Chapter 1

Comparison of design intentions and construction solutions delivered to enhance environmental performance and minimize carbon emissions of a new public school in Wroclaw

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Abstract The paper presents an analysis of the first public school complex in Wroclaw, Poland to use renewable energy sources with an introductory summary of low emissions constructions in Poland. Described is the process of the building's delivery and a preliminary evaluation of selected design solutions. The building, completed in the year 2009, is planned for an in-depth POE to start this year – the first such broad evaluation project to be carried out in Poland. An in depth knowledge of the design and construction process, measurements taken already, feedback from the occupants, and tracks of all faults reported so far, allow a preliminary evaluation of the building's environmental performance. A comparison of total energy consumption and CO_2 emissions between the analyzed building and two other selected schools from Wroclaw is included. It is based on energy bills for all fuel sources used. It indicates energy efficiency of the building and relatively high CO_2 emissions due to its sole dependence on electricity.

1.1 Introduction

Architecture following the triple bottom line guidelines is only now emerging in Poland. High energy efficiency and low carbon emissions are not yet major concerns for architects and clients. They are neither required by building regulations nor economically viable so far. The year 2010 saw first commercial developments

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receive BREEAM and LEED certificates[3]. The first detached house certified by Passivhause Institut (Bac 2006) was completed in 2006 in Smolec, near Wroclaw and has no successors so far. The first public building within passive standard - a sports hall adjacent to a secondary school building in Slomniki, Little Poland, was completed in February 2011. The first passive school in the country is currently under construction in a village of Budzow in Lower Silesia. Only single public investments use renewable energy sources (RES) so far. The building analyzed in this paper is one of them. There are signs of interest in both low and high tech ecological solutions among individual clients but still at a limited scale. Polish construction industry, the clients and occupants are all at an early learning stage in terms of low emissions building, though Poland as a member of the EU is obliged to implement the EU energy efficiency objectives i.e. the 20-20-20 targets.

The early learning stage means that there are numerous green-bling solutions available, strongly promoted by their manufacturers, promising zero-energy construction at hand, but little practice in their actual delivery and performance, maintenance requirements, usability for the occupants combined with scarce financial or legal incentives for building green and no support for microgeneration. No in-depth POE or BPE research has been conducted on the few green buildings constructed so far.

1.2 The background for the case study building design

Having all that in mind, it is easier to understand the environmental targets set by the Wroclaw City Council's vote in the year 2006 for the analyzed public school building, though limited and general: the school was to make use of RES, must nevertheless be regarded as a 'green avant-garde'. They were the first and so far the last environmental targets set for a public investment in Wroclaw to go beyond the legal requirements in that respect. An architectural competition followed that vote but no further details in terms of environmental performance were articulated: the school was to make use of renewable energy sources but the type, extent or energy targets were not specified (Zarzad Inwestycji Miejskich 2006). An integration of local community with the school was proposed at the competition stage through inclusion of several public functions into the school: a public library, community club, local community council and a city guard office. The sport facilities were also to be let to local community after school working hours. A greenfield site at Suwalska street, in a currently developing suburban housing district of Wroclaw was designated. The 'sustainable' direction for the development was taken when the jury selected the winner of the 1st prize – a design by Grupa

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3 BorgWarner Turbo Systems Poland – LEED Silver (PGS Software 2012) and Trinity Park III BREEAM very good (Grontmij 2012).

Synergia architectural office, led by Anna Bac and Krzysztof Cebrat, experts in sustainable construction and landscaping at Wroclaw Faculty of Architecture.

1.3 The choice of case study example

The choice of the case study example reflects the fact that it is the first, and so far the last, public investment completed in Wroclaw that was to make use of renewable energy sources. Dissemination of evidence based evaluation of its performance may have a major influence on both public opinion and the shape of local policies towards sustainable architecture. The building is presented in a book on recent Polish architecture (Ruminska 2011) and received three local architectural prizes[4].

The competition entry's environmental scheme was developed in cooperation with environmental engineer Wojciech Stec from First Q Amsterdam office.

Grupa Synergia was commissioned all design stages until the handover of the building. The architects invited Eko Energia System for environmental engineering. Eko Energia System developed a feasibility study for the competition entry scheme, which proved many of the proposed 'green' features not be economically viable and in result were dropped from the final design (see Table 1.1 and Table 1.2). Department of Municipal Development (DMD) (the client), though strongly represented in the competition jury, had no previous experience in the procurement and management of energy efficient buildings, and in the course of the design proved not to be a partisan of a 'green' design approach. DMD was responsible for the organization of the tender process and as usual the lowest price was the main criterion for the choice of the contractor.

Fig 1.1 a) View towards school entrance zone with distinct volumes housing different functions. b) View towards a courtyard between school and preschool wing. A copper volume with dining room is shared by the two functions

[4] 2010 – II prize in the category of a public building in a competition “Beautiful Wroclaw”, 2011 – PLGBC award I prize in the category of “Green building of the Year” and honorable mention in the category “Green Interior of the Year”, 2011 - honorable mention in a competition organized by a local branch of Polish Society of Architects SARP in the category “user friendly space”.

The 6000-square-meters building accommodates 450 pupils and 100 preschool children. There are 80 employees in the building including: teachers, administration and technical staff. The school's population is divided between two classroom wings with shared entrance lobby, library, sport and dining facilities. The third wing with a separate entrance is dedicated to the preschool. The dining area serves as a connection point between the school and the preschool (see Fig. 1.1).

1.4 The context and the stage of data collection

The building has been occupied since September 2009. Some observations, measurements and troubleshooting were performed up to date. In the year 2010 a questionnaire survey for the children of classes 3-6 was personally distributed and collected by the architects to learn about the reception of selected issues in the school's design. After the first winter the leading environmental engineer Andrzej Bugaj was commissioned a year