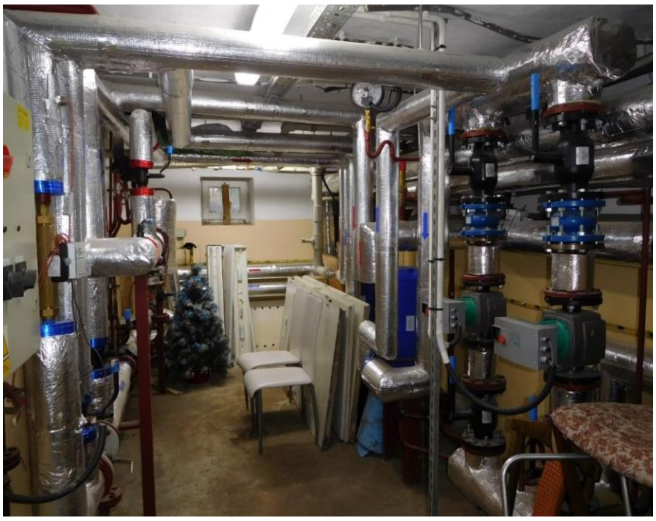

*Figure 2 **Heating source** in the building*

The insulation of the heat distribution system in the unheated zones is in a poor condition, many parts of pipes are lacking a thermal insulation. According to [1], the overall equals the overall system efficiency equals 90%.

Figure 3 Insulated pipes

Heat convectors in the building are in good condition. They are equipped with thermostats. Convectors are mostly located in the niche under the windows, following the Polish construction requirements. According to [1], the overall system efficiency equals 89%.

Figure 4 Water convectors with thermostatic valves

4.1.1. Classrooms

Water convectors in classrooms are the same as in the rest of the building, including thermostats. Temperature regulation in classrooms according to information gained during the audit is problematic and thermal comfort is not preserved. During cold days convectors do not supply enough heat to heat cold air coming through leaky windows. Convectors in classrooms are located in the niche under the windows, following the Polish construction requirements.

*Figure 5 Convectors in **classrooms***

4.1.2. Sport hall

Water convectors in the sport hall are the same as in the rest of the building, including thermostats. They are located along the external wall. Temperature regulation in the sport hall according to information gained during the audit is good and the thermal comfort is well preserved since windows have been changed to new in 2015. Convectors are located in the niche under the windows, following the Polish construction requirements.

Figure 6 Convectors in the sport hall

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, defining its efficiency as 0.90. The pipes are insulated, however the insulation condition is bad. In the system there is a circulation pump installed and it works constantly. There is less than 100 sinks or showers in the building, so seasonal efficiency of domestic hot water distribution equals 60%, according to [1]. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Classrooms

There are no water access points in classrooms.

4.2.2. Sport hall

There are no water access points in the sport hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The whole building is ventilated naturally, except the kitchen which is equipped with mechanical exhaust ventilation. Natural ventilation is provided with brick ducts. Fresh air is supplied through air leakages in windows.

4.3.1. Classrooms

Classrooms are ventilated naturally by gravitation and infiltration of fresh air through windows.

4.3.2. Sport hall

The sport hall is ventilated naturally by gravitation and infiltration of fresh air through windows. There are ventilation extracts in the roof of the sport hall which are not controlled, so they are fully opened all the time.

Figure 7 Sport hall ventilation

4.4. Cooling system

There is no cooling system in the building.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building. There are two pumps for DHW and the central heating.

4.5.1. Classrooms

Classrooms do not have any dedicated electric system. They are equipped with lighting and 230V sockets.

4.5.2. Sport hall

The sport hall does not have any dedicated electric system. It is equipped with lighting and 230V sockets.

4.6. Building envelope

The building was built in 1956, and first ever regulations concerning building partitions requirements in Poland have been introduced in 1955. It is probable that if the building design was finished before 1955, the partitions were not designed according to any regulations.

Investigation of materials shows that external walls are made of around 40 cm of full brick. External elevation is covered with sandstone tiles. Internal floors are made of reinforced concrete (10 cm). The ventilated roof is constructed with 10 cm of reinforced concrete filled partially with aerated brick, covered with black roofing paper.

Windows are double glazed with PCV frame windows. Windows mounted in 1998 have the declared heat transfer coefficient have the declared heat transfer coefficient equal 2.6 W/m^{2}K. In the sport hall there are new windows with the declared coefficient of 1.1 W/m^{2}K.

Information on external partitions are presented in the table below.

Table 4 Heat parameters of external partitions in the building.

Partition	Heat transfer coefficient [W/m^{2}K]	Resistance [m^{2}K/W]
External walls	1.48	0.68
Flat roof	1.81	0.55
Windows	2.60	0.38
Windows in the sport hall	1.10	0,91

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

Almost the whole building is equipped with fittings with 2x58W fluorescent bulbs. Corridors lighting works rarely because it is very well illuminated by natural light. There are individual switches at each floor. The sport hall is equipped with halogen lighting.

4.8.1. Sport hall

The sport hall is equipped with 12 halogen fittings (around 150 W each). Lighting in the sport hall is divided into 4 zones allowing for using only part of the fittings if it is sufficient. The lighting is switched on manually by the users when needed.
Power installed in lighting per square meter is around 7.5 W/m^2.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal act cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 5 Non-renewable primary energy indicators

Parameter	**Heat**	**Electricity**
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 8 North-western elevation

Figure 9 South elevation (sport hall)

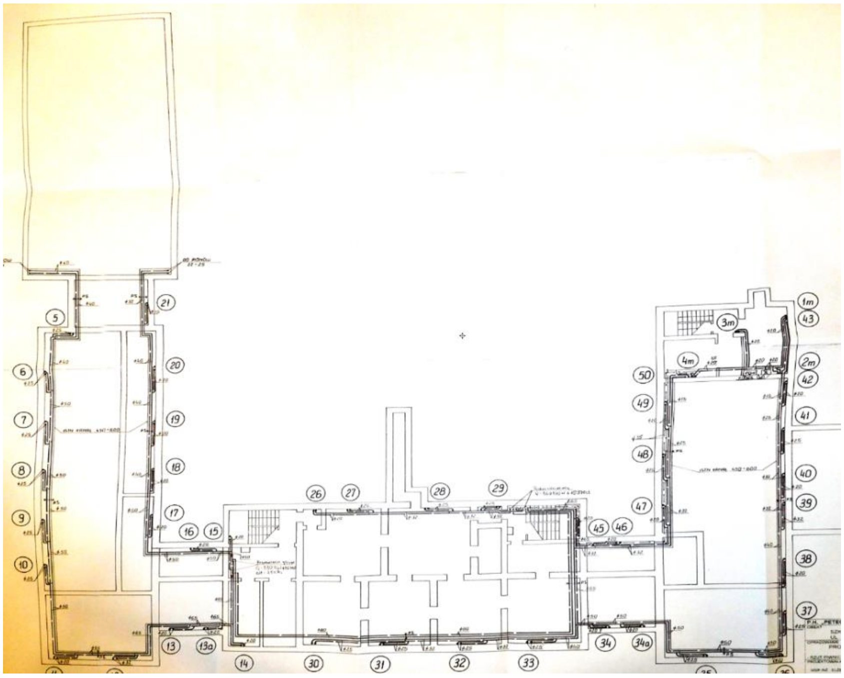

Figure 10 Basement floor plan

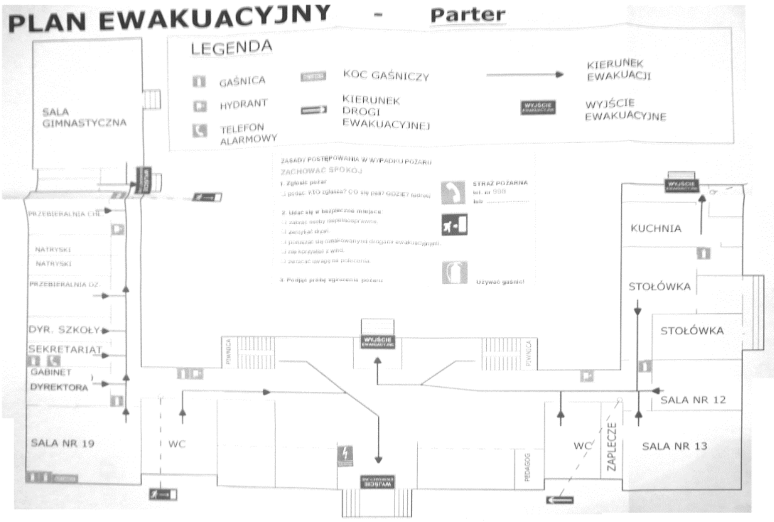

Figure 11 Ground floor plan

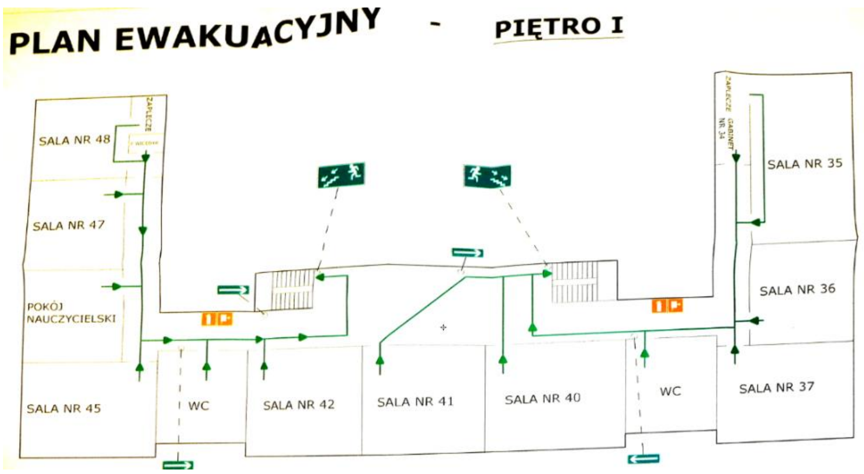

Figure 12 First floor plan

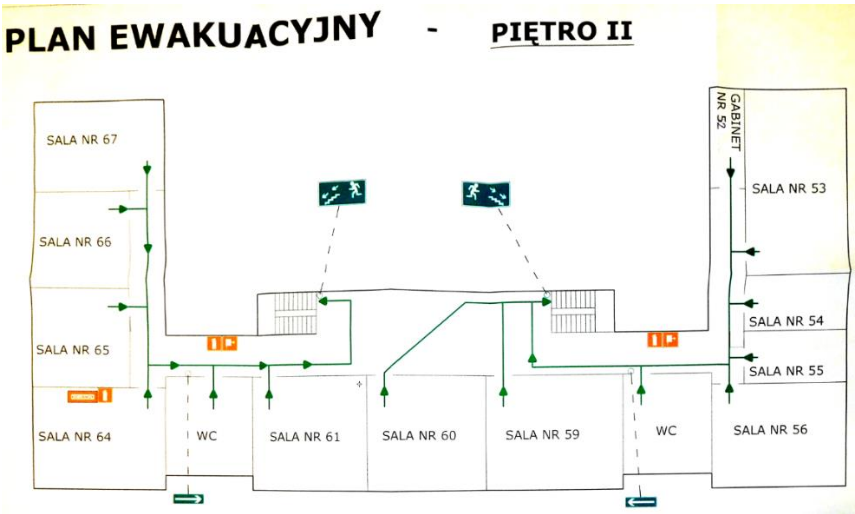

Figure 13 Second floor plan

II. Building #2 SP 340 building B (ul. Eugeniusza Lokajskiego 3, 02-793 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built between 1993 and 1997. It was constructed and designed in 3-stages. The building envelope is well preserved. Since the beginning, thermal insulation has been never upgraded. Only windows were changed around 2014. In one of the sport halls (fencing hall), a mechanical ventilation and air conditioning have been installed. The building is connected to the district heating network. Both central heating and domestic hot water system is supplied by a heat exchanger. The building has been insulated with a thick layer of polystyrene (6-8 cm) on the external walls, 16 cm of mineral wool on the roof, and 6 cm of hard polystyrene on the ground floor. The building is ventilated naturally except the large sport hall and the fencing hall. The large sport hall is equipped with mechanical exhaust fans located on the ceiling, however they have not been used for a long time. The fencing hall has been recently equipped with new air handling unit with heat recovery. The lighting system is composed of traditional fluorescent bulbs controlled manually by users. The building does not have any BMS system.

The general overview of the building allowed for giving good opinion about energy efficiency of the building. The measured final energy indicator for heating is 122.95 kWh/m^{2}a, which is typical for this type of building.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 340 in Warsaw, located in the southern part of the city. The school occupies a middle-sized building with 4 floors including a basement. Its total area is 5,915 m^2, while the area of rooms dedicated strictly for the educational purposes equals 1692.6 m^2. There are 27 classrooms, three sport halls of 530 m^2, 102 m^2 and 80 m^2 and one canteen in the building. The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 1000 children. Children attending the school are around 10 – 14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control, thermostats control and windows closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit – scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor and for delivering information and documentation were Ms. Grażyna Sadurska and Ms. Ewa Niemirska. Several years ago school has been divided into two parts (wing A and wing B) which are separate buildings now. This energy audit concerns only part B of the school – the old building. During an interview, Ms. Ewa Niemirska mentioned that the building has some heating problems. In the corridors and sport halls there are no thermostatic valves on most of the plate heaters which does not allow for proper control of temperature. As a result, it is usually too cold in the school, both in corridors and in classrooms. She pointed out that some of the heaters does not heat at all, and even if they work, the most of them are hot only in the top part of the heater while the bottom part stays cold. Generally, in her opinion, thermal comfort in the building is low.

The first visit in the school was performed on 17.01.2019 and included a technical documentation analysis and digitalization, connected with the whole building inspection (classrooms, sport halls and canteen, technical rooms) and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and evaluation and domestic hot water systems evaluation. One of the sport halls is equipped with mechanical ventilation and cooling, so the system has been investigated as well.

The on-site visit of the building included also a lighting system analysis (power, number, location, type and control method investigation) in different rooms: classrooms, sport halls, canteen, entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was built between 1993 and 1997. It was constructed in 3 phases, so when the phase 2 and phase 3 have been under construction, the phase 1 has been already in use. The building has 4 floors including a basement. A total area of building according to documentation is 5,915.30 m^2. There are 27 classrooms of 1,692.6 m^2, three sport halls of 530 m^2, 102 m^2 and 80 m^2 and one canteen in the building of 223.1 m^2, including facilities.

The building envelope has not been modernized except windows, which have been exchanged in 2014. New windows have a declared heat transfer coefficient of 1.0 W/(m^2*K). Windows have 2 layers of glass.

Building has been insulated with 6 and 8 cm of polystyrene on the external walls (phase 1 and 2 – 6 cm, phase 3 – 8 cm). A roof has a layer of 16 cm of mineral wool insulation. A floor on the ground has been insulated with 6 cm of hard polystyrene. External walls are constructed with 25 cm of insulation layer and 12 cm of aerated brick. Roof is constructed with 12 cm of aerated brick.

The building is heated with a heat exchanger powered by district heating system. Heat is distributed with traditional plate heaters. The whole building is ventilated naturally except the fencing sport hall and the kitchen. The fencing hall is equipped with cooling units. The lighting system is composed of 58 W fluorescent bulbs controlled manually.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 6 Standards used during energy audit

	Applied version	**English version**
1	Norma PN-EN 16247-1 “Audity Energetyczne: Wymagania Ogólne”	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 “Audity Energetyczne Część 2: Budynki”	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 “Audity Energetyczne Część 3: Procesy”	EN 16247-3“Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego.”	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń.”	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania.”	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne.”	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia.”	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values

10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania”	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system”	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 7 Regulations used during energy audit

	Applied version	**English version**
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) - raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"

7	KOBiZE (The National Centre for Emissions Management) – raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 340 in Warsaw started with on-site visit that took place on 17th of January 2019. It began with an interview with an economic manager of the school, Ms. Ewa Niemirska. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis.

Ms. Ewa Niemirska pointed out a few problems. In her opinion it is too cold in the whole building, which is a result of faulty heat distribution installation. Most of the plate heaters do not have thermostatic valves, also many of them are hot only in the upper part of the convector is hot, while bottom of is it cold.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through audit the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules. The mechanical exhaust ventilation in the large sport hall is not used. Mechanical ventilation in fencing hall is used always when the room is occupied, cooling in fencing hall is used only when needed. Kitchen has an exhaust mechanical ventilation in exhaust hood. It is used only when food is being processed. In the whole building the applied lighting is fluorescent light bulbs with traditional manual control. Only a corridor and canteen have typical compact fluorescent light bulbs. Most of the data concerning HVAC and electric systems could be gained during the walk-through audit. Data about the envelope of the building was gained from the technical documentation of the building that was available during the on-site visit.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator equal wi=3.0 for electricity, and applying the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 340 w Warszawie (building B)
Street, number, city and postcode	Lokajskiego 3, 02-793 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	*52.14*
Latitude [DD.dd°]	21.06
Height above the see level [m]	*104*
Year of construction	*1993-1997*
Useful area - the whole building [m^2]	*5 915.30 m^2*
Useful area - audited part [m^2]	*Classrooms: 1,692.6 m^2* *Sport hall: 712 m^2* *Canteen: 224.1 m^2 (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 9,500 kWh/month, with total yearly consumption of 114,273 kWh in 2018. The maximum ordered power is 111 kW on two electric connection, 71 kW and 40 kW. The graph below presents consumption of electricity, the maximum ordered power and maximum power consumed for each connection.

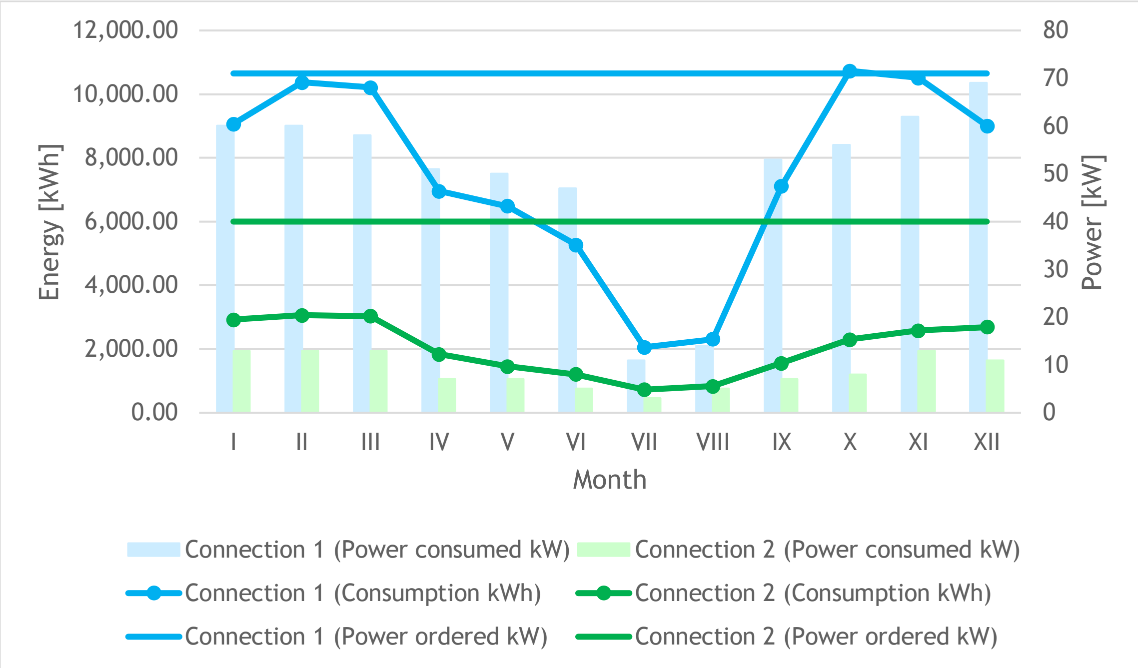

Figure 14 Electricity consumption, power ordered and power consumed in 2018

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels for heating, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2018 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water.

Table 8 Heat consumption in 2018

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	612.10	170.03	-3.7
II	465.70	129.36	-0.8
III	494.50	137.36	6.1
IV	248.10	68.92	7.7
V	11.60	3.22	14.6
VI	7.90	2.19	18.5
VII	5.50	1.53	18.9
VIII	7.00	1.94	19.7
IX	8.10	2.25	14.0
X	147.40	40.94	10.0
XI	288.20	80.06	4.9
XII	322.20	89.50	2.5
TOTAL	**2 618.30**	**727.31**	

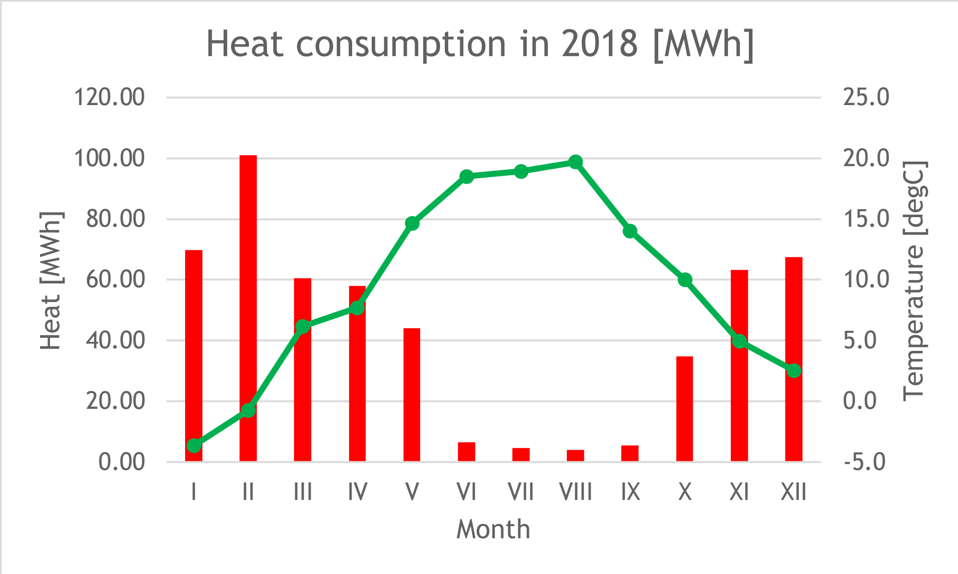

Figure 15 Heat consumption in 2018

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO_2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi), the value declared by Veolia Energia Warszawa S.A. was applied.

Table 9 Energy consumption and emissions

Parameter	Heat	Electricity	Total
Final energy consumption [kWh/a]	727,305.56	114,273.00	841,578.56
Final energy consumption indicator [kWh/m^{2}a]	122.95	19.32	142.27
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	632,755.83	342,819.00	975,574.83
Primary energy consumption indicator [kWh/m^{2}a]	106.97	57.95	164.92
CO_2 emissions [tCO_2/a]	241.67	82.05	323.72

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between around 7.00 AM – 6.00 PM Monday-Friday. The large sport hall is often used till 10.00 PM and on weekends. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

Lighting in the building is switched manually when needed separately in each room/corridor.

4. Existing state of building energy systems

The building was built in 3 stages between 1993 and 1997. It has not been modernized since that time, except the windows exchange and installation of a mechanical ventilation in one of the sport halls.

4.1. Heating system

The heating source in the building is a double traditional heat exchanger "JAD" type with a weather control. The heating load for the building is 562 kW. Water is the heating factor in the installation. The heat exchanger station, powered by the district heating, is insulated, so according to [1] its efficiency equals 99%.

Figure 16 ***Heating source*** *in the building*

The heat exchanger cooperates with the insulated distribution system, providing heat for the covering central heating and domestic hot water in the building. The insulation is maintained in very good condition. Basement where the heating source is located is also a heated space. According to [1] the system efficiency equals 96%.

Figure 17 Insulated pipes

Heaters have not been changed since the building had been built. They are mostly located in the niche under the windows, following the Polish construction requirements. In the whole building there are plate convectors. Convectors in the corridors are covered with wooden boards which is done for safety issues in order to not allow kids to get burn when the system is working. This however decreases the efficiency of radiant heating of plate heaters and may be cause of decreased efficiency of distribution in the system. Around ¾ of convectors are without thermostats. According to [1] system efficiency equals 77%.

Figure 18 Plate heaters in the building

4.1.1. Sport hall

Water convectors in the sport hall are the same as in the rest of the building. They are not equipped with thermostats and they are hidden behind wooden boards. They are located along the external wall.

Figure 19 Convectors in the sport hall

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, defining its efficiency as 0.90. The pipes are insulated and insulation condition is good. In the system there is a circulation pump installed and it works constantly. There is more than 100 sinks or showers in the building, so seasonal efficiency of domestic hot water distribution equals 50%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in sports hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The whole building the whole building is ventilated naturally, except kitchen which is equipped with the mechanical exhaust ventilation and fencing sport hall which recently gained new mechanical ventilation and also have cooling system. Natural ventilation is provided with brick ducts. Fresh air is supplied through air leakages in windows. Thermal comfort in zones is maintained by window opening and room ventilating.

4.3.1. Sport hall

The large sport hall is ventilated naturally by gravitation and infiltration of fresh air through windows. It also have mechanical ventilation (three exhaust fans with nozzle located on the ceiling), however it is not used.

Figure 20 Large sport hall ventilation

Fencing sport hall has recently (last year) gained new mechanical ventilation system with heat recovery. It is turned on when needed, usually always when the hall is occupied. This room has been designed as furniture storage room, so ventilation was very poor.

Figure 21 Fencing sport hall ventilation ducts

The last sport hall is ventilated naturally only.

4.4. Cooling system

The only cooling system in the building is fencing sport hall. It is used only when needed.

4.4.1. Sport hall

Fencing sport hall is the only room with cooling system in the building.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid by two connections and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building. Also there are two pumps for DHW and central heating. The highest power installed for one space is fencing sport hall in ventilation and cooling device. Also high power connected is in the kitchen for electric ovens.

4.5.1. Sport hall

Sports hall does not have any dedicated electric system. It is equipped with lighting and 230V sockets.

4.6. Building envelope

Building external walls are made of:

- full brick / reinforced concrete. thickness 25 cm,
- insulation layer made of 6 cm of polystyrene (stage 1 of the building) and with 8 cm of polystyrene (stage 2 and 3 of the building),
- aerated brick with thickness 12 cm,

Roof in all three stages is made of:

- 12 cm of aerated brick,
- 16 cm of mineral wool,

Floor on the ground:

- Concrete layer,
- Insulation layer made of 6 cm of polystyrene.

In 2014 windows were changed to new. According to on-site investigation, building is now equipped with PCV framed, 2-glass windows with heat transfer coefficient equal 1.0 W/m^{2}K.

Information on external partitions are presented in the table below.

Table 10 Heat parameters of external partitions in the building

Partition	Heat transfer coefficient [W/m^{2}K]	Resistance [m^{2}K/W]
External walls (stage 1)	0.42	2.38
External walls (stage 2. 3)	0.35	2.86
Flat roof	0.23	4.35
Ground floor	0.5	2.00
Windows	1.00	1.00
External walls (stage 1)	0.42	2.38

4.6.1. Sports hall

External partitions of the sports hall are identical as in the whole building.

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

The whole building is equipped with 2xT8 fittings with 2x58W fluorescent bulbs. Some of the corridors lighting works usually from Monday to Friday between 7.00 and 18.00. There are individual switches at each floor.

4.8.1. Sport hall

The large sport hall is equipped with 23 3xT8 fittings (with 3x58 W fluorescent bulbs). The lighting in the large sport hall is usually switched on, as observed during the walk-through audit. The lighting is switched on manually by the users. Power installed in lighting per square meter in the large sport hall is around 8 W/m^2 including fluorescent fittings ballast.
The fencing sport hall is equipped with 9 2x58 W fluorescent bulbs. This hall does not have windows, thus lighting is switched on whenever hall is occupied. Power installed in lighting per square meter in the fencing sport hall is around 11 W/m^2 including fluorescent fittings ballast.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal act cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 11 Non-renewable primary energy indicators

Parameter	**Heat**	**Electricity**
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 22 School SP 340 building (source: Google Maps)

Figure 23 Main entrance (north elevation)

Architectural documentation (floor plans) are available only as paper drawings of very poor quality, thus they are not attached to this report.

III. Building #3 SP 378 (ul. Bartnicza 8, 00-814 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built between 1974 and 1976. The building envelope is well preserved. It has been slightly renewed since original state but it has not been thermally insulated. Windows were exchanged in 2006 with PCV framed double-glazed ones. In 2006 there was a modernization of the sport hall, and new mechanical ventilation with heat recovery and a water heating coil was installed. The mechanical ventilation is also installed in a canteen and in the kitchen. Its installation is dated for 1975 when the building was built. The rest of the building is ventilated naturally. The building is heated by heat exchanger connected to the district heating. The pipes with heating factor are insulated, but insulation is not tight. The heat is distributed by old pipe heaters on the corridors and old iron ribbed heaters in other rooms. The most of the convectors does not have thermostats. There are also some leakages in installation, so the water must be refilled periodically. The sports hall is also heated with ventilation air from air handling unit. The whole building is equipped with traditional T8 fluorescent bulbs manually controlled by users. The building does not have any BMS system.

The general overview of the building allowed for giving a neutral opinion about energy efficiency of the building. The measured final energy indicator for heating is 131.54 kWh/m^{2}a, which is typical for this type of building.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 378 in Warsaw, located in the northern part of the city. The school occupies a building with 4 floors including a basement, of total area of 7,060 m^2. There are 28 classrooms with a total area of 1,683 m^2, two sport halls of total area of 827 m^2 and a canteen of 160 m^2 (266 m^2 including facilities). The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 700 children. Children attending the school are around 6 – 14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control and window closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit – scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor was Ms. Dorota Górska, who is an economic manager in the school, taking care of energy and other media management in the building. Ms. Dorota Górska mentioned that the building has some heating issues.

Due to the old heating installation, there are many leakages and it is necessary to refill water in installation even few times a year. Furthermore, convectors gets often aerated and intervention of technical staff is required, which results in insufficient heating conditions and poor thermal comfort in classrooms. During very cold days, temperature on the 2nd floor gets really low, partially because of the ventilation holes under a ceiling. Another problem are leaky windows, causing not only air leakage, but also in some cases, due to lacking sills, water leakage during heavy rains.

The first visit in the school was taken on 21.01.2019 and included technical documentation analysis and digitalization, connected with the whole building inspection (classrooms, sport hall, canteen, technical rooms), and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and domestic hot water systems evaluation.

The on-site visit of the building included also the lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms, the sport hall, the canteen, an entrance hall and corridors.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was finished in 1976. It has 4 floors including (partially) basement, ground floor, first floor and second floor. The building is divided into 4 zones: A, B, C and D, which covers parts of the building, though all the parts are one block on the plan of square. A total area of building is 7,057 m^2 including 827 m^2 of two sport halls, 1,683.8 m^2 of classrooms and 265.9 m^2 of the canteen with facilities.

The building envelope has not been modernized except windows, which have been exchanged in 2006. New windows have the declared heat transfer coefficient of 1.5 W/(m^2*K). Windows have 2 layers of glass.

The building has been insulated with 2-3 cm of polystyrene on the external walls, which are made of concrete with aerated brick. Roof has 6 cm of mineral wool insulation. The floor on the ground has been insulated with 2-4 cm of hard polystyrene.

The building is heated with the heat exchanger powered by the district heating. The heat is distributed with old iron ribbed convectors in classrooms and with old pipe convectors in corridors. There is an old mechanical ventilation in the canteen, kitchen and its facilities. In the large sport hall there is a new mechanical ventilation with the heat recovery and water heating coils. Lighting in school is mainly fluorescent bulbs - depending on the type of fitting, it is 2x36W, 2x40 W or 4x18W.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 12 Standards used during energy audit

	Applied version	English version
1	Norma PN-EN 16247-1 "Audity Energetyczne: Wymagania Ogólne"	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 "Audity Energetyczne Część 2: Budynki"	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 "Audity Energetyczne Część 3: Procesy"	EN 16247-3"Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego."	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń."	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania."	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne."	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia."	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania"	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system"	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 "Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance"	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 13 Regulations used during energy audit

	Applied version	English version
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) – raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) – raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 378 in Warsaw started with on-site visit that took place on 21st of January 2019. It began with an interview with an economic manager of the school, Ms. Dorota Górska. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis.

Ms. Dorota Górska pointed out a few problems. In her opinion the central heating installation is old and faulty thus it requires modernization. Most of the heaters lack thermostats so it is difficult to keep the required heat comfort in rooms. On the second floor it is cold during winter because of faulty natural ventilation channels under the sills.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions applied and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules.

The mechanical ventilation in the large sport hall is working 24/7. Mechanical ventilation in the kitchen and canteen is used only when needed and is turned on manually by the kitchen staff. In the whole building the applied lighting is fluorescent light bulbs with traditional manual control. Most of the data concerning HVAC and electric systems was be gained during the walk-through audit. Data about the envelope of the building was gained from the technical documentation of the building that was available during the on-site visit.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator equal wi=3.0 for electricity, and applying the non-renewable primary energy indicator from the declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 378 w Warszawie
Street, number, city and postcode	Bartnicza 8, 00-814 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	52.29
Latitude [DD.dd°]	21.03
Height above the see level [m]	83 m
Year of construction	*1976*
Useful area - the whole building [m^2]	*7 057 m^2*
Useful area - audited part [m^2]	*Classrooms: 1,683.8 m^2* *Sport hall: 827 m^2* *Canteen: 265.9 m^2 (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 10.5 MWh/month, with total yearly consumption of 128,567 kWh in 2018 and 125,288 kWh in 2017. The maximum ordered power is 82 kW on two electric connection, 49 kW and 33 kW. The graph below presents the consumption of electricity consumption, the maximum ordered power and maximum power consumed for each connection in 2018.

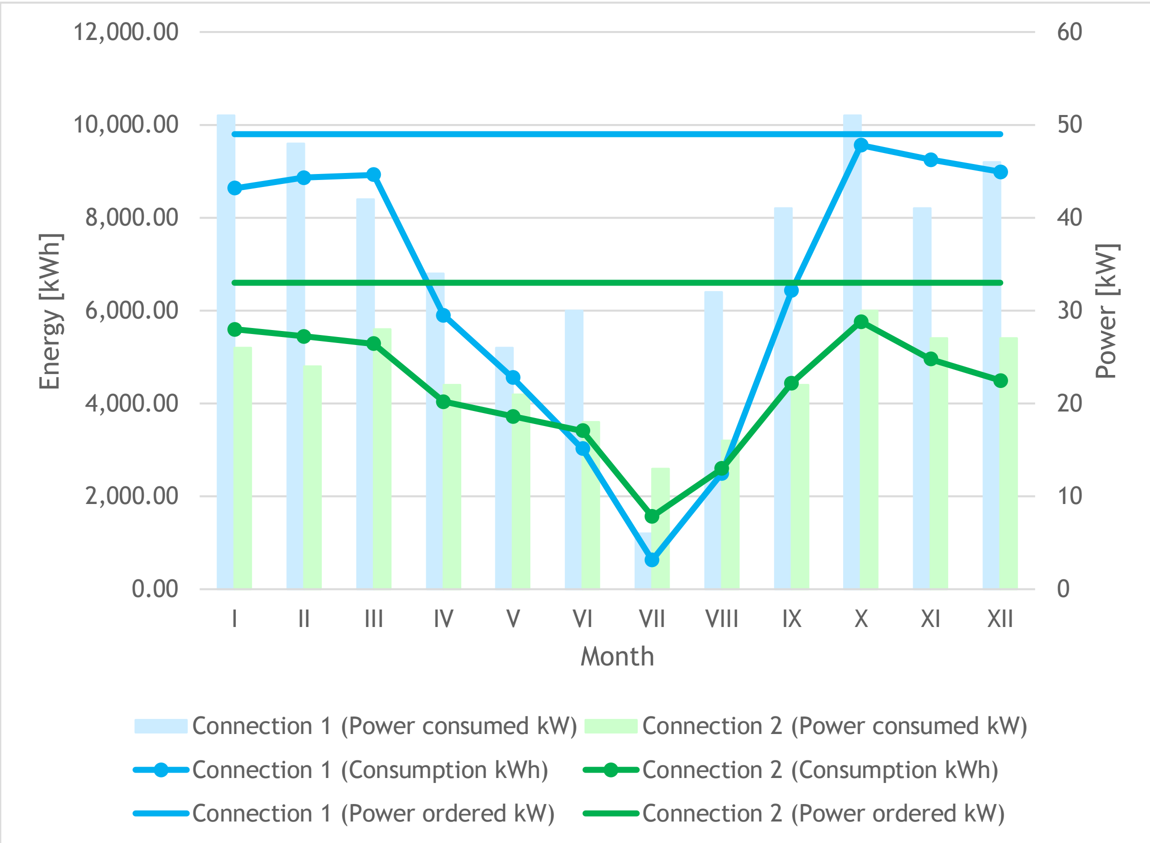

Figure 24 Electricity consumption, power ordered and power consumed in 2018

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2018 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water, as well as technical heat for heating coil in an air handling unit in the sport hall.

Table 14 Heat consumption in 2018

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	673.20	187.00	-3.7
II	642.70	178.53	-0.8
III	376.30	104.53	6.1
IV	348.40	96.78	7.7
V	250.80	69.67	14.6
VI	25.70	7.14	18.5
VII	19.50	5.42	18.9
VIII	20.70	5.75	19.7
IX	29.00	8.06	14.0
X	184.30	51.19	10.0
XI	370.40	102.89	4.9
XII	400.20	111.17	2.5
TOTAL	**3 341.20**	**928.11**	

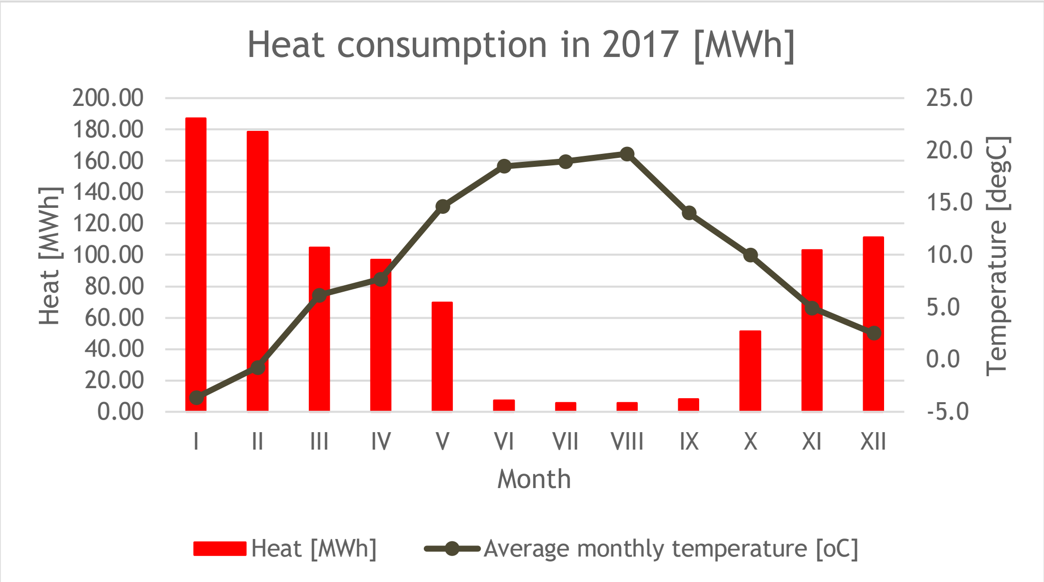

Figure 25 Heat consumption in 2017

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO_2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied.

Table 15 Energy consumption and emissions

Parameter	**Heat**	**Electricity**	**Total**
Final energy consumption [kWh/a]	928,111.11	128,567.00	1,056,678.11
Final energy consumption indicator [kWh/m^{2}a]	131.52	18.22	149.73
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	807,456.67	385,701.00	1,193,157.67
Primary energy consumption indicator [kWh/m^{2}a]	114.42	54.66	169.07
CO2 emissions [tCO2/a]	308.39	92.31	400.70

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between 7.00 AM – 4.00 PM Monday-Friday, except the both sport halls (large and small one) which are also used in the evenings and on weekends. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

The heating and mechanical ventilation in the large sport hall systems work with no pre-defined breaks. . The lighting in the corridors is switched on manually in the morning and turned off the same way after 4.00 PM. The lighting in the classrooms, sport hall and canteen is used only if needed.

4. Existing state of building energy systems

4.1. Heating system

The heating source in the building is a traditional heat exchanger “JAD” type with weather control. Heating load for the building is 677 kW. Water is the heating factor in the installation. The heat exchanger station powered by the district heating is insulated, so according to [1] its efficiency equals 99%.

*Figure 26 **Heating source** in the building*

The heat exchanger cooperates with insulated distribution system, feeding the central heating and domestic hot water systems in the building. The insulation is maintained in acceptable condition but there are some parts that lack insulation. Basement where the heating source is located is also a heated space. According to [1] the system efficiency equals 96%.

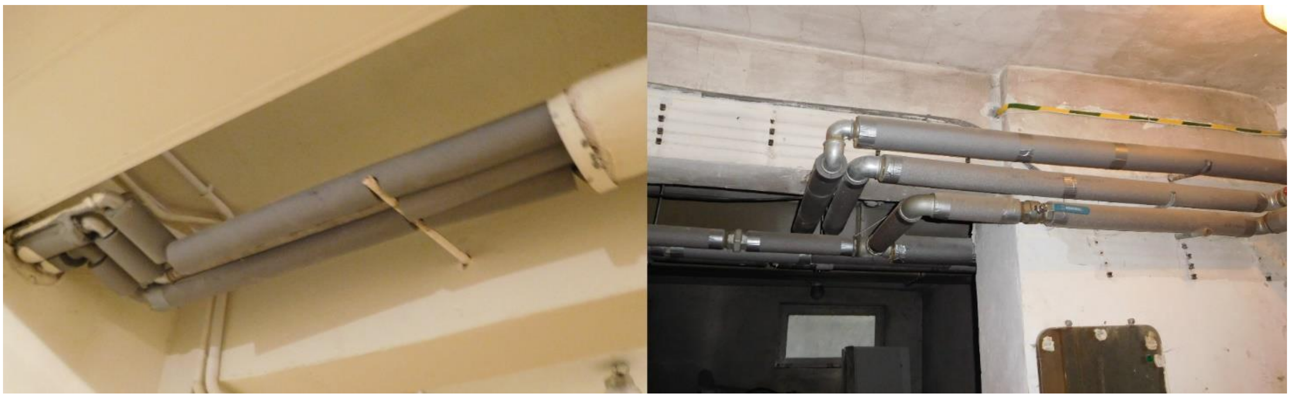

Figure 27 Insulated pipes

Heaters have not been replaced since the building had been built. They are mostly located in the niche under windows, following the Polish construction requirements. In the building there are mainly pipe heaters and several iron ribbed convectors in the corridors that are usually not equipped with thermostats. Convectors in the corridors are covered with wooden boards which due to safety issues, in order to not allow kids to get burn when the system is working. This, however, decreases the efficiency of radiant heating of plate heaters and may be cause of decreased efficiency of the distribution system. The most of convectors are not equipped with thermostats. According to [1] the system efficiency equals 77%.

Figure 28 Pipe heaters in the corridors

4.1.1. Sport hall

Radiators in the sport halls are old traditional iron ribbed radiators. They are hidden behind wooden boards. The large sport hall is additionally heated with ventilation unit.

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, with the seasonal efficiency equals 0.98. The pipes are insulated, however the insulation condition is not perfect. In the system there is a circulation pump installed and it works constantly. There is more than 100 sinks or showers in the building, so seasonal efficiency equals 50%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in sports hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The whole building is ventilated naturally, except the kitchen which is equipped with mechanical ventilation and the large sport hall which recently gained new mechanical ventilation. Natural ventilation is provided with brick ducts. Fresh air is supplied through air leakages in windows. Thermal comfort in zones is maintained by window opening and room ventilating.

4.3.1. Sport hall

The small sport hall is ventilated naturally. The large sport hall and its facilities gained new mechanical ventilation with heat recovery recently. The system is divided into 3 parts:
1N/1W – ventilation of sport hall,
2N/2W – ventilation of facilities (changing rooms and showers),
3W – exhaust ventilation of toilets.

The total air volume of the 1N/1W system is 3,000 m^3/h. There is a filter, heating coil and two fans (1 kW each), heat recovery heat exchanger and electric heating coils for the frost protection. The capacity of the heating coil y is 28.4 kW. Declared heat recovery efficiency is 55%.

The total air volume of 2N/2W system is 1,850 m^3/h. There is a filter, heating coil and two fans (0.5 kW each), heat recovery heat exchanger and electric heating coils for frost protection. The capacity of the heating coil is 8.8 kW. Declared heat recovery efficiency is 70%.

System 3W is an exhaust system of 9 small fans with 500 m^3/h total air flow from toilettes, showers and corridors.

Figure 29 Mechanical ventilation in the sport hall

4.4. Cooling system

There is no cooling system in the building.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid by two connections and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building, some of it is consumed for ventilation systems (canteen with facilities and the large sport hall). Also there are two pumps for DHW and central heating.

4.5.1. Sport hall

Sports hall does not have any dedicated electric system. They are equipped with lighting and 230V sockets.

4.6. Building envelope

The building project has been prepared according to requirements as of 1974.

The external walls construction parts are made with prefabricated concrete with tube holes, insulated with 2-3 cm of polystyrene and 12 cm aerated concrete slabs. In other places there are 24 cm aerated concrete slabs and 2-3 cm of polystyrene.

The roof of the greater part of the building is made of reinforced concrete and insulated with 6 cm of mineral wool, covered with roofing paper.

The roof of the large sport hall is made of prefabricated concrete boards, insulated with 9 cm of mineral wool.

The roof of corridor near the entrance is made of prefabricated material (DZ-3 type), made of reinforced concrete frame and aerated bricks. It is was insulated in the same way as rest of the building that is with 6 cm of mineral wool.

The ground floor was insulated with 2-4 cm of polystyrene.

Information on external partitions are presented in the table below.

Table 16 Heat parameters of external partitions in the building

Partition	Heat transfer coefficient [W/m²K]	Resistance [m²K/W]
External walls	0.65	1.54
Roof	0.5	2.00
Roof (sport hall)	0.35	2.86
Roof (entrance hall)	0.37	2.70
Ground floor	0.8	1.25
Windows	1.5	0.67

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

The building was designed with fluorescent fittings 2x40W. There are some areas in the building where old fittings have been exchanged with new 2x36W fluorescent fittings.

There is no central switch for the lighting. It is turned on manually in morning when needed. If it is used, it works between 7.00 AM – 4.00 PM, when school works.

4.8.1. Sport hall

The large sport hall is equipped with 72 fittings with 2x40 W fluorescent bulbs. Lighting in the sport hall is divided into 3 zones allowing for lighting only part of the sport hall that is used at the moment. Windows in the sport hall are big enough so that lighting is not used during the day. The lighting is switched on manually by the users when needed.
Power installed in lighting per square meter is around 10 W/m2 including fluorescent fittings ballast.

Small sport hall has been renovated recently. Now there are 15 fittings with 4x18 W fluorescent bulbs. Power installed in lighting per square meter is around 6 W/m^2 including fluorescent fittings ballast.

4.9. Other systems

There are no other systems in the building that are relevant for the audit.

5. Other information

Legal act cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 17 Non-renewable primary energy indicators

Parameter	Heat	Electricity
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 30 East side of the building

Figure 31 South-wester side of the building

Figure 32 Basement floor plan

Figure 33 Ground floor plan

Figure 34 First floor plan

Figure 35 Second floor plan

IV. Building #4 SP 341 (ul. Oławska 3, 01-494 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built between 1993 and 1998. It was designed in 4 stages. The building envelope is well preserved. Since the beginning, it has been well thermally insulated, with mineral wool on the roofs of 10-20 cm, and polystyrene on the external walls of 9-10 cm. The ground floor is insulated with 4 cm of hard polystyrene. There were no modernizations performed in the building yet. The building is ventilated naturally except the sport hall and the canteen kitchen which are equipped with mechanical ventilation. There are 13 cooling units installed in the building. The building is connected to the district heating network. Both the central heating and domestic hot water are supplied by the heat exchanger. The lighting system in the building is composed of traditional fluorescent bulbs controlled manually by users. The building does not have any BMS system.

The general overview of the building allowed for giving a good opinion about energy efficiency of the building. The measured final energy indicator for heating is 127.40 kWh/m^{2}a, which is typical for this type of building.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 341 in Warsaw, located in the western part of the city. The school occupies a middle-sized building with 3 floors including a basement, with a total area of 7,791 m^2, while the area of rooms dedicated strictly for the educational purposes is 1,808,6 m^2. There are 34 classrooms, two sport halls of 676.2 m^2 and 76.6 m^2 area and one canteen in the building. The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 1200 children. Children attending the school are around 6 – 14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the school technical staff are limited to lighting control, thermostats control and windows closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit – scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor is Mr. Andrzej Łaszcz, who is an economic manager in the school, taking care of energy and other media management in the building. Mr. Andrzej Łaszcz mentioned that there is sometimes cold in the main entrance hall. Except that, the thermal comfort in the building is usually well preserved, and there are generally no problems with overheating or too cold conditions.

There are however problems with the water leakage through windows during heavy rains. The windows were not mounted correctly, thus sometimes when it rains the water flows into the rooms.

The first visit in the school was performed on 23.01.2019. Documentation was already digitized, as the school manager delivered full documentation to city hall where it was available for the investigation. The walk through audit included classrooms, sport halls, canteen and technical rooms investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and evaluation and domestic hot water systems evaluation. The large sport hall is equipped with mechanical ventilation, and the small sport hall is equipped with 4 individual cooling systems.

The on-site visit of the building included also the lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms, sport halls, canteen, entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and information gained from technical staff of the building.

2.4. Description of audited object

The building was built between 1993 and 1998. It was constructed in 4 phases. The building has 2-3 floors (locally including ground floor and basement) with area of 7,791 m^2. The area of classrooms is 1,808.6 m^2. There are 34 classrooms, two sport halls of 676.2 m^2 and 76.6 m^2 area and one canteen of 81.6 m^2 (212.6 m^2 including facilities) in the building. The building envelope has not been modernized since the beginning. All the external partitions are insulated achieving much better parameters than required by law in 90's. External walls are insulated with 9 – 10 cm of polystyrene. Roofs are insulated with 10 cm (stage I and II) or 18-20 cm of mineral wool (stage III and IV). Ground floors are insulated with 4 cm of polystyrene. External walls are constructed with full brick and aerated brick. Roofs are made with reinforced concrete or steel layers filled with mineral wool, depending on the area. The building is heated with the heat exchanger powered by the district heating. Heat is distributed with traditional plate heaters. The whole building is ventilated naturally except the sport hall and the kitchen. The small sport hall, canteen and a few other rooms are equipped with cooling units. Lighting installed in the building are mainly 36 W fluorescent bulbs controlled manually.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

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6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania."	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne."	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia."	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania"	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system"	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 "Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance"	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 19 Regulations used during energy audit

	Applied version	English version
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) - raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) - raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 341 in Warsaw started with a technical documentation investigation that was delivered to the city hall by the school management staff. The first on-site visit took place on 23rd of January 2019. It began with an interview with an economic manager of the school, Mr. Andrzej Łaszcz. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis.

Mr. Andrzej Łaszcz stated that thermal comfort in the building is well preserved. The only exception is the main entrance hall, where sometimes it is getting cold. The economic manager supposes that roof over the hall is not insulated, however according to the design it is insulated with 20 cm of mineral wool, which generally gives a good heat resistance.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules. There is a mechanical ventilation in the large sport hall with heat recovery which works 24/7 according. There is also a mechanical ventilation in the canteen and in the kitchen -it is equipped with a water heating coil and it works only when turned on by the kitchen staff.

In the building there is a fluorescent light bulbs with traditional manual control, mainly 2x36W fittings lighting installed. In the large sport hall there are 15x400 W halogen lamps installed. The lighting is controlled manually. During night about 1/5 of the fitting in the corridors is turned on for the safety issues. Most of the data concerning HVAC and electric systems was gained during the walk-through audit. Data about the envelope of the building was gained from the technical documentation of the building that was made available for the auditor.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator equals wi=3.0 for electricity, and the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 341 w Warszawie
Street, number, city and postcode	Oławska 3, 01-494 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	*52.26*
Latitude [DD.dd°]	20.93
Height above the see level [m]	*108 m*
Year of construction	*1993-1998*
Useful area - the whole building [m²]	*7,791 m²*

Useful area - audited part [m²]	*Classrooms: 1,808.6 m²* *Sport hall: 752.8 m²* *Canteen: 212.6 m² (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 15,600 kWh/month, with total yearly consumption of 188,070 kWh in 2017. The maximum ordered power is 162 kW on two electric connection, 120 kW and 42 kW.

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2017 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water.

Table 20 Heat consumption in 2017

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	674.90	187.47	-3.7
II	630.10	175.03	-0.8
III	399.70	111.03	6.1
IV	387.90	107.75	7.7
V	291.40	80.94	14.6
VI	41.60	11.56	18.5
VII	22.90	6.36	18.9
VIII	26.40	7.33	19.7
IX	34.70	9.64	14.0
X	212.10	58.92	10.0
XI	417.90	116.08	4.9
XII	433.80	120.50	2.5
TOTAL	3 573.40	992.61	

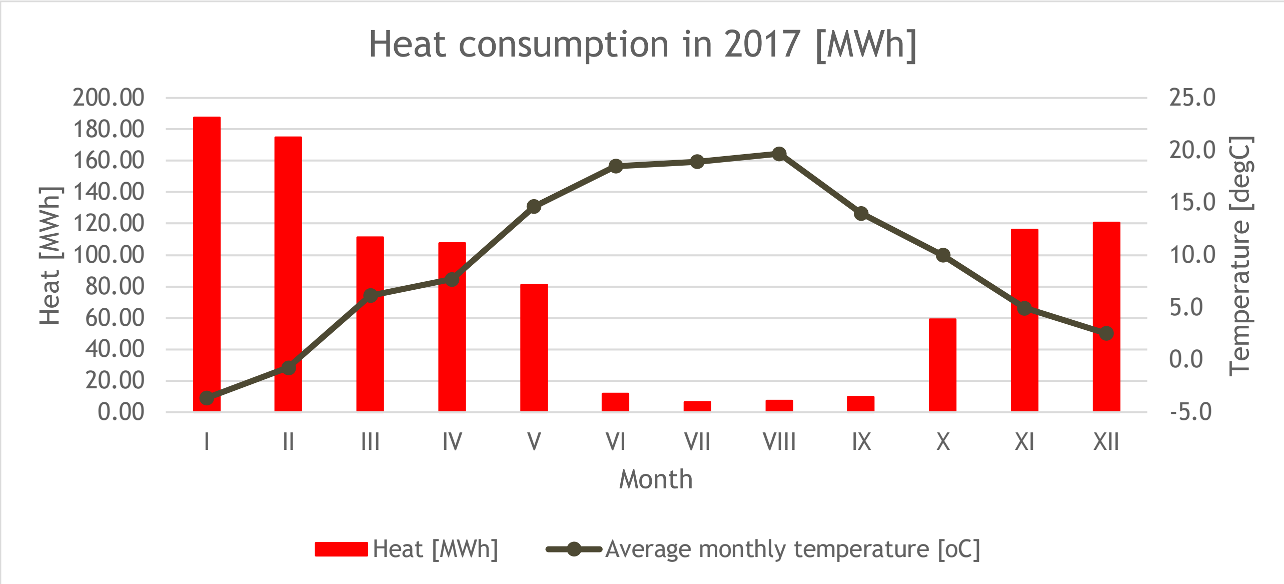

Figure 36 Heat consumption in 2017

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO_2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied.

Table 21 Energy consumption and emissions

Parameter	**Heat**	**Electricity**	**Total**
Final energy consumption [kWh/a]	992,611.11	188,070.00	1,180,681.11
Final energy consumption indicator [kWh/m^{2}a]	127.40	24.14	151.54
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	863,571.67	564,210.00	1,427,781.67
Primary energy consumption indicator [kWh/m^{2}a]	110.84	72.42	183.26
CO2 emissions [tCO_2/a]	329.82	135.03	464.86

3.3. Building exploitation, maintenance and management

Typical hours of exploitation in school buildings is 7.00 AM – 17.00 PM. The sport hall is often used until 10 PM on week days and also whole days during weekends. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

Lighting in the building is switched manually when needed, separately in each room/corridor. During the night there is always 20% of light working for safety issues (CCTV).

A mechanical ventilation in the canteen and kitchen works only when turned on by the kitchen staff. The mechanical ventilation in the sport hall works 24/7.

4. Existing state of building energy systems

Building was built in 4 stages between 1993 and 1998. It has not been modernized since then.

4.1. Heating system

The heating source in the building are traditional heat exchangers "JAD" type with weather control. Heating capacity ordered for the building is 500 kW.

Designed heating capacity of each heat exchanger are:
- School central heating: 420 kW,
- Sport hall central heating: 150 kW,
- Domestic hot water: 80 kW,
- Technological heat (ventilation): 40 kW.

Water is the heating factor in the installation. The heat exchanger station powered by district heating is insulated, so according to [1] its efficiency equals 99%.

The heating system for domestic hot water is equipped with an accumulation tank. Due to the accumulation tank installed in the system, its total efficiency equals 65%, according to [1].

Figure 37 Heating source in the building

The heat exchanger cooperates with the insulated distribution system, covering central heating, domestic hot water and technological heat for the building. The insulation is in a poor condition. A basement where the heating source is located is a heated space. According to [1], the system efficiency equals 96%.

Figure 38 Insulated pipes

The heat distribution system in the school is original as designed. There are mainly iron ribbed convectors installed in stage I and II, plate convectors in stages III and IV, and some pipe convectors on corridors and in the canteen. The most of them are equipped with thermostats. Many of the convectors are covered with huge wooden plate which is done for safety issues in order to not allow kids to get burn when the system is working. This however decreases the efficiency of radiant heating of plate heaters and may be a cause of decreased efficiency of the distribution in the system.

Convectors are mostly located in the niche under the windows, following the Polish construction requirements. According to [1], system efficiency equals 89%.

Figure 39 Water convectors with thermostatic valves

4.1.1. Sport hall

Water convectors in the sport hall are plate convectors with thermostats. They are located along the external wall. Temperature regulation in the sport hall, according to information gained during the audit,

is good and thermal comfort is well preserved. Convective heaters are supported with a mechanical ventilation with heat recovery.
The sport hall is also heated with three electric heaters with fans located on the external wall of the sport hall, but it is not necessary to use them, as thermal comfort is well preserved. They are tested occasionally to check their availability and they work correctly.

Figure 40 Thermal control devices in the sport hall

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water has a separate source from the central heating, with overall efficiency equal 0.91. The pipes are insulated and insulation condition is good. In the system there is a circulation pump installed and it works constantly. There is less than 100 sinks or showers in the building, so seasonal efficiency of domestic hot water distribution equals 60%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary. The heating system for domestic hot water is also equipped with an accumulation tank. Due to the accumulation tank installed in the system, the overall efficiency of the system equals 65%, according to [1].

4.2.1. Sport hall

There are no water access points in the sport hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The most of the building is ventilated naturally. The only exceptions are: large sport hall with its facilities and canteen with facilities.

4.3.1. Sport hall

The sport hall is equipped with supply-exhaust air handling unit with air flow volume of 4,000 m^3/h, which, according to the project, shall be used only when there is an audience in the sport hall. There is an electric heating coil with heating capacity of 30 kW.
For daily use there should be used only natural ventilation, and if necessary, exhaust fan located in the ceiling with air flow of 1,400 m^3/h.
Sport hall facilities are equipped with mechanical ventilation with supply of fresh air. There are 4 air handling units with water heating coils of 3.3 kW heating capacity each, dedicated for the changing rooms.

4.4. Cooling system

There are 17 cooling units in the building. Each of them is a small cooling unit with cooling capacity around 4-5 kW. Most of them are installed in administration office.

4.4.1. Sport hall

There are 4 cooling units in the large sport hall and 2 cooling units in small sport hall.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building. Another important energy consumption is caused by the mechanical ventilation, as there is 30 kW electric heating coil in the ventilation system of the sport hall.

4.5.1. Sport hall

Sport halls itself do not have any dedicated electric system. There is a mechanical ventilation dedicated for the sport hall and facilities, which is powered by electricity. Total power installed is about 1.5 kW for fans and 30 kW for heating coil.

4.6. Building envelope

The building was built between 1993 and 1998 with accordance to actual requirements for that time.

Building external walls are made of:

- 25 cm of full brick / reinforced concrete
- insulation layer made of 9 cm (stage I and II)) or 10 cm (stage III and IV) of polystyrene
- 12 cm of aerated brick,

Roofs in stage I and II are made of:

- 10 cm of aerated brick on concrete construction frame,
- 10 cm (stage I) or 15 cm (stage II) of mineral wool,
- Roofing paper.

Roofs over the entrance hall is made of:

- 0.75 mm of brass plate,
- 20 cm of mineral wool,
- 0.75 mm of brass plate.

Roofs in stage IV is made of:

- 10 cm of aerated brick on 25 cm of reinforced concrete,
- 18 cm of mineral wool,
- Roofing paper.

Floor on the ground:

- Concrete layer.
- Insulation layer made of 4 cm of polystyrene.

It was assumed that all windows have a heat transfer coefficient equal to 2.6 W/m^{2}K, which was typical for that period.

Information on external partitions are presented in the table below.

Table 22 Heat parameters of external partitions in the building

Partition	Heat transfer coefficient [W/m^{2}K]	Resistance [m^{2}K/W]
External walls (stage I & II)	0.32	3.13
External walls (stage III & IV)	0.3	3.33
Roof (stage I)	0.35	2.86
Roof (stage II)	0.24	4.17
Roof (stage III)	0.2	5.00
Roof (stage III B - entrance hall)	0.2	5.00
Roof (stage IV + sport hall)	0.22	4.55
Ground floor	0.6	1.67
Windows	2.6	0.38

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

Lighting installed in the building are mainly 2x36W fluorescent fittings controlled manually. During the night about 20% of lights is turned on for safety issues and for correct functioning of CCTV system.

4.8.1. Classrooms

Classrooms are equipped with 2x36 W fluorescent bulbs. The typical size class room (60 m^2) is equipped with 16 fittings. Lighting in classrooms is divided into three zones (inner zone + windows zone + blackboard zone). The lighting is switched on manually by the users when needed.
Power installed in lighting per square meter is around 20 W/m^2 including fluorescent fittings ballast.

4.8.2. Sport hall

The large sport hall is equipped with 15x400W halogen lamps. Lighting in the large sport hall is usually switched on, as observed during the walk-through audit. The lighting is switched on manually by the users. Power installed in lighting per square meter in the large sport hall equals 9 W/m^2.
Lighting in the small sport hall is 8x (2x36W) fluorescent fittings. Power installed in lighting per square meter in the small sport hall is 9 W/m^2.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal act cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 23 Non-renewable primary energy indicators

Parameter	Heat	Electricity
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 41 School SP 341 building (source: Google Maps)

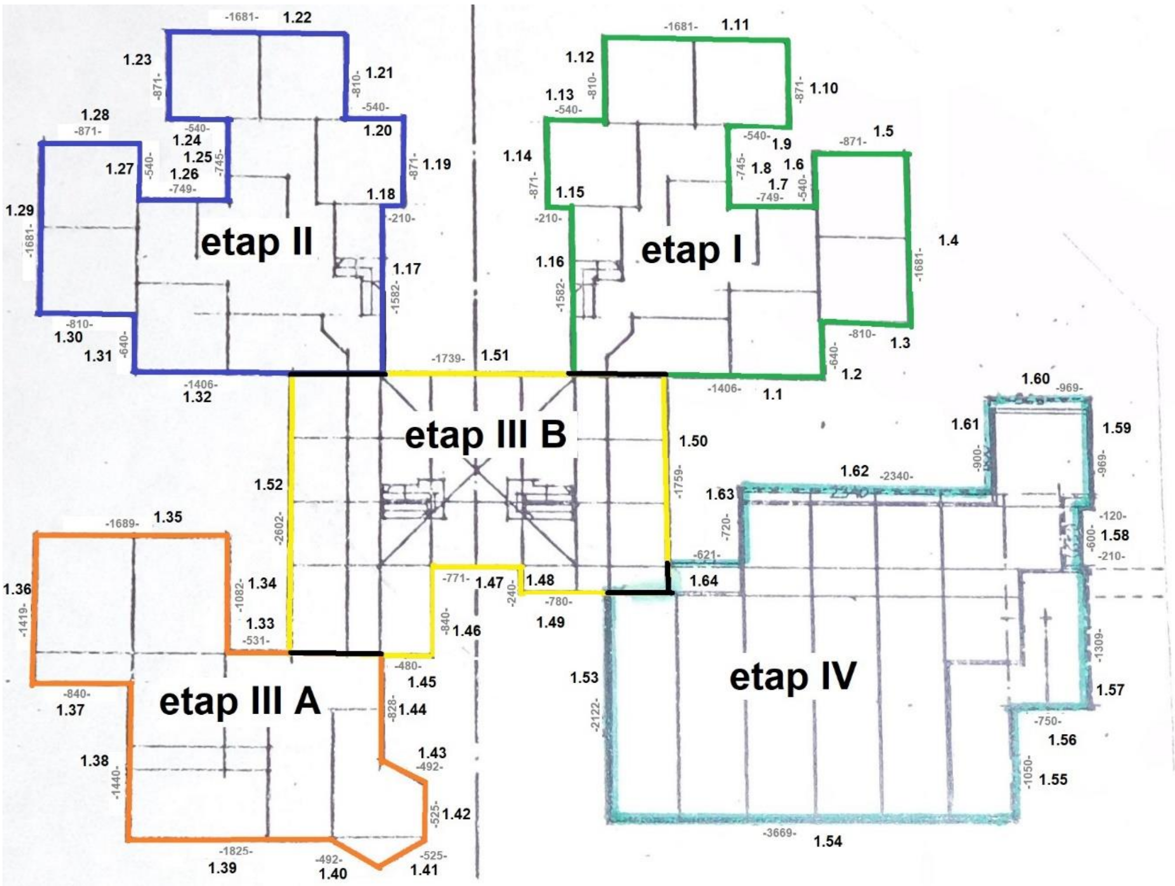

Figure 42 Building divided into stages of construction

Architectural documentation (floor plans) are available only as paper drawings with very poor quality, thus were not attached into this report.

V. Building #5 SP 77 (ul. Samogłoska 9, 01-980 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built in 1963. Last year (2017) the building has been completely modernized, including thermal modernization and a new storey over a part of a building has been added. The building envelope is new. A thermal modernization included an insulation of the building, which has been performed with graphite polystyrene. Insulation parameters are very good. Windows have been exchanged with 3-glazed ones. The building is heated with its own gas boiler, which is also planned to be exchanged to a new, condensing boiler during the upcoming summer. Pipes transporting heat are insulated, a boiler is located in the non-heated basement with separate entrance from the outside of the building. The boiler generates heat for a central heating and domestic hot water. There is an accumulation tank in the system of 500 dm^3. A heat distribution system in the school is new and all plate convectors are equipped with thermostats, however most of convectors are covered with shield with holes for safety issues. This decreases the efficiency of radiant heating of plate heaters. A sport hall is heated and ventilated with two fans with heating coils transferring fresh air into the room. Most of the building is ventilated naturally with assist of small exhaust fans in toilets, except the sport hall, new classrooms in the recently added part of the building and the kitchen. There are two classrooms that have air conditioning units. In the whole building there is energy efficient fluorescent lighting installed. Most of the fittings are 2x58W, some are 2x36W. There are a few individual CLFs in the small rooms (sanitary etc.) The sport hall is equipped with 3x36W fittings. There is one general switch for lighting that is used during the unoccupied period. The building does not have any BMS system, however it has well organized security monitoring system.

The School owns also a balloon-covered football field that is heated with gas heater mounted on the pressurizing fan for the balloon.

The general overview of the building allowed for giving very good opinion about energy efficiency of the building. Thus, it is surprising that the final energy indicator for heating in 2017 reached 162.08 kWh/m^2a, which is very high as for the building after recent thermal modernization. This might be explained by including to the calculation the heat for the sport field covered with the balloon, owned by school. The gas consumption of heaters for the balloon shall be further investigated.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 77 in Warsaw, located in the northern side of the city. The school occupies a middle-sized building with 3 floors (basement, ground floor and 1st floor), with total area of 2,919.59 m^2. There are 20 classrooms, one sport hall of 159 m^2 area and one canteen in the building. The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 600 children. Children attending the school are around 6 – 14 years old, there is also one class of pre-school children with around 25 children. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control, window closing and thermostats regulation. There is a staff responsible for controlling if thermostats have good settings. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit - scope. aim and thoroughness. timeframe and boundaries

A person responsible for the contact with an auditor is Ms. Krystyna Kasprowicz, who is an economic manager in the school, taking care of energy and other media management in the building. Ms. Krystyna Kasprowicz mentioned that the building has some technical issues after recent modernization. There is a problem of humid floor and walls in room 124. The reason of this situation is probably caused by defective waterproofing on the ground floor (this part of the building does not have a basement). Another issue are entrance stairs, which are very slippery especially during winter. The accidents happen there very often. Ms. Krystyna Kasprowicz did not mention any problems with heating, cooling or ventilating the building. Thermostats settings and windows are controlled very carefully by the staff, thus thermal comfort in the building is kept at the very good level.

The first visit in the school was performed on 16.01.2019 and included technical documentation analysis and digitalization, as well as the whole building inspection (classrooms, sport hall and canteen, technical rooms) and technical systems investigation. The investigation of HVAC systems included the heating system overview (heating source, distribution and regulation systems), ventilation system investigation and evaluation a domestic hot water systems evaluation. The building is equipped with two air conditioning units of 5.0 kW cooling capacity located in the computer class room and another one in one class room with south exposition.

The on-site visit of the building included also a lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms, sport hall, canteen, entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on the auditor's experience and law acts introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was built in 1963. Last year (2017) the building has been completely modernized, including thermal modernization and a new storey over a part of a building has been added.. The school occupies a middle-sized building with 3 floors (basement, ground floor and 1st floor). Its total area is 2 919.59 m^2. There are 20 classrooms with a total area of 1,001.63 m^2, one sport hall of 159 m^2 area and one canteen in the building with total are of 159.45 m^2 including facilities.

Recent modernization was performed in 2017 in accordance to actual requirements described in [2]. External walls were insulated with 15 cm of graphite polystyrene with thermal conduction parameter of λ<=0.032 W/(m*K), flat roof was insulated with 25 cm of standard polystyrene λ<=0.038 W/(m*K). New mechanical ventilation has been applied in the part of the building that was added. New 3-glazed windows were mounted, with declared heat transfer coefficient of 1.0 W/(m^2*K).

The heat source in the building is a gas boiler that will be changed to a new one in the upcoming summer season. The boiler produces heat for technological purposes for ventilation units with water heating coils in the sport hall, central heating and domestic hot water system. The system is equipped with a heat accumulation tank with volume of 500 dm^3.

The heat distribution system in the school is new and all plate convectors are equipped with thermostats, however most of convectors are covered with shield with holes for safety issues. This decreases the efficiency of radiant heating of plate heaters. The sport hall is heated and ventilated with two fans with heating coils transferring fresh air into the room. Most of the building is ventilated naturally except the sport hall, new classrooms with facilities in the recently added part and the kitchen with facilities. There are two classrooms that have air conditioning installed. In the whole building there are energy efficient fluorescent lighting fittings installed. Most of the fittings are 2x58W, some are 2x36W. There are a few individual CLFs in the small rooms (sanitary etc.) The sport hall is equipped with 3x36W fittings.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 24 Standards used during energy audit

	Applied version	**English version**
1	Norma PN-EN 16247-1 “Audity Energetyczne: Wymagania Ogólne”	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 “Audity Energetyczne Część 2: Budynki”	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 “Audity Energetyczne Część 3: Procesy”	EN 16247-3“Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego.”	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń.”	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania.”	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne.”	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values

8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia.”	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania”	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system”	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 25 Regulations used during energy audit

	Applied version	English version
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building

	charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	
6	KOBiZE (The National Centre for Emissions Management) – raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) – raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 77 in Warsaw started with on-site visit that took place on 16th of January 2019. It began with an interview with an economic manager of the school, Ms. Krystyna Kasprowicz. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis.

Ms. Krystyna Kasprowicz mentioned that the building has some technical issues after recent modernization. There is a problem of humid floor and walls in room 124. The reason of this situation is probably caused by defective waterproofing on the ground floor (this part of the building does not have a basement). Another issue are entrance stairs, which are very slippery especially during winter. The accidents happen there very often. Ms. Krystyna Kasprowicz did not mention any problems with heating, cooling or ventilating the building. Thermostats settings and windows are controlled very carefully by the staff, thus thermal comfort in the building is kept at the very good level.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules.

The cooling system in the building is limited to two cooling units dedicated for the computer classroom and one other classroom with south exposition. Air conditioning in those rooms is used only when necessary.

A part of the building is equipped with a mechanical ventilation. The Mechanical ventilation in the kitchen works only when needed. The mechanical ventilation in the new classrooms and its facilities works 24h/7. The mechanical ventilation of sport hall with heating coils works only when needed.

There is a main switch for the lighting which is used for turning off the light in the building during unoccupied period.

Building working time is 7.00 – 16.30. The balloon-covered football field is used also during evenings and weekends. The pressurizing and heating system for the balloon works during winter time, namely from around 15 October till 15 April.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] and applying the non-renewable primary energy indicator for gas fuel wi=1.1 and wi=3.0 for electricity.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 77 w Warszawie
Street, number, city and postcode	Samogłoska 9, 01-980 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	*52.31*
Latitude [DD.dd°]	20.92
Height above the see level [m]	*86 m*
Year of construction	*1963*
Useful area - the whole building m^2]	2 919.59
Useful area - audited part [m^2]	*Classrooms: 1,001.63 m^2* *Sport hall: 159.00 m^2* *Canteen: 159.45 m^2 (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 4,800 kWh/month, with total yearly consumption of 57,497 kWh in 2017. The maximum ordered power is 40 kW on one electric connection.

3.2.2. Gas/Oil/solid Fuel Consumption

The building uses gas for heating. Gas is delivered by PGNiG Obrót Detaliczny sp. z o.o. at the BW-5 tariff. Maximum ordered capacity for the building is 241 kWh/h. The declared net calorific value is 40.453 MJ/m^3, (11.237 kWh/m^3). Gas consumption in 2017 reached 42,111 m^3, which gives 473.2 MWh of heat consumed in the form of gas. Information about monthly consumption of gas by the building could not be obtained.

Table 26 Gas consumption in 2017

Month	Gas [m3]	Heat [MWh]	Average annual temperature [°C]
2017	42 111	473.20	9.5

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and gas for 2017 were applied for calculation of CO2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the actual one according to [1] was applied.

Table 27 Energy consumption and emissions

Parameter	Heat	Electricity	Total
Final energy consumption [kWh/a]	473,201.31	57,497.00	530,698.31
Final energy consumption indicator [kWh/m^{2}a]	162.08	19.69	181.77
Non-renewable primary energy indicator (wi)	1.10	3.00	-
Primary energy consumption [kWh/a]	520,521.44	172,491.00	693,012.44
Primary energy consumption indicator [kWh/m^{2}a]	178.29	59.08	237.37
CO_2 emissions [tCO_2/a]	2,362.43	41.28	2,403.71

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between around 7.00 AM - 4.30 PM Monday-Friday. The balloon-covered football field is usually used until 9 PM every day and sometimes during weekends. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

The heating and mechanical ventilation systems work with no pre-defined breaks. Lighting in the corridors is switched individually by staff in the morning when it is required, but can be turned off with central switch, which happens usually after 4.30 PM. Lighting is the classrooms, sport hall and canteen is used only when needed.

4. Existing state of building energy systems

The building was built in 1963. Last year (2017) building has been completely modernized, including thermal modernization. The school occupies a middle-sized building with 3 floors (basement, ground floor and 1st floor). The requirements concerning thermal modernization of building has to be fulfilled, thus the building had to be redesigned according to [2], when the modernization project was accepted by the City Hall's Infrastructure Office.

4.1. Heating system

Heat for the building is produced with a traditional gas boiler. Heating factor parameters are 80/60°C. The designed heating load of the building calculated according to documentation is 300.1 kW. The boiler is located in non-heated basement room that has a separate entrance from the outside. The boilers (DeDietrich) heat capacity ranges from 189 to 300 kW, and the declared efficiency equals 90%. There is an accumulation tank in the system (500 dm^3), which allows the boiler to work with a nominal capacity most of the time.

*Figure 43 **Heating source** in the building*

The actually installed boiler will be exchanged in the upcoming season with a condensing gas boiler (Bosch model Condens 700 F). The new boiler has already been bought, and it is waiting for summer to be installed.

The insulation is in poor condition, many parts of pipes are lacking a thermal insulation, the boiler room is not heated, so heat loss through pipes is huge. According to [1] overall system efficiency equals 90%.

Figure 44 Insulated pipes

The heat distribution system in the school is new, all plate convectors are equipped with thermostats. Many of the convectors are covered with a huge wooden plate holes which is done for safety issues in order to not allow kids to get burn when the system is working. This however decreases the efficiency of radiant heating of plate heaters, and may be cause of decreased efficiency of distribution in the system.

Convectors are mostly located in the niche under the windows, following the Polish construction requirements. According to [1], the overall system efficiency equals 89%.

Figure 45 Water convectors with thermostatic valves

4.1.1. Sport hall

Water convectors in the sport hall are the same as in the rest of the building, including thermostats, and shield with holes. They are located along the external wall. Temperature regulation in the sport hall according to information gained during the audit is good and thermal comfort is well preserved. Convectors are located in the niche under the windows, following the Polish construction requirements.

The sport hall is also heated with two fans with heating coils located below the ceiling. They also provide fresh air for the users inside of volume 2x1250 m^3/h, as the room is designed for 50 people. Total air flow through the fan coil units is 2,500 m^3/h each. They are controlled according to thermostat setpoint in the sport hall. A variable speed drive allows fan to vary flow volume when needed. There is also a mixing unit located on the ceiling of the sport hall and exhaust fan on the external wall near the ceiling. Water heating coil in each fan-coil unit has heating capacity of 20 kW.

Figure 46 Thermal control devices in the sport hall

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, with a total efficiency of 0.90. The pipes are insulated and the insulation condition is good. There is a circulation pump installed in the system and it works constantly. There is less than 100 sinks or showers in the building, so seasonal efficiency of domestic hot water distribution equals 60%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in the sport hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

Most of the building is ventilated naturally, with several fans exhausting air from “dirty” zones like toilets. The only exceptions are: sport hall, three classrooms with adjacent corridors and facilities which are located in the newest part of the building, close to sport hall and canteen’s kitchen, which have mechanical ventilation with dedicated air handling units.

The building is equipped with 3 ventilation systems, marked as:

- NWK – air handling unit for the kitchen and its facilities,
- R1 and R2 – air handling units with heat recovery supplying fresh air for 3 classrooms,
- G1 and G2 – air handling units for the sport hall,

Also there are several small fans exhausting air from toilets.

4.3.1. Sport hall

The ventilation in the sport hall is handled by two fan-foil units (named G1 and G2) working on fresh air with possible recirculation. The volume of fresh air on each fan equals 1,250 m^3/h which gives in total 2,500 m^3/h per unit. The maximum flow through units is 2500 m^3/h each, which means that 1250 m^3/h is fresh air and another 1250 m^3/h is recirculated air. Air in the units is filtrated and heated in the water heating coil of capacity of 20 kW. Units are controlled according to a thermostat setpoint in the sport hall. The variable speed drive allows fan to vary flow volume when needed. There is also a mixing unit located on the ceiling of the sport hall and an exhaust fan on the external wall near the ceiling.

Electric power of fans engines is 240 W in each fan coil unit. Power of extract fan mounted on the wall is 283 W. The system is controlled by a computer and is used only when needed.

Figure 47 HVAC installation in the sport hall

4.4. Cooling system

The only cooling system in the building is located in two classrooms of southern exposition. One is a computer class room and another one is located in the standard class room. The air conditioning system is supplied by two external units of around 5 kW cooling capacity. According to information gained during the interview, cooling units are used only when needed, during hot days. Temperature setpoint is set by the teacher controlling the unit at the time.

4.4.1. Sport hall

There is no cooling system in the sport halls.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz.

The most of the electricity consumption is spent on lighting in the building, as well as fir HVAC systems. Another devices with excess energy consumption are located in the balloon-covered football field. There are installed there 4 electric heaters, lighting and fans of a total electric power around 8 kW.

4.5.1. Sport hall

The sport hall does not have any dedicated electric system. It is equipped with lighting 16x3x36W (fluorescent bulbs) and 230 V sockets. HVAC devices supplying air to the sport hall are located on the walls and ceiling inside of the hall.

Table 28 Electric power in the sport hall

	Power [W]	Quantity	Total power [W]	Total power (including ballast in lighting) [W]
HVAC	7,280	1		7,280.0
Lighting	36	48	1 728.0	1,900.8
TOTAL				9,180.8

4.6. Building envelope

The building has been renovated recently (2017). The building external walls were insulated with 15 cm of graphite polystyrene with thermal conduction parameter of λ<=0.032 W/(m*K), the flat roof was insulated with 25 cm of standard polystyrene λ<=0.038 W/(m*K). The new mechanical ventilation has been applied in the part of the building that was added. New 3-glazed windows were mounted, of the declared heat transfer coefficient of 1.0 W/(m^2K). Information on external partitions are presented in the table below.

Table 29 Heat parameters of external partitions in the building

Partition	Heat transfer coefficient [W/m^2K]	Resistance [m^2K/W]
External walls	0.23	4.35
Flat roof	0.18	5.56
Ground floor	0.28	3.58
Flor above basement	1.18	0.85
Windows	1.00	1.00

4.6.1. Sport hall

External partitions of the sport hall are identical as in the whole building.

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

In the whole building there is an energy efficient fluorescent lighting installed. Most of the fittings are 2x58W, some are 2x36W. There are a few individual CLFs in the small rooms (sanitary etc.) The sport hall is equipped with 3x36W fittings. Corridors lighting works usually from Monday to Friday between 7.00 – 16.30 in case it is needed, as in the middle part of the hall there are windows which allows natural light to come into the corridor. There are individual switches at each floor and the main switch used for turning off the light in the whole building at once, which is used during unoccupied periods.

4.8.1. Sport hall

The sport hall is equipped with 16 3x36W fluorescent bulbs fittings. The lighting is switched on manually by the users when needed. Power installed in lighting per square meter is around 12.8 W/m^2 including fluorescent fittings ballast.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal acts cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[2] Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. z 2015 r. poz. 1422 i z 2017 r. poz. 2285)

6. Attachments

Table 30 Non-renewable primary energy indicators

Parameter	Gas	Electricity
Non-renewable primary energy indicator (wi)	1.1	3.00

Figure 48 South-western side of the building

Figure 49 North-eastern side of the building

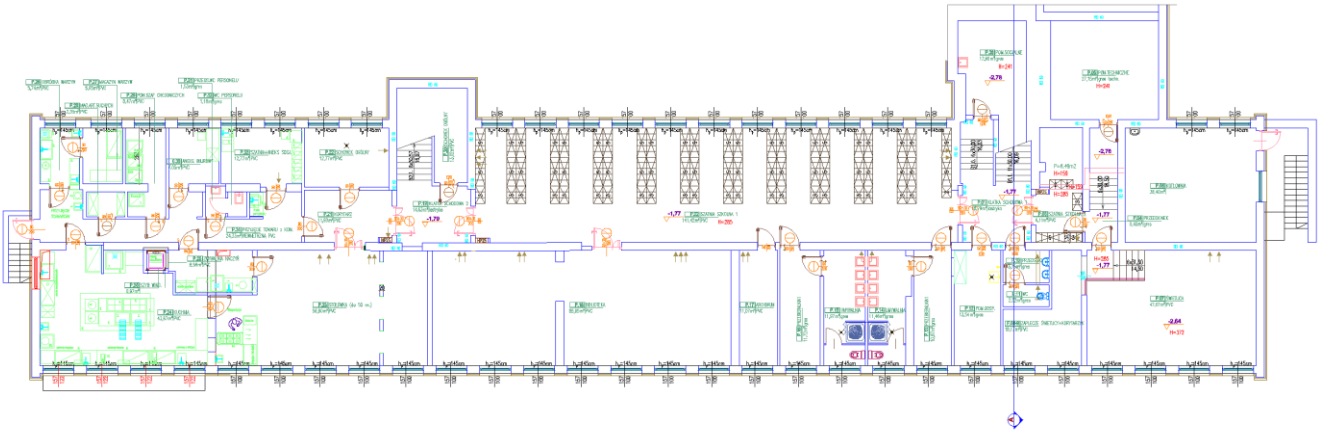

Figure 50 Basement floor plan

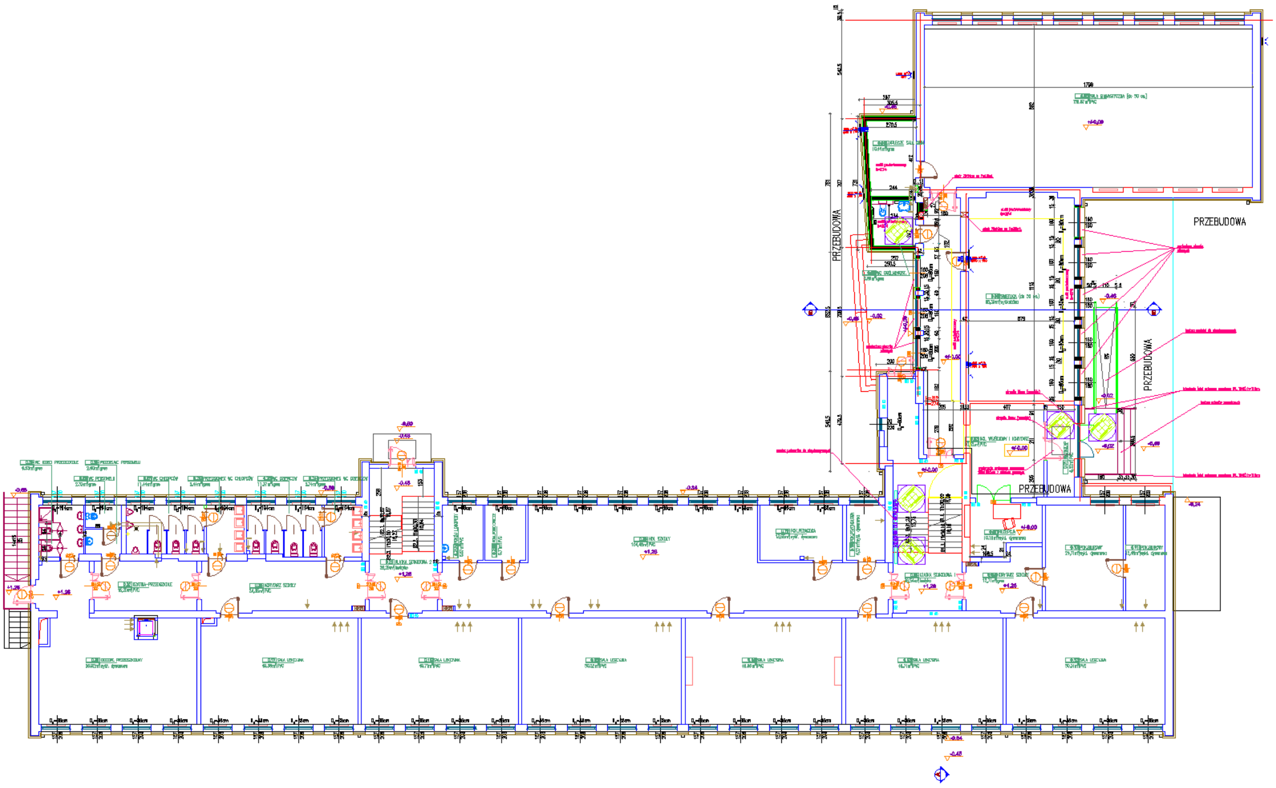

Figure 51 Ground floor plan

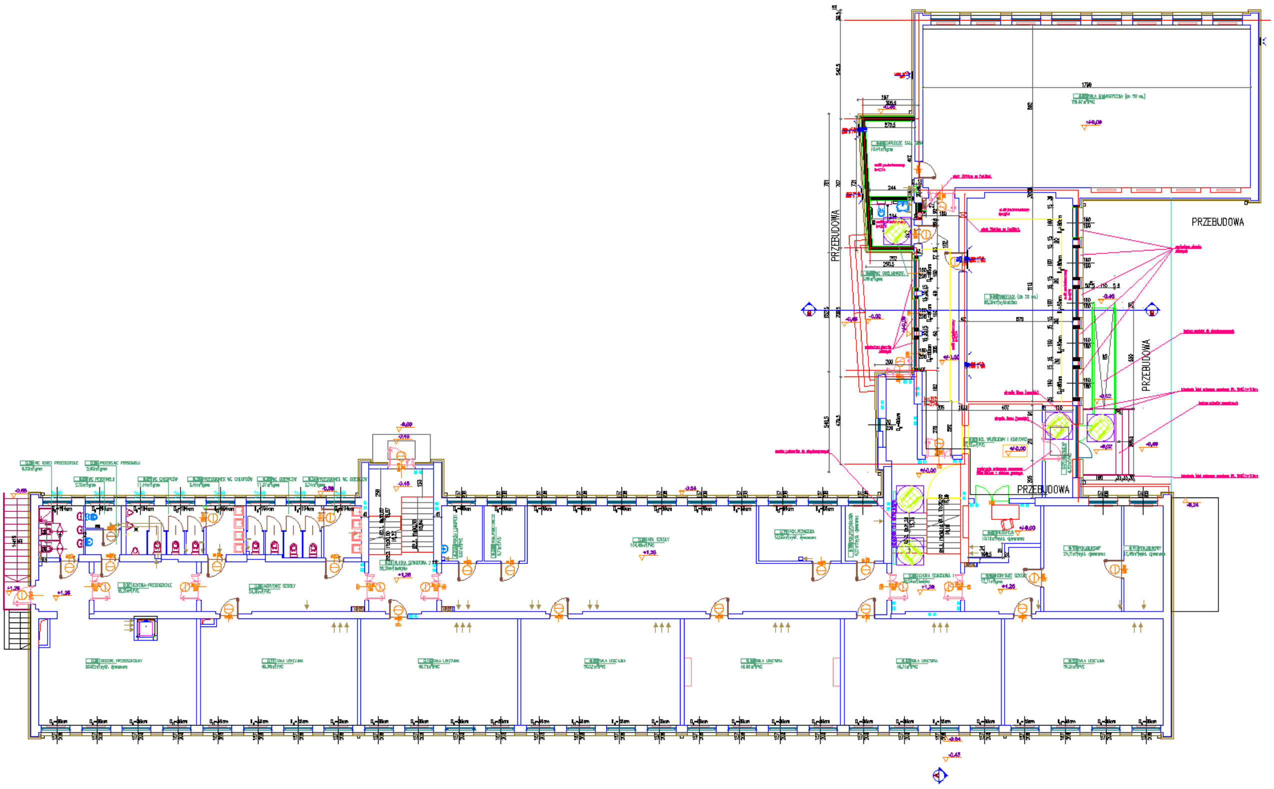

Figure 52 First floor plan

VI. Building #6 SP 28 (ul. Gościeradowska 18/20, 93-535 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built in 1964. The building envelope is well preserved, however it has not been modernized since original state, so the heat parameters of external partitions are poor. Windows were changed around 2000-2002 and have an acceptable heat transfer coefficient, however some of them are leaky. In 1994 the heat source in the building has been modernized and exchanged with insulated district heating heat exchanger. Pipes with heating factor are insulated since then. The insulation condition is satisfactory. Old iron ribbed convectors in classrooms and corridors have not been exchanged since original state and they lack thermostats. Only sport hall heating units have been changed to plate convectors and are now equipped with thermostats. The building does not have any HVAC systems except a dedicated mechanical ventilation in the kitchen and cooling unit in the computer server room. The whole building is equipped with traditional T8 fluorescent bulbs manually controlled by users. The building does not have any BMS system.

The general overview of the building allowed for giving a poor opinion about energy efficiency of the building. The measured final energy indicator for heating is 147.53 kWh/m^{2}a, which is high.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 28 in Warsaw, located in the eastern side of the city. The school occupies a middle-sized building with 3 floors, partially with basement. Its total area is 3,521.2 m^2, while the area of rooms dedicated strictly for the educational purposes is 1,976.2 m^2. There are 28 classrooms, one sport hall of 288 m^2 area and one canteen in the building. The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 400 children. Children attending the school are around 6 – 14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control and window closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit - scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor is Ms. Wiesława Marciniak, who is an economic manager in the school, taking care of energy and other media management in the building. Ms. Wiesława Marciniak mentioned that the building has some overheating issues. Due to lack of thermostats the only way for controlling temperature in the classrooms is ventilation by windows opening. This causes large heat loss. The same problem concerns the canteen. At the same time the temperature in the sport hall is too low, mostly due to leaky windows.

The first visit in the school was performed on 11.01.2019 and included technical documentation analysis and digitalization, connected with the whole building inspection (classrooms, sport hall and canteen, technical rooms) and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and evaluation and domestic hot water systems evaluation. The building is equipped also with one air conditioning unit of 4.4 kW cooling power, located in the server room near the computer classrooms.

The on-site visit of the building included also the lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms, sport hall, canteen but also entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was built in 1964, while documentation stands for 1962. The original purpose of the building was partially the school with 16 classrooms and partially the medical clinic. Later the whole building has been adapted for the primary school. According to project documentations, materials and insulation parameters were selected according to the Polish law and were compliant with the requirements at the time (year 1962)[2]. External walls are made with aerated brick, internal walls are made with full brick. A flat roof is a type of DMS traditional construction with insulation. Some of double-glazed PCV windows have been exchanged between 2000 and 2001. Originally the building was equipped with a gas boiler, however in

[2] *„Rozporządzenie Przewodniczącego Komitetu Budownictwa, Urbanistyki i Architektury z dn. 21 lipca 1961 r. w sprawie warunków technicznych, jakim powinny odpowiadać obiekty budowlane budownictwa powszechnego (Dz. U. nr 38, poz 196)".*

1994 it was replaced with a heat exchanger supplying heat from the district heating system in Warsaw. The building is heated with traditional plate heaters. The whole building is ventilated naturally, except the canteen kitchen which has a mechanical ventilation. The only cooled room is s server room. The lighting installed in in the whole building is composed of T8 fluorescent bulbs.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards typically used in energy calculations in Poland was used, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 31 Standards used during energy audit

	Applied version	**English version**
1	Norma PN-EN 16247-1 "Audity Energetyczne: Wymagania Ogólne"	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 "Audity Energetyczne Część 2: Budynki"	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 "Audity Energetyczne Część 3: Procesy"	EN 16247-3"Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego."	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń."	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania."	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne."	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia."	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania"	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system"	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system

12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 32 Regulations used during energy audit

	Applied version	**English version**
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5^{th} October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) - raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) - raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 28 in Warsaw started with the on-site visit that took place on 11th of January 2019. It began with an interview with an economic manager of the school, Ms. Wiesława Marciniak. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis. Ms. Wiesława Marciniak pointed out a few problems. The most important is the overheating observed in the whole building, which is caused mainly by lack of thermostats on the old plate heaters. Another problem was a temporary heating problem with plate heaters on the top floor corridor, which were probably aerated. The technical staff from the City Hall has been already alarmed about the issue. The last problem mentioned by the manager is a highly ventilated and too cold sport hall.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules. Cooling system in the building is limited to one cooling unit dedicated for the computer server room working 24h/7. The building is not equipped with the mechanical ventilation except kitchen with dedicated exhaust ventilation. In the whole building the applied lighting is composed of fluorescent T8 light bulbs with traditional manual control. Corridors are also connected to the main switch allowing for turning off all of the lightings at once. Most of the data concerning HVAC and electric systems could be gained during the walk-through audit. Data about the envelope of the building was gained from the technical documentation of the building that was available during the on-site visit.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator equal wi=3.0 for electricity, and applying the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 28 w Warszawie
Street, number, city and postcode	Gościeradowska 18/20, 02-535 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	52,27 N
Latitude [DD.dd°]	21,05 E

Height above the see level [m]	*83 m.n.p.m.*
Year of construction	*1964*
Useful area - the whole building [m²]	*3 521.2 m²*
Useful area - audited part [m²]	*Classrooms: 1,224.58 m²* *Sport hall: 288 m²* *Canteen: 113.25 m² (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 9,200 kWh/month, with total yearly consumption of 110,284 kWh in 2017. The maximum ordered power is 60 kW on one electric connection.

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2017 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water.

Table 33 Heat consumption in 2017

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	251.06	69.74	-3.7
II	363.80	101.06	-0.8
III	217.80	60.50	6.1
IV	209.00	58.06	7.7
V	158.50	44.03	14.6
VI	23.30	6.47	18.5
VII	16.70	4.64	18.9
VIII	14.40	4.00	19.7
IX	19.80	5.50	14.0
X	125.00	34.72	10.0
XI	227.60	63.22	4.9
XII	243.20	67.56	2.5
TOTAL	**1,870.16**	**519.49**	

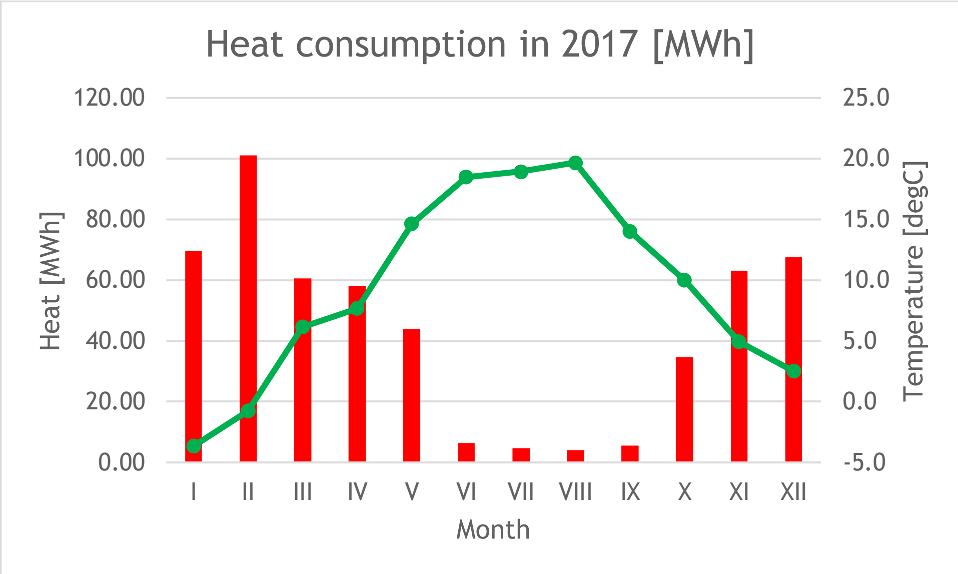

Figure 53 Heat consumption in 2017

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied.

Table 34 Energy consumption and emissions

Parameter	**Heat**	**Electricity**	**Total**
Final energy consumption [kWh/a]	519,488.64	110,284.00	629,772.64
Final energy consumption indicator [kWh/m^{2}a]	147.53	31.32	178.85
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	451,955.12	330,852.00	782,807.12
Primary energy consumption indicator [kWh/m^{2}a]	128.35	93.96	128.45
CO2 emissions [tCO_2/a]	172.62	79.18	251.80

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between around 7.30 AM - 4.30 PM Monday-Friday. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

The heating, cooling (computer server room) and lighting systems work with no pre-defined breaks. Lighting in the corridors is usually switched on by the central switch in the morning and turned off the same way after 4.30 PM. Lighting is the classrooms, sport hall and canteen is used only when needed.

4. Existing state of building energy systems

The building was built in 1964, while a project of architectural design stands for 1962. The original purpose of the building was partially a school with 16 classrooms and partially a medical clinic. Later the whole building has been adapted for the primary school. The building has been partially modernized in 1994 when the original boiler has been exchanged with a district heating heat exchanger. Around 2000 – 2002 the windows in the building have been exchanged as well.

4.1. Heating system

The heating source in the building is a traditional heat exchanger "JAD" type with weather control. The designed heating load for the building is 376 kW. The central heating installation works on parameters 85/60°. Water is the heating factor in the installation. The heat exchanger station powered by district heating is insulated, so according to [1] its efficiency equals 99%.

Figure 54 ***Heating source*** *in the building*

The heating source and some heating systems have been changed during modernization in 1994. Currently the heat exchanger cooperates with the insulated distribution system, supplying the central heating and domestic hot water systems. The insulation is maintained in the good condition. Basement where the heating source is located is also a heated space. According to [1] the overall system efficiency equals 96%.

Figure 55 Insulated pipes

Heaters in some zones has been exchanged during modernization in 1994. They are mostly located in the niche under the windows, following the Polish construction requirements. In the corridors there are old traditional iron ribbed radiators without thermostats, which causes overheating and eventually results in heat waste due to ventilation by frequent windows openings. According to [1] the overall system efficiency equals 77%.

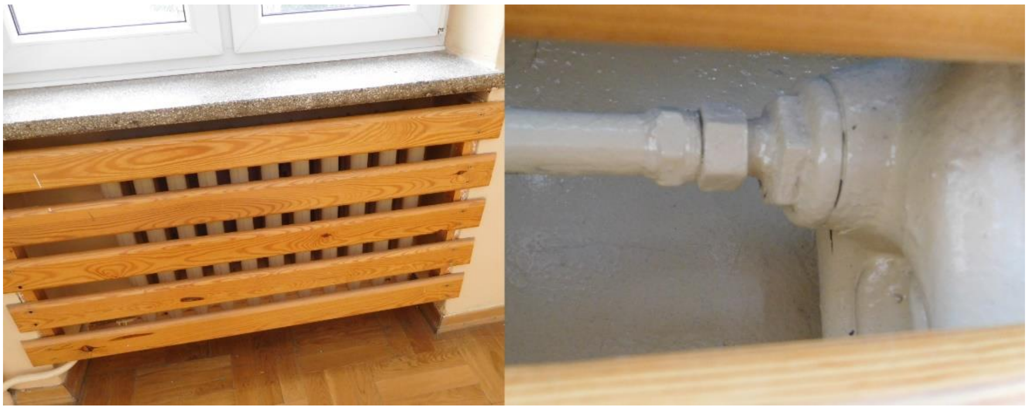

Figure 56 Iron ribbed convectors in corridors

The heating system does not have any dedicated accumulation tank. The total volume of water in the system is around 6,915 liters.

4.1.1. Sport hall

Heaters in the sport hall have been replaced in 1994 during the building modernisation. They are equipped with thermostats. Radiators in the sport hall are located on both sides of the hall. During the interview, the energy manager pointed out the problem with low temperatures in the sport hall during winter time, explaining it with air leakage through windows. Investigation of the radiators showed that thermostats were set to low temperature, which could be partially a problem of bad thermal comfort situation. Windows however showed high exploitation level and were not hermetic enough, so the problem with leaky windows was confirmed.

Figure 57 Plate heaters in the sport hall with thermostats

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, with total seasonal efficiency of 0.98. The pipes are insulated, and insulation condition is good. There is a circulation pump installed in the system and it works constantly. There is less than 100 sinks or showers in the building, so seasonal efficiency equals 60%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in the sport hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The whole building is ventilated naturally, except kitchen which is equipped with the mechanical exhaust ventilation. Natural ventilation is provided with brick ducts. Fresh air is supplied through air leakages in windows and through brick channels above radiators. Channels and chimneys are protected on the outside from weather conditions by plate rooftops made with steel. The only air-conditioned room in the building is the computer server room. The thermal comfort in other zones is kept maintained by window opening and room ventilating.

4.3.1. Sport hall

The sport hall is ventilated naturally by gravitation and infiltration of fresh air through windows. During warm periods of the year, windows are kept open for most of the time. There are ventilation extracts in the roof of the sport hall which are not controlled, so they are fully opened all the time. Because of intensive exploitation of windows, it turns out they are not as hermetic as they should be, consequently during winter it is often cold in the sport hall.

Figure 58 Sport hall ventilation

4.4. Cooling system

The only cooling system in the building is one unit dedicated for the computer server room. The air conditioner installed is Toshiba RAS-167SAV-E5 of 4.4 kW cooling capacity and COP of 2.82. The R410A refrigerant is used. The cooling system keeps temperature at 17°C 24/7.

4.4.1. Sport hall

There is no cooling system in the sport hall.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building. Other significant consumption is done by two pumps for DHW and central heating, as well as electric ovens in the kitchen. The highest power installed for one space is the computer server room and its cooling device.

4.5.1. Sport hall

Sport hall does not have any dedicated electric system. It is equipped with lighting and 230V sockets.

4.6. Building envelope

The building project has been prepared according to requirements as of 1960.

External walls are made with aerated brick with thickness 38 cm insulated with 3 cm of chipboard.

The flat roof is made with DMS technology prefabricated with steel reinforced concrete and aerated concrete slabs, insulated with 10cm of reed mat, covered with roofing paper.

The ground floor is made with 10 cm sand, 10 cm gravel based soil, roofing paper, 22 cm air gap, 3.2 cm frame finished with 1.5 cm wooden (oak) floor tiles.

The floor above basement is made with DMS technology prefabricated with steel reinforced concrete and aerated concrete slabs, insulated with 3 cm of reed mat, covered with terracotta.

The windows have been changed around 2000-2002. According to the on-site investigation, building is now equipped with double-glazed PCV framed windows with heat transfer coefficient equal 1.1 W/m^2K, except sport hall, where heat transfer coefficient equals 1.4 W/m^2K.

Information on external partitions are presented in the table below.

Table 35 Heat parameters of external partitions in the building.

Partition	Heat transfer coefficient [W/m²K]	Resistance [m²K/W]
External walls	0.95	1.05
Flat roof	0.50	2.00
Ground floor	0.92	1.09
Flor above basement	0.90	1.11
Windows	1.10	0.91
Windows in the sport hall	1.40	0.71

4.6.1. Sport hall

External partitions of the sport hall are identical as in the whole building. Windows for sport hall were made by P.S.T. model X 2000r. IMK-1.4.

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

The whole building is equipped with 2xT8 fittings with 2x36W fluorescent bulbs. There is a central switch for corridors that is used for turning on the light in the morning and turning it off in the evening. The corridors lighting works usually from Monday to Friday between 7.15 and 16.30. There are also individual switches at each floor, however according to the information given by energy manager during interview, they are not used.

4.8.1. Classrooms

Classrooms are equipped with 2xT8 fittings (with 2x36W fluorescent bulbs). The typical size class room (54m^2) is equipped with 15 fittings. Lighting in classrooms is divided into three zones (inner zone + windows zone + front zone). The lighting is switched on manually by the users when needed.
Power installed in lighting per square meter is around 22 W/m^2 including fluorescent fittings ballast.

4.8.2. Sport hall

The sport hall is equipped with 48 4xT8 fittings (with 4x36W fluorescent bulbs). Lighting in the sport hall is divided into 8 zones allowing for using only part of the fittings if it is sufficient. The lighting is switched on manually by the users when needed.
Power installed in lighting per square meter is around 26 W/m^2 including fluorescent fittings ballast.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal acts cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 36 Non-renewable primary energy indicators

Parameter	Heat	Electricity
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 59 South-eastern side of the building

Figure 60 North-western side of the building

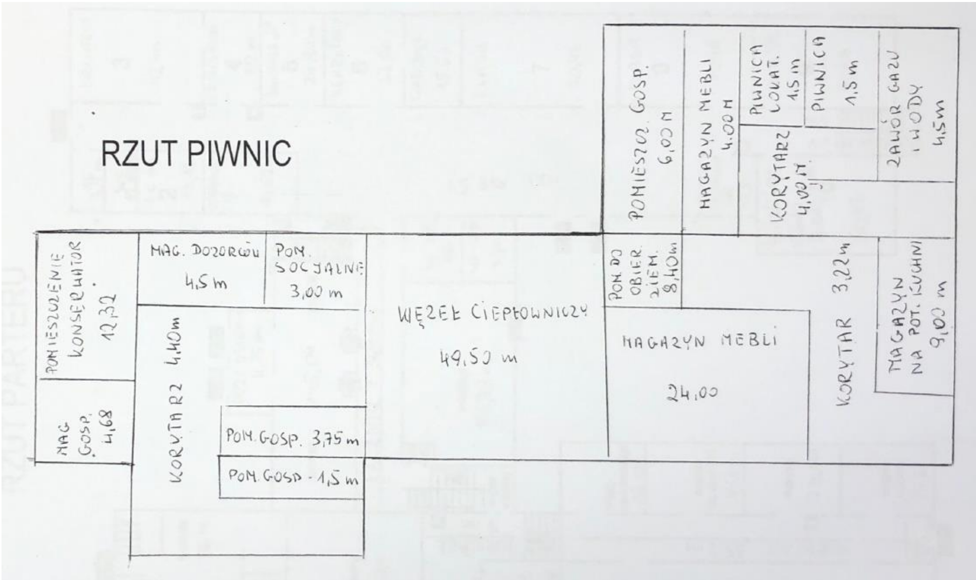

Figure 61 Basement floor plan

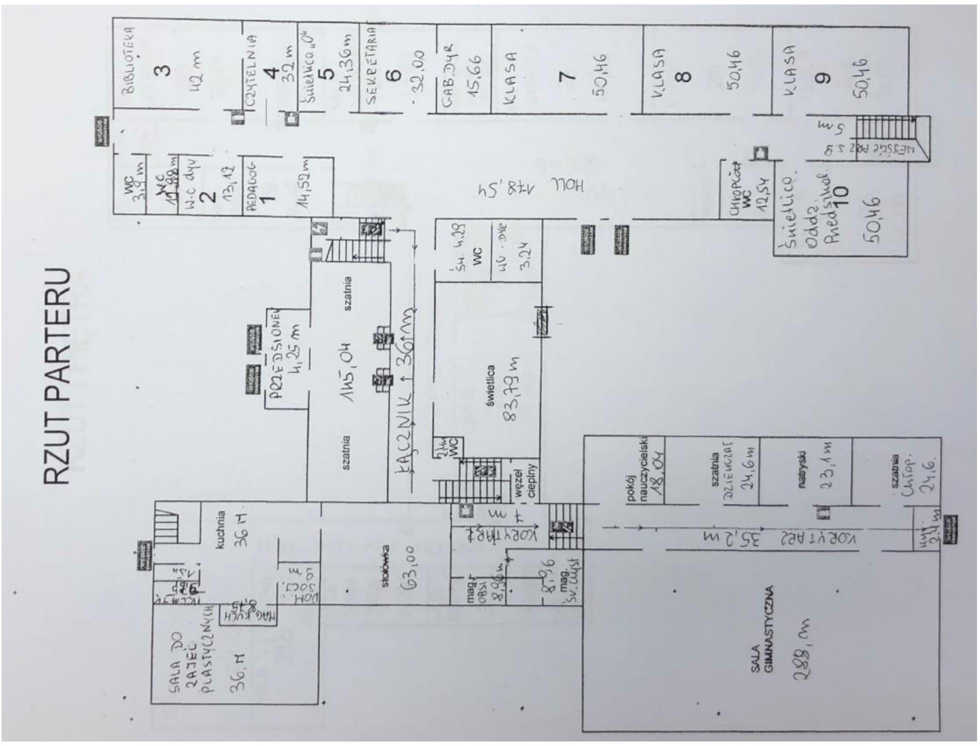

Figure 62 Ground floor plan

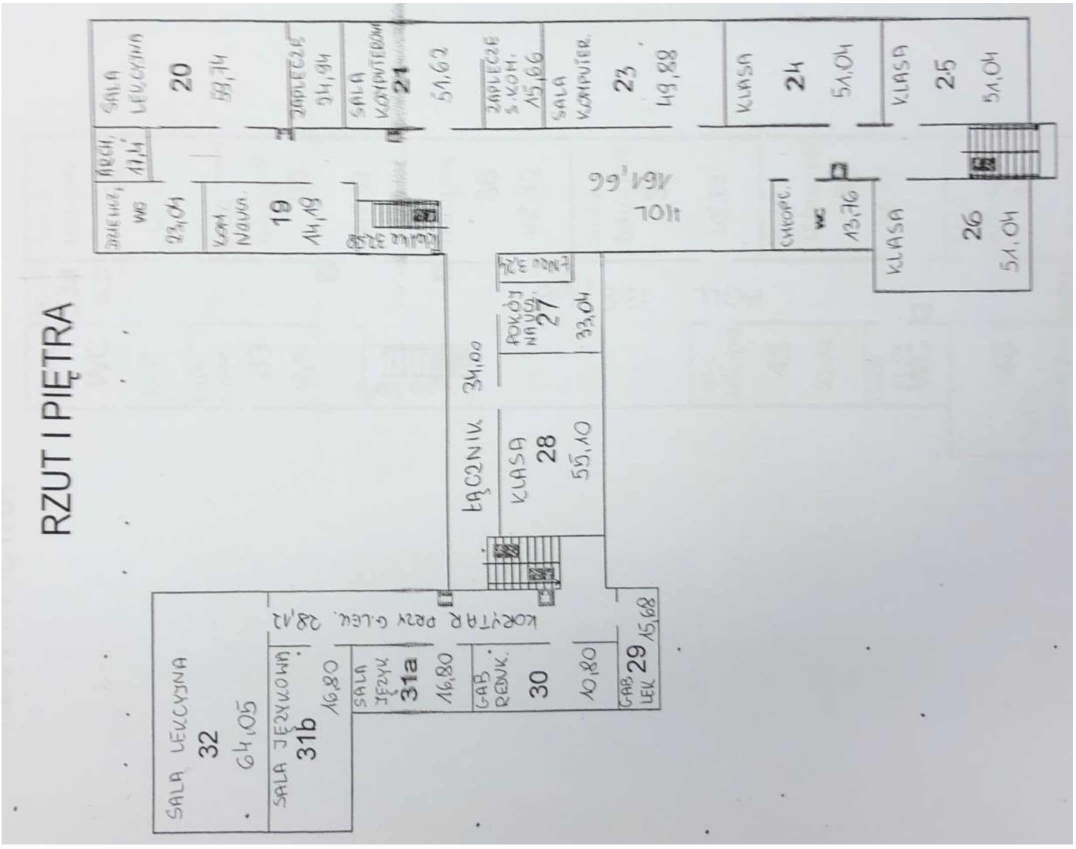

Figure 63 First floor plan

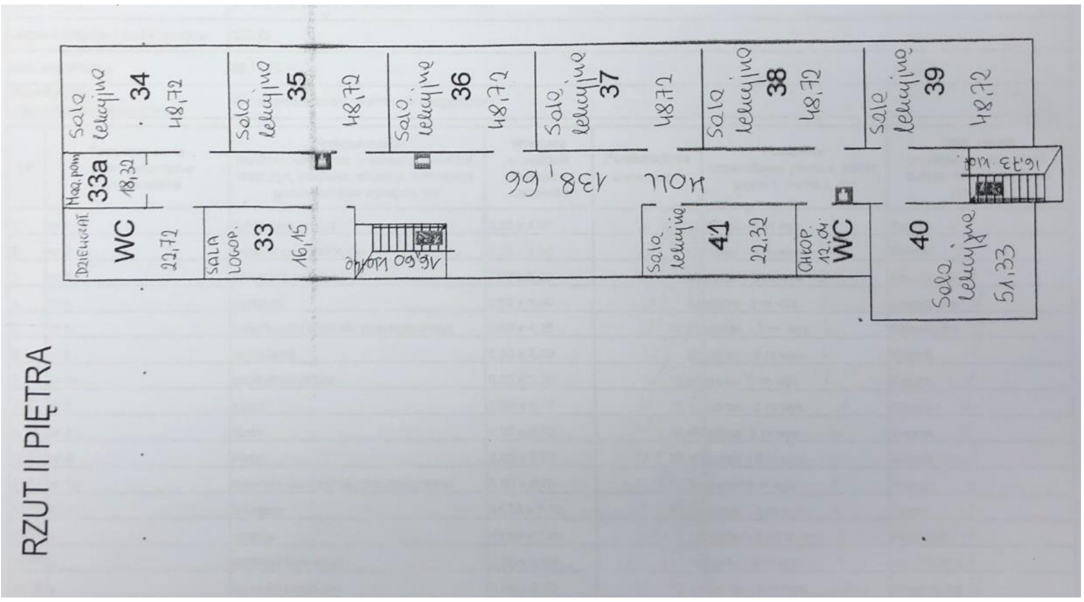

Figure 64 Second floor plan

VII. Building #7 SP 227 (ul. Suwalska 29, 03-252 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building was built in 1970. Since then, there were a few modernizations of the building envelope and systems: a modernization of a district heating heat exchanger in 1980, a modernization of windows and walls in a sport hall in 1995 (walls were insulated), exchange of windows in the rest of the building in 2000.. In 2005 there was a modernization of roof in the sport hall and it was thermally insulated. Heat parameters of external partitions are poor. New PVC windows are leaky, and it is often cold in the building. The installation of the central heating system is old, and it often gets aerated, so the city hall technical crew must intervene even a few times during the heating season. The building is heated with the district heating, the system is weather controlled and the heating schedules are applied. Old iron ribbed convectors in classrooms and corridors have never been exchanged and they lack thermostats. The building does not have any HVAC systems except dedicated mechanical ventilation in the kitchen and one cooling unit in the computer room. The whole building is equipped with traditional fluorescent bulbs manually controlled by users. The building does not have any BMS system.

The general overview of the building allowed for giving a poor opinion about energy efficiency of the building. The measured final energy indicator for heating is 172.77 kWh/m2a, which is high.

In 2013 there was a new investment near the school building. The pre-school barrack was connected to the main building, however it is not treated as typical building. It does not consume any heat energy, it is fully powered by electricity, and thus the heating parameter concerns only the main school building.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 277 in Warsaw, located in the north-eastern side of the city. The school occupies a middle-sized building with 4 floors including a basement and a ground floor, with total area of 3,753 m^2, while the area of rooms dedicated strictly for the educational purposes is about 1,640 m^2. There are 28 classrooms, one sport hall of 191 m^2 area and one canteen in the building. The canteen kitchen is rented, so it has a private owner. The school is able to provide conditions for educational purposes for around 800 children. Children attending the school are around 6 – 14 years old. The energy management and services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control and window closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit – scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor is Ms. Teresa Gołdowska, who is an economic manager in the school, taking care of energy and other media management in the building. Ms. Teresa Gołdowska mentioned that the building has some heating issues. It is often too cold in the building. The probable reason of this is an old central heating installation that gets aerated very often. The technical staff from city hall comes for the service of heating installation even few times during one heating season. Furthermore, windows are very leaky and cold air gets through draughty windows lowering the thermal comfort in the classrooms. It often happens that water flows through windows during heavy rains.

The first visit in the school was performed on 24.01.2019 and included technical documentation analysis and digitalization, connected with the whole building inspection (classrooms, sport hall, canteen, and technical rooms) and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), ventilation system investigation and evaluation and domestic hot water systems evaluation. The building is equipped with one air conditioning unit located in the computer classroom.

The on-site visit of the building included also lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms, sport hall, canteen, entrance hall, corridors, and external lighting.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor's experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building was built in 1970, according to available documentation. It has been slightly modernized since that time. There is no architecture design project neither layouts, thus approximate measurements were performed and basing on fire escape plans.. It is assumed that materials and insulation parameters were selected according to the Polish law and were compliant with the requirements at the time (year 1962)[3]. There are double-glazed PCV-framed windows installed, with the declared heat transfer coefficient of U=1.1

[3] Rozporządzenie Przewodniczącego Komitetu Budownictwa, Urbanistyki i Architektury z dn. 21 lipca 1961 r. w sprawie warunków technicznych, jakim powinny odpowiadać obiekty budowlane budownictwa powszechnego (Dz. U. nr 38, poz 196)

W/m²K. The building is heated with the heat exchanger supplied with heat by the district heating grid. The building heat distribution system is insulated and equipped with iron ribbed heaters. The whole building is ventilated with natural ventilation except canteen's kitchen which has a mechanical ventilation. The only cooled room is one computer classroom. The lighting is composed of 2x36W fittings with mainly fluorescent bulbs.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 37 Standards used during energy audit

	Applied version	English version
1	Norma PN-EN 16247-1 "Audity Energetyczne: Wymagania Ogólne"	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 "Audity Energetyczne Część 2: Budynki"	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 "Audity Energetyczne Część 3: Procesy"	EN 16247-3"Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego."	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń."	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania."	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne."	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia."	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania"	ISO 50001:2018 Energy management systems -- Requirements with guidance for use
11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system"	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system

12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 38 Regulations used during energy audit

	Applied version	**English version**
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) – raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) – raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"
8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 277 in Warsaw started with on-site visit that took place on 24th of January 2019. It began with an interview with an economic manager of the school, Ms. Teresa Gołdowska. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis. Ms. Teresa Gołdowska pointed out a few problems. First of all it is usually too cold in the whole building, which is caused mainly by leaky windows and faulty heating installation that often gets aerated and needs to be serviced. There are no thermostats on the convectors, thus the only control of the thermal comfort in the rooms is possible by opening the windows, which causes heat loss.

After the interview there was a walk-through audit that allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules. School works usually from Monday to Friday from 7 AM to 5 PM. The sport hall is used till 9 PM. The school is empty during weekends. The building is not equipped with mechanical ventilation except the kitchen with a dedicated exhaust ventilation, used only when needed (exhaust hoods over ovens). In the whole building it is fluorescent light bulbs with traditional manual control lighting applied.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator which equals wi=3.0 for electricity, and applying the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 277 w Warszawie
Street, number, city and postcode	Suwalska 29, 03-252 Warsaw
Province/Region	Mazovia
Country	Poland
Longitude [DD.dd°]	*52.30*
Latitude [DD.dd°]	21.04
Height above the see level [m]	*83 m*
Year of construction	*1970*
Useful area - the whole building [m^2]	*3 753 m^2*

Useful area - audited part [m²]	*Classrooms: 1,638 m²* *Sport hall: 191 m²* *Canteen: 245 m² (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 18,400 kWh/month, with total yearly consumption of 220,599 kWh in 2017. This however includes energy consumption of barracks with pre-school. Because energy consumption of these units is not separated from each other, it is impossible to separate the energy used strictly by the building of SP 277.

The maximum ordered power is 160 kW on three electric connection: 140 kW, 14 kW and 6 kW, however it is not known which connection serves which installation.

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2017 is known only as total heat delivered by heat supplier (PGNiG TERMIKA S.A.).

Heat consumption in 2017: 2,334.2 GJ (648.39 MWh). Total heat capacity ordered is 285 kW that is 220 kW for central heating and 65 kW for domestic hot water.

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO_2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied. The electricity consumption includes energy delivered to pre-school barracks.

Table 39 Energy consumption and emissions

Parameter	**Heat**	**Electricity**	**Total**
Final energy consumption [kWh/a]	648,388.89	220,599.00	868,987.89
Final energy consumption indicator [kWh/m²a]	172.77	58.78	231.54
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [MWh/a]	564,098.33	661,797.00	1,225,895.33
Primary energy consumption indicator [kWh/m2a]	150.31	176.34	326.64
CO_2 emissions [tCO_2/a]	215.45	158.39	373.84

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between around 7.00 AM – 5.00 PM Monday-Friday. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August. This school however organizes often summer school, when for around 2-3 weeks there are about 150 children attending the school.

Lighting is used when needed only, and the same applies for the cooling system in the computer room.

4. Existing state of building energy systems

4.1. Heating system

The heating source in the building is a traditional heat exchanger "JAD" type with weather control. Heat capacity ordered for the building is 285 kW. The central heating installation works on parameters 85/60°. Water is the heating factor in the installation. The heat exchanger station powered by the district heating is insulated, so according to [1] its efficiency equals 99%.

*Figure 65 **Heating source** in the building*

The heating source has been modernized in 1980. Currently the heat exchanger cooperates with insulated distribution system, covering central heating and domestic hot water for the building. The insulation is maintained in good condition. A basement where the heating source is located is also a heated space. According to [1], the system efficiency equals 96%.

Figure 66 Insulated pipes

Heaters are mostly located in the niche under windows, following the Polish construction requirements. There are old traditional iron ribbed radiators without thermostats in the building. According to [1] the system efficiency equals 77%.

Figure 67 Iron ribbed convectors in corridors

4.1.1. Sport hall

There are old traditional iron ribbed radiators without thermostats in the sport hall.

Figure 68 Iron ribbed convectors in the sport hall

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, with total seasonal efficiency of 0.98. The pipes are insulated and insulation condition is good. In the system there is a circulation pump installed and it works constantly. There are less than 100 sinks or showers in the building, so seasonal efficiency equals 60%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in the sport hall itself, however the changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The whole building is ventilated naturally, except the kitchen which is equipped with mechanical exhaust ventilation. Natural ventilation is provided with brick ducts. Fresh air is supplied through air leakages in windows and through brick channels. The only air-conditioned room in the building is a computer classroom. Thermal comfort in other zones is maintained by window opening and room ventilating.

4.3.1. Sport hall

The sport hall is ventilated naturally by gravitation and infiltration of fresh air through windows. There are ventilation extracts in the ceiling of the sport hall which are not controlled, and they are fully open all the time.

Figure 69 Sport hall ventilation

4.4. Cooling system

The only cooling system in the building is the one unit dedicated for the computer classroom. Its cooling capacity equals 4 kW.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz. There is no individual electric system in the building. Most electric power consumption is spent on lighting in the building. There are two pumps for DHW and the central heating system. The highest power installed for one space is the computer server room and its cooling device. Another device with high power consumption is an electric oven, located in the kitchen and connected to a 400V socket.

4.6. Building envelope

The building project has been prepared according to requirements as of 1970. There was no technical documentation concerning architecture design of the building available. The typical construction for that time is that external walls are made with brick with thickness around 35-40 cm insulated with chipboard. Flat roofs were usually made with DMS technology prefabricated with steel reinforced concrete and aerated concrete slabs, insulated with 10 cm of reed mat, covered with roofing paper. Windows have been exchanged in 2000. According to the on-site investigation, the building is now equipped with double-glazed PCV-framed windows and the heat transfer coefficient equals 1.1 W/m^{2}K.

In 2005 the roof of the sport hall has been modernized. During the modernization it was thermally insulated with 10 cm of polystyrene.

Information on external partitions are presented in the table below.

Table 40 Heat parameters of external partitions in the building.

Partition	**Heat transfer coefficient [W/m^{2}K]**	**Resistance [m^{2}K/W]**
External walls	0.95	1.05
Flat roof	0.50	2.00
Roof in the sport hall	0.33	3.00
Windows	1.10	0.91

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

The whole building is equipped with 2xT8 fittings with 2x36W fluorescent bulbs. Corridors lighting works usually from Monday to Friday between 7.00 and 17.00. There are individual switches at each floor.

4.8.1. Sport hall

The sport hall is equipped with 48x2x36W fluorescent fittings. The lighting is switched on manually by the users when needed.
The power installed in lighting per square meter is around 17 W/m^2 including fluorescent fittings ballast.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal acts cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

6. Attachments

Table 41 Non-renewable primary energy indicators

Parameter	Heat	Electricity
Non-renewable primary energy indicator (wi)	0.87	3.00

Figure 70 South-east side of the building

Figure 71 South-western side of the building

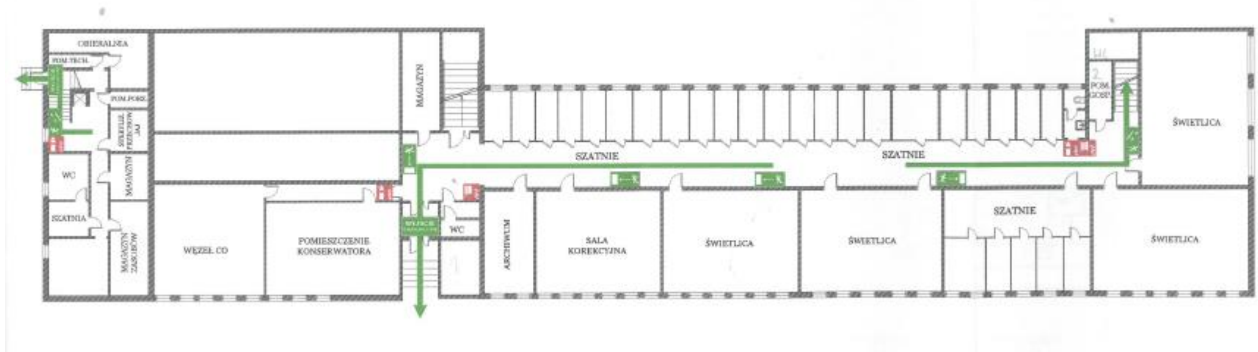

Figure 72 Basement floor plan

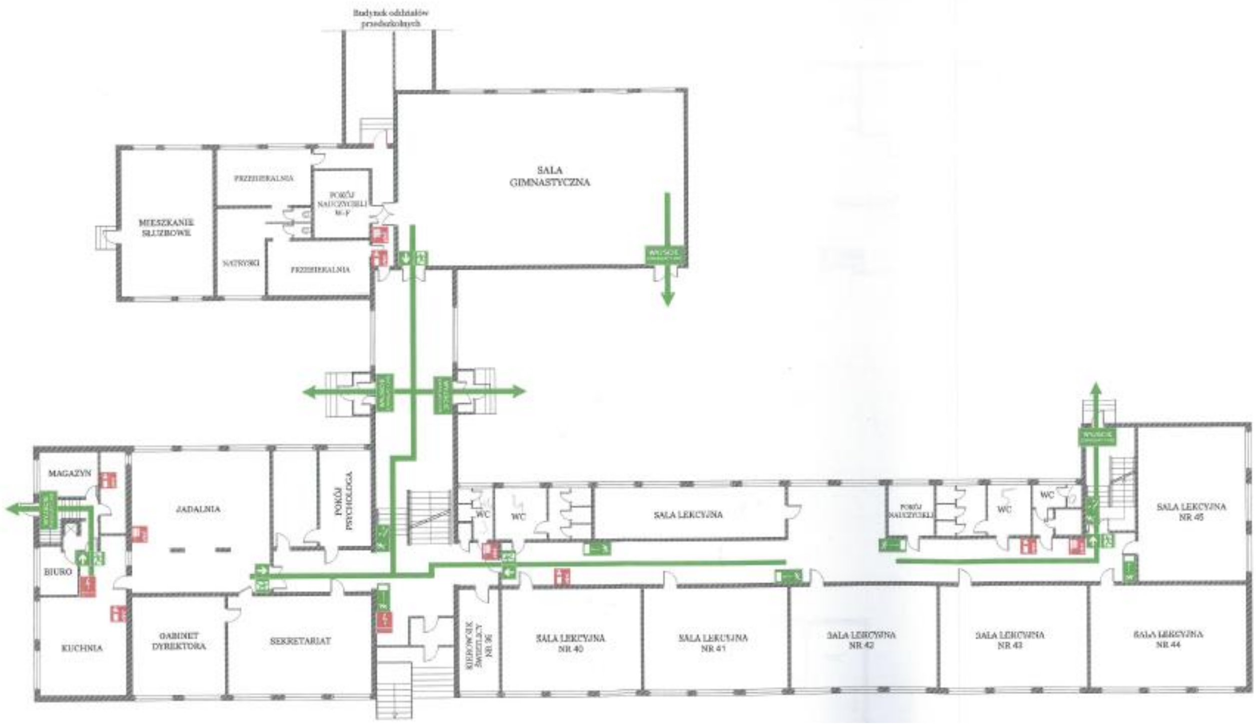

Figure 73 Ground floor plan

Figure 74 First floor plan

Figure 75 Second floor plan

VIII. Building #8 SP 26 (ul. Miedziana 8, 00-814 Warszawa)

1. Summary of the energy performance of the building and suggested improvement options

1.1. Summary of the existing state of the building

The building consists of two parts. The first one was built around 1890, and was later modernized around 1933, however the precise history of the building is not well known. During the II World War a huge part of the buildings was damaged and rebuild in the next few years. Around 1960 a new part of the building has been added and finally between 2002 and 2007 the whole building has been renovated and the newest part with a new sport hall has been added. A heat distribution system has been modernized and new water convectors with thermostats were installed. It is supposed that the building was refurbished according to construction requirements as of 1960. Therefore, U-value of external partitions U-value equals 1.35 W/(m^2K) for external walls and 0.87 W/(m^2K) for a flat roof. Windows has been exchanged to new around 2002-2004 with the declared U-value of 1.1 W/(m^2K). There is only a natural ventilation in the building, except a part of building with the sport hall and changing rooms, where air handling units with heat recovery are installed. Furthermore, a canteen has its own air handling unit. The only room with air conditioning is a computer classroom. The most of the building is equipped with T8 36W fluorescent bulbs controlled manually. The building does not have any BMS system.

The general overview of the building allowed for giving a good opinion about energy efficiency of the building, concerning its age and a fact that only a moderate amount of insulation can be applied for thermal modernization of the external partitions. Nevertheless, there are still some measures that can be taken into account to decrease the energy consumption. The measured final energy indicator for heating is 114.27 kWh/m^2a, which is quite good for this kind of building.

2. Introduction

2.1. General information of audited organisation

The audited building hosts the Primary School no. 26 in Warsaw, located in the city center. The school occupies an old building and a newly added part that consists of sport hall and its facilities. The building consists of 4 floors including a basement, with total useful area of 5,593.53 m^2. There are 22 classrooms, 4 sport halls (3 small ~100 m^2 and 1 large ~400 m^2) and a canteen located in the basement. There are around 400 children attending the school. The canteen kitchen is rented, so it has a private owner who takes care of energy consumption in the area. Children attending the school are around 6 – 14 years old. The energy management services are provided by the City technical staff on request from the School authorities in case of emergency situations. The energy management on the daily basis is limited to bill controls by the economic management staff, and feasible energy saving measures that could be applied by the schools technical staff are limited to lighting control and window closing. School authorities cannot decide on the budget and investment issues in the building. This is the role of City Hall (The District Finance Bureau of Education).

2.2. Energy auditor(s)

Name	Olaf Dybiński
Phone	+48 600 114 923
e-mail	odybinski@olaffenergy.pl
Accreditations and certificates	N/A

2.3. Context of the energy audit - scope, aim and thoroughness, timeframe and boundaries

A person responsible for the contact with an auditor is Ms. Irena Nowakowska, who is an economic manager in the school, taking care of energy and other media management in the building. The walk-through has been performed in the assistance of Mr. Andrzej Ługowski, a school technician. Both of them agreed that the comfort in the building is quite good, however in winter it is sometimes cold, but it is not very bad. Since the canteen has its own air handling unit there are no problems with lack of fresh air. Furthermore, there is no need for opening windows and increasing thermostats setpoint, as the fresh air is provided at the temperature of 21°C. In summary, the thermal comfort in the building is well preserved.

The first visit in the school was performed on 14.01.2019 and included technical documentation analysis and digitalization, connected with the whole building inspection (classrooms, sport hall, canteen, technical rooms) and technical systems investigation. The investigation of HVAC systems included heating system overview (heating source, distribution and regulation systems), domestic hot water system evaluation and ventilation system investigation, except air handling units for sport hall purposes, which are located on the roof of the building. The building is equipped also with two air conditioning units of around 4 kW cooling power located in the computer classrooms.

The on-site visit of the building included also lighting analysis (power, number, location, type and control method investigation) in different rooms that is classrooms and sport hall. Recently there has been an audit of electric installation in the building performed, therefore precise information about installed electric devices is available.

The audit was performed on the basis of an agreement regarding FEEDSCHOOLS project and is supposed to provide information on the current state of the building. The audit will be a basis for preparation of a comprehensive analysis of energy consumption in the building, supported by simulations of energy losses in the building. Based on these results, suggestions for modernizations allowing for decreasing the energy consumption of the building will be proposed. The calculations in the energy audit are based on the available technical documentation and information gained during the on-site visit in the building. Due to lack of BMS in the building, some assumptions regarding exploitation schedule and timetables were made, basing on auditor’s experience, documents introduced by Polish national law, and on the information gained from technical staff of the building.

2.4. Description of audited object

The building consists of two parts. The old part was built around 1890 and then modernized in 1933. During the II World War a huge part of the building was damaged and rebuild in the next few years. Around 1960 a new part of the building has been added and finally between 2002 and 2007 the whole building has been renovated and the newest part with a new sport hall has been added. The precise information about materials applied in the building is not known as the project documentation has been lost or destroyed during the years.

The most recent renovation of the building that included external walls renovation took place around 1960, therefore it is assumed that external partitions' U-values are supposed to reach around 1.35 W/(m²K) for external walls and 0.87 W/(m²K) for the flat roof. Windows has been exchanged to new double-glazed PCV-framed around 2002 - 2004 with a declared U-value of 1.1 W/(m²K). There is only natural ventilation in the building, except the part of building with the sport hall and changing rooms, where air handling units with heat recovery are installed. A canteen has its own air handling unit. The only room with air conditioning is a computer classroom. The building is supplied with heat from the district heating network. Heat is distributed through traditional plate heaters with thermostats. The most of the building is equipped with T8 36W fluorescent bulbs controlled manually. The building does not have any BMS system.

2.5. Energy audit methodology

2.5.1. Relevant standards

Standards used during the energy audit are mostly standards typically used in energy calculations in Poland, as according to the Polish law, the standard shall not be implemented until it is fully translated into Polish language.

Table 42 Standards used during energy audit

	Applied version	**English version**
1	Norma PN-EN 16247-1 "Audity Energetyczne: Wymagania Ogólne"	EN 16247 Energy audits - Part 1: General requirements
2	Norma PN-EN 16247-2 "Audity Energetyczne Część 2: Budynki"	EN 16247 Energy audits - Part 2: Buildings
3	Norma PN-EN 16247-3 "Audity Energetyczne Część 3: Procesy"	EN 16247-3"Energy audits - Part 3: Processes
4	Polska Norma PN-EN 12831:2006 „Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego."	EN 12831 Energy performance of buildings – Method for calculation of the design heat load
5	Polska Norma PN-EN ISO 6946:2008 „Elementy budowlane i części budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczeń."	EN ISO 6946 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods
6	Polska Norma PN-EN ISO 13370 „Właściwości cieplne budynków - Wymiana ciepła przez grunt - Metody obliczania."	EN ISO 13370 Thermal performance of buildings - Heat transfer via the ground - Calculation methods
7	Polska Norma PN-EN ISO 14683 „Mostki cieplne w budynkach - Liniowy współczynnik przenikania ciepła - Metody uproszczone i wartości orientacyjne."	ISO 14683 - Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values
8	Polska Norma PN-EN ISO 13790:2009 „Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii do ogrzewania i chłodzenia."	ISO 13790:2008 Energy performance of buildings -- Calculation of energy use for space heating and cooling
9	Polska Norma PN-EN ISO 10456:2009 "Materiały i wyroby budowlane -- Właściwości cieplno-wilgotnościowe -- Tabelaryczne wartości obliczeniowe i procedury określania deklarowanych i obliczeniowych wartości cieplnych"	ISO 10456:2007 Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values
10	Norma ISO 50001 „Systemy Zarządzania Energią. Wymagania i zalecenia użytkowania"	ISO 50001:2018 Energy management systems -- Requirements with guidance for use

11	Norma ISO 50004 „Energy management systems - Guidance for the implementation, maintenance and improvement of an energy management system”	ISO 50004:2014 Energy management systems -- Guidance for the implementation, maintenance and improvement of an energy management system
12	Norma ISO 50006 “Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance”	ISO 50006 Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance

2.5.2. Regulations

List of regulations used during the energy audit:

Table 43 Regulations used during energy audit

	Applied version	**English version**
1	Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej (Dz. U. 2016 Poz. 831 z późn. zm.)	Act of 20 May 2016 on energy efficiency
2	Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego (Dz.U. nr 43, poz. 346 z późn. zm.).	Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit
3	Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. nr 75, poz. 690 z późn. zm.)	Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions that buildings and their location should meet
4	Rozporządzenie Ministra Gospodarki z dnia 5 października 2017 r. w sprawie szczegółowego zakresu i sposobu sporządzania audytu efektywności energetycznej, wzoru karty audytu efektywności energetycznej oraz metody obliczania oszczędności energii (Dz.U. 2017 poz. 1912).	Regulation of the Minister of Economy dated 5th October 2017 on the detailed scope and method of preparation of the energy efficiency audit, model of the energy efficiency audit card and methods for calculating energy savings
5	Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej (Dz. U. 2015 poz. 376 z późn. zm.)	Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building
6	KOBiZE (The National Centre for Emissions Management) - raport „Wartości opałowe (WO) i wskaźniki emisji CO2 (WE) w roku 2014 do raportowania w ramach Systemu Handlu Uprawnieniami do Emisji za rok 2017”	KOBiZE (The National Center for Emissions Management) - report "Calorific Values (WO) and CO2 emission factors (EC) in 2014 for reporting under the emission trading regulation scheme for 2017"
7	KOBiZE (The National Centre for Emissions Management) - raport „WSKAŹNIKI EMISYJNOŚCI CO2, SO2, NOx, CO i pyłu całkowitego DLA ENERGII ELEKTRYCZNEJ na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2017 rok”	KOBiZE (The National Center for Emissions Management) - report "CO2, SO2, NOx, CO and total dust EMISSION RATES FOR ELECTRICITY based on information contained in the National Database on greenhouse gas emissions and other substances for 2017"

8	Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE w sprawie efektywności energetycznej	Directive 2012/27/EU on energy efficiency

2.5.3. Information on data collection

The energy audit in Primary School no. 26 in Warsaw started with on-site visit that took place on 14th of January 2019. It began with an interview with an economic manager of the school, Ms. Irena Nowakowska and technical staff leader Mr. Andrzej Ługowski. The experience shows that the best procedure is to ask about energy and thermal comfort issues in the building at first, as there might be some problems in the building that could be missed by an auditor during the walk-through and are well-known to the people exploiting building on the daily basis. Both Ms. Irena Nowakowska and Mr. Andrzej Ługowski did not mention about special comfort problems, in their opinion the thermal comfort in the building is well preserved.

After the interview there was a walk-through audit accompanied by Mr. Ługowski. The walk-through allowed to investigate the envelope, materials, solutions and HVAC systems. The most important for the auditor was the inspection of the heating system. The auditor investigated the heating source, control and distribution system in the building, and made photographic documentation of the existing state of the systems. During the walk-through the auditor continued an interview, gaining information about schedules of occupation of building, as well as light and heating schedules. The cooling system in the building is limited to two cooling units dedicated for the computer classroom working only if required (only during hot days). The building is equipped with a mechanical ventilation, however there is no BMS system for the HVAC installation, so the energy consumption, temperature, air flow volume etc. is not registered. Data about the mechanical ventilation system was gained from the documentation. There are mainly fluorescent T8 light bulbs with traditional manual control applied in the building. Corridors are also connected to main switch allowing for turning off all of the lightings at once, but it is never used. There is metahalogen lighting applied in the large sport hall and it is controlled manually.

Data about electricity consumption, heat consumption, heat load and power load of the building was provided by the City Hall. The greenhouse gasses emissions were calculated according to KOBiZE (The National Centre for Emissions Management) report relating to the amount of greenhouse gas emissions from fuel utilization. The primary energy consumption was calculated according to Polish legislation [1] applying the non-renewable primary energy indicator wi=3.0 for electricity, and applying the non-renewable primary energy indicator from declaration of the owner of district heating in Warsaw (Veolia Energia Warszawa S.A.), which equals wi=0.87.

3. General building data

3.1. Location

Building name	Szkoła Podstawowa nr 26 w Warszawie
Street, number, city and postcode	Miedziana 8, 00-814 Warszawa
Province/Region	Mazovia
Country	Poland

Longitude [DD.dd°]	*52.2 N*
Latitude [DD.dd°]	*20.99 E*
Height above the see level [m]	*114 m.*
Year of construction	*1890 / 1960 / 2000*
Useful area - the whole building [m²]	*Total useful area of the building*
Useful area - audited part [m²]	*Classrooms: 1,346 m²* *Sport halls: 745 m²* *Canteen: 198 m² (with facilities)*

3.2. Energy and water consumption

3.2.1. Electricity Consumption and Mix

The building is supplied with electricity from the power grid managed by a corporation Innogy Stoen Operator Sp. z o.o. which is the only operator of the Warsaw electricity distribution infrastructure. It is connected to the low voltage grid and uses C21 tariff. The typical consumption of electricity in the building is around 8,400 kWh/month, with total yearly consumption of 101,040 kWh in 2017. The maximum ordered power during the year is 86 kW in total, divided to 3 electric connections.

Table 44 Electricity consumption in 2017

No.	Consumption in 2017 [kWh]	Power ordered [kW]
Electric connection 1	7,282	10
Electric connection 2	72,192	46
Electric connection 3	21,566	30
Total	101,040	86

3.2.2. Gas/Oil/solid Fuel Consumption

The building does not consume any fuels, as it is connected to the district heating grid powered mainly by two CHP plants Żerań and Siekierki in Warsaw, both utilizing coal and biomass for electricity and heat production. The non-renewable primary energy indicator for the system heating is claimed by Veolia Energia Warszawa S.A. to be equal to 0.87. The heat consumption by building in 2017 and average monthly external temperatures are presented in the table and on the graph below. The consumption includes both central heating and domestic hot water.

Table 45 Heat consumption in 2017

Month	Heat [GJ]	Heat [MWh]	Average monthly temperature [°C]
I	485.40	134.83	-3.7
II	455.20	126.44	-0.8
III	243.60	67.67	6.1
IV	227.50	63.19	7.7
V	172.30	47.86	14.6
VI	20.50	5.69	18.5
VII	13.80	3.83	18.9
VIII	13.90	3.86	19.7
IX	15.50	4.31	14.0

X	122.70	34.08	10.0
XI	242.10	67.25	4.9
XII	288.50	80.14	2.5
TOTAL	2 301.00	639.17	

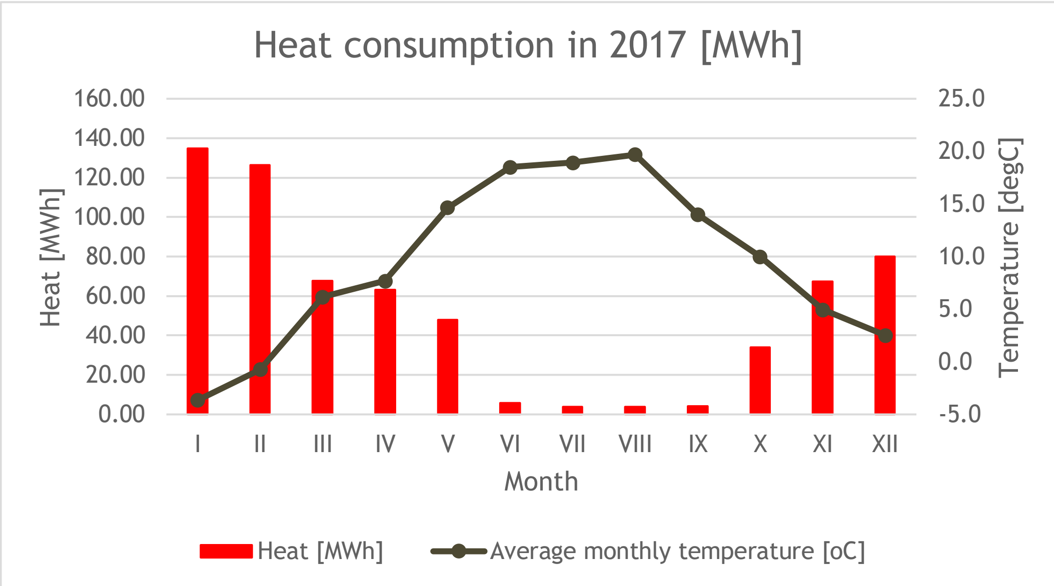

Figure 76 Heat consumption in 2017

Total heat consumption in 2017 reached 639.17 MWh. The maximum ordered power is 0.4113 MW (heating) and 0.0640 MW (domestic hot water preparation), which makes 0.4753 MW heating power ordered in total.

3.2.3. Renewable Energy Sources

There are no renewable energy sources installed in the building.

3.2.4. Other Generation

The building is not equipped with any other generation systems.

3.2.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)

National emission factors for electricity and heat for 2017 were applied for calculation of CO_2 emissions (according to KOBIZE reports). In case of the non-renewable primary energy indicator (wi) the value declared by Veolia Energia Warszawa S.A. was applied.

Table 46 Energy consumption and emissions

Parameter	Heat	Electricity	Total
Final energy consumption [kWh/a]	639,166.67	110,284.00	749,450.67
Final energy consumption indicator [kWh/m²a]	**114.27**	**19.72**	**133.99**
Non-renewable primary energy indicator (wi)	0.87	3.00	-
Primary energy consumption [kWh/a]	556,075.00	330,852.00	886,927.00
Primary energy consumption indicator [kWh/m²a]	**99.41**	**59.15**	**158.56**
CO2 emissions [tCO2/a]	212.38	79.18	291.57

3.3. Building exploitation, maintenance and management

According to information gathered during the interview, the school is used between around 7.30 AM and 4.30 PM Monday-Friday. The sport hall might be used during evenings, weekends and on holidays. The Polish educational system defines periods of winter holidays as two weeks during winter season (January/February) while the exact date of winter holidays is decided by ministry of education each year. Summer holidays starts and finishes at the same time each year, beginning on Monday of the last week of the June and finishing with the last week of the August.

The heating system works with no pre-defined breaks. The lighting is turned off during unoccupied period. Lighting in the corridors is usually switched on in the morning and turned off after 4.30 PM. Lighting in the classrooms, sport hall and canteen is used only when needed.

Air handling units in the new sport hall work 24/7.

4. Existing state of building energy systems

According to historical information, the oldest part of the building was built around 1890, than rebuilt after II World War and modernized completely in 1960 with new parts added. According to the Polish law concerning requirements about buildings for 60's[4], the heat transfer coefficient (U-value) of the external partitions is supposed to reach up to 1.35 W/(m^{2}K) for external walls and 0.87 W/(m^{2}K) for a flat roof. Windows has been exchanged with new around 2002 - 2004 with a declared U-value of 1.1 W/(m^{2}K).

4.1. Heating system

The heating source in the building is a compact type heat exchanger with weather control. The designed heating load for the building is 475 kW. It is assumed that the central heating installation works on parameters 85/60°C. Water is the heating factor in the installation. The heat exchanger station powered by the district heating is insulated, so according to [1] its efficiency equals 99%.

Figure 77 Heating source in the building

The heating source has been renewed during modernization around 2005. Currently the heat exchanger cooperates with an insulated distribution system, covering central heating, domestic hot water for the building and technological heat (water heating coils in air handling units).

[4] *Rozporządzenie Przewodniczącego Komitetu Budownictwa, Urbanistyki i Architektury z dnia 21 lipca 1961 r. w sprawie warunków technicznych, jakim powinny odpowiadać obiekty budowlane budownictwa powszechnego (Dz. U. nr 38, poz. 196)*

The insulation is maintained in a good condition. A basement where the heating source is located is also a heated space. According to [1] the system total efficiency equals 96%.

Figure 78 Insulated pipes

Heat is distributed by water convectors equipped with thermostatic valves. They are mostly located in niches under the windows, following the Polish construction requirements. According to [1], the overall system efficiency equals 89%.

Figure 79 Water convectors with thermostatic valves

4.1.1. Sport hall

Water convectors in the sport halls are the same as in the rest of the building, including thermostats. Temperature regulation in the sport halls according to information gained during the audit is good and thermal comfort is well preserved. In the large sport hall temperature is also regulated by air handling unit that keeps a heating parameter setpoint at 16°C using a rotary heat exchanger and a water heating coil.
Convectors are located on the internal and external walls of the large sport hall. In small sport halls convectors are located in the niches under windows, following the Polish construction requirements.

Figure 80 Plate heaters in the sport hall with thermostats

4.2. Water and sewage system

The water is provided to the building from the Warsaw water supply network. The main valve is located in the basement. Domestic hot water is prepared in the same source as the central heating, with total seasonal efficiency as 0.98. The pipes are insulated and the insulation condition is good. There is a circulation pump installed in the system and it works constantly. There is less than 100 sinks or showers in the building, so seasonal efficiency equals 60%. There is no water leakage control in the system, so regular controlling of toilet flush and taps is necessary.

4.2.1. Sport hall

There are no water access points in the sport hall itself, however changing rooms for children are connected with shower rooms and toilets.

4.3. HVAC

The old part of the building is ventilated naturally, except a new large sport hall with facilities (including 6 classrooms with entrances from corridors connected to the new sport hall), canteen and kitchen which are equipped with the mechanical ventilation. Natural ventilation is provided with brick ducts. . Fresh air is supplied through air leakages. The only air-conditioned room in the building is a computer classroom. Thermal comfort in zones with natural ventilation is maintained by thermostats setpoint. Additionally, windows are open if needed.

Electric power of ventilation system is presented in the table below.

Table 47 Electric power of ventilation systems

Location	**Power [W]**	**Quantity**	**HVAC total power [kW]**
Sport hall	4.4	2	8.8
Changing rooms + basement	2.2	2	4.4
Sport hall changing rooms + toilets	1.2	2	2.4
Classrooms exhaust fans	0.13	15	1.95
TOTAL			**17.6**

The information about the device installed in the canteen could not be found.

4.3.1. Sport hall

Three small sport halls located in the old part of the building are ventilated naturally. The large sport hall (the new one) is equipped with air handling unit with rotary heat recovery.

The air handling unit is equipped with a water heating coil and heat recovery. A temperature setpoint of supplied air is set to 16°C during the day and 8°C at night. The total supplied air flow equals 16,480 m^3/h, and the exhaust air flow equals 14,830 m^3/h. Fresh air is supplied on the level of 2.5 m above the floor, and the flow is directed towards ground. Extracts are located on the same wall right under the roof.

Figure 81 Large sport hall ventilation

4.4. Cooling system

The only cooling system in the building is a computer classroom air conditioning, supplied by two external units of around 4 kW each. According to information gained during the interview, cooling units are used only when needed, during hot days. The temperature setpoint is set by the teacher controlling the unit at the time.

4.4.1. Sport hall

There is no cooling system in the sport halls.

4.5. Electric system

The building is connected to the power grid owned by Innogy Stoen Operator Sp. z o.o. The building is connected to the low voltage grid and uses C21 tariff. The electric socket voltage is 230V and frequency is 50 Hz.

Most electric power consumption is spent on lighting in the building. HVAC system of a sport hall requires huge amount of energy and power as well.

Devices installed in the technical room are mainly pumps in heating system and sewage water system. In the building there is one elevator installed with electric engine requiring 8.5 kW of power.

4.5.1. Sport hall

Sport halls does not have any dedicated electric system. They are equipped with lighting (16x150W metahalogen) and 230V sockets. HVAC devices supplying air to the new large sport hall are located on the roof of the building.

4.6. Building envelope

The most recent renovation of the building that included external walls renovation took place around 1960. Unfortunately, there is no documentation concerning the renovation. Therefore, it is assumed that external partitions' U-values are supposed to reach around 1.35 W/(m^{2}K) for external walls and 0.87 W/(m^{2}K) for the flat roof. Windows have been exchanged with new double-glazed PCV-framed ones around 2002 - 2004 with declared U-value of 1.1 W/(m^{2}K).

The newest part of the building connected to the new sport hall was built in 2005. According to regulations of that time, both external walls and flat roofs were required to have U-value not higher than 0.3 W/(m^{2}K).

4.6.1. Sport hall

External partitions of small sport halls located in the old part of the building are identical as in the rest of old part of the building. External walls and flat roofs of the new sport halls have, according to technical construction requirements of 2005[5], heat transfer coefficient U equals 0.3 W/(m^{2}K).

4.7. Renewable energy sources

There are no renewable energy sources in the building.

4.8. Lightning system

Most of the building (except the large sport hall) is equipped with 2xT8 fittings with 2x36W fluorescent bulbs. There is no central switch in the building, however there are people responsible for turning off the lights during unoccupied hours. The corridors lighting works usually from Monday to Friday between 7.30 and 16.30. There are individual switches at each floor. The large sport hall is equipped with 16x150W halogen fittings turned on when needed.

4.8.1. Sport hall

The sport hall is equipped with 16x150W halogen fittings turned on when needed. Small sport halls are equipped with 2x36W fluorescent fittings, 20 in each hall, turned on when needed. Power installed in lighting per square meter is around 6 W/m^2 for the large hall and 12 W/m^2 for small sport halls.

4.9. Other systems

There are no other systems in the building relevant for the audit.

5. Other information

Legal acts cited:

[1] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[5] Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. z 2002 r. nr 75, poz. 690 z późn. zm.)

6. Attachments

Table 48 Non-renewable primary energy indicators

Parameter	Heat	Electricity
Non-renewable primary energy indicator (wi)	0.87	3.00

Building is located tight between other buildings, so it was not possible to take a photo of elevations.

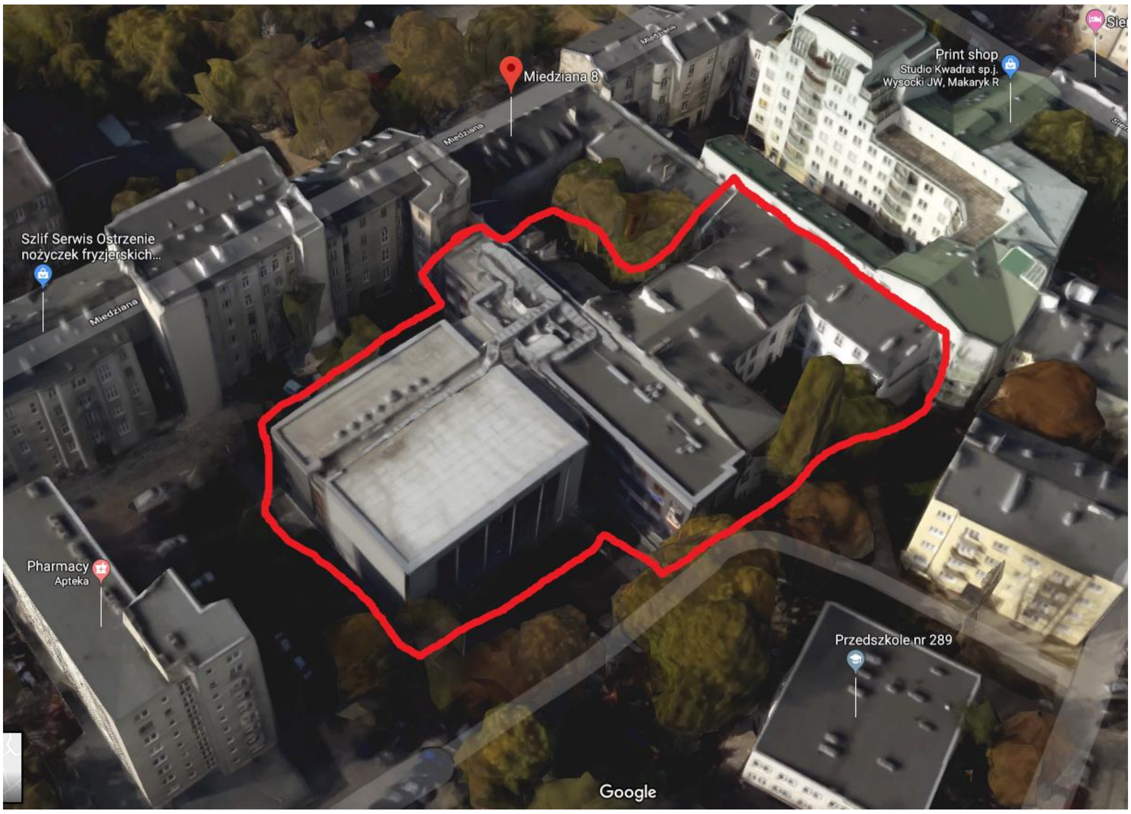

Figure 82 Building location (Source: Google Maps)

Figure 83 North-western side of the building

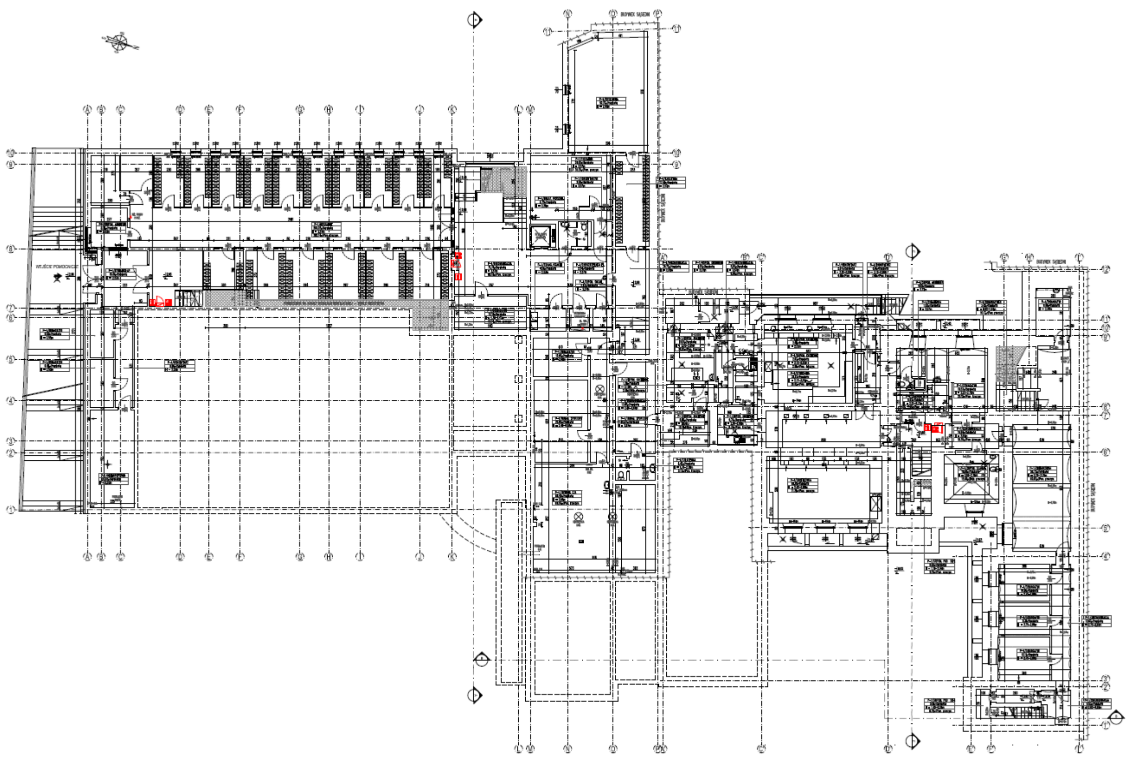

Figure 84 Basement floor plan

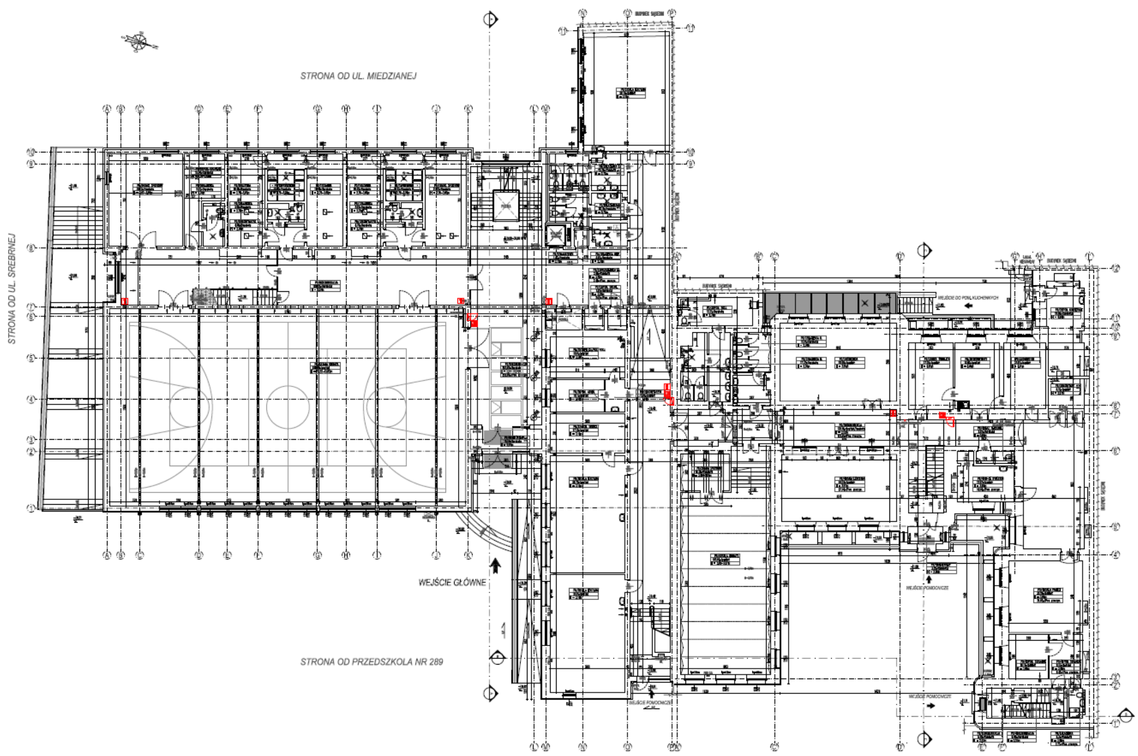

Figure 85 Ground floor plan

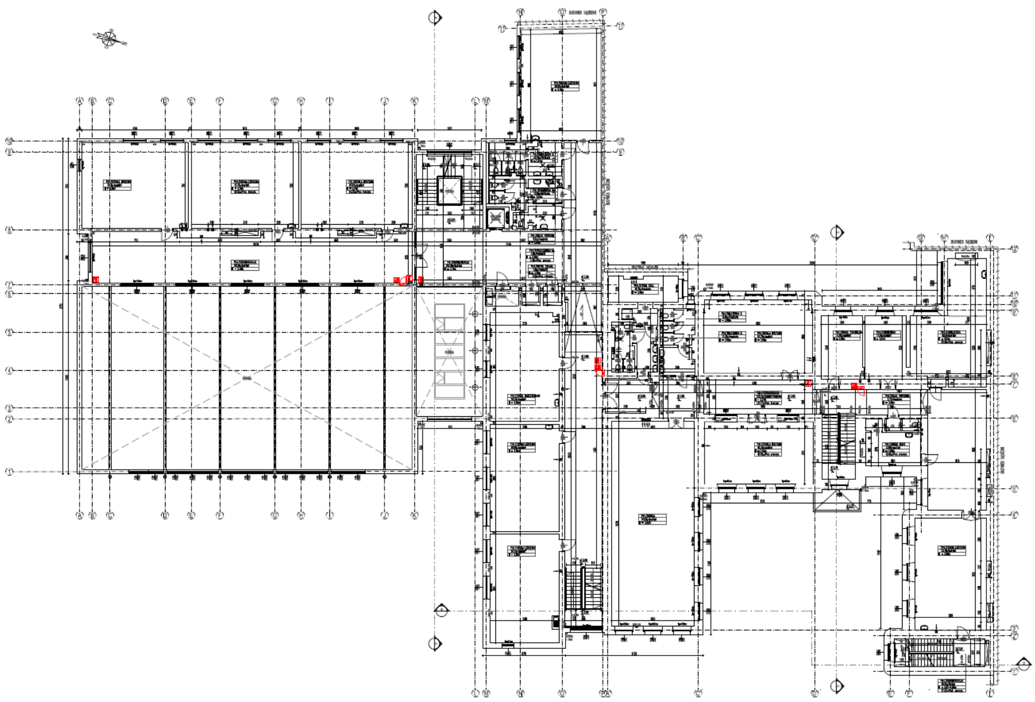

Figure 86 First floor plan

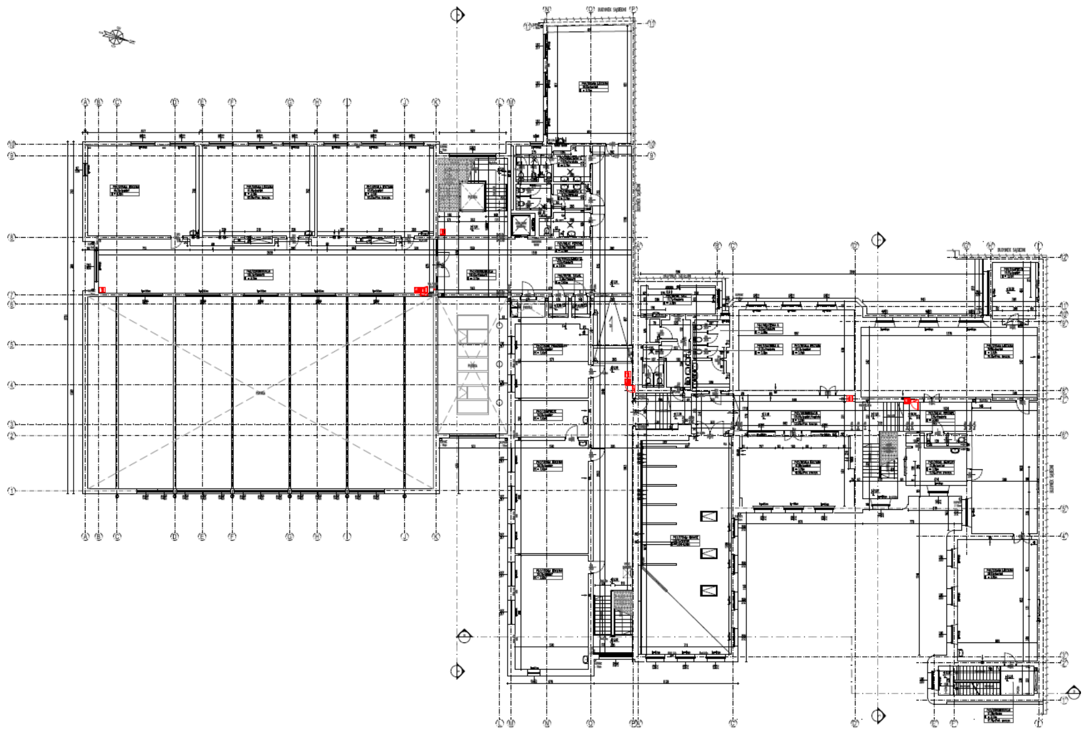

Figure 87 Second floor plan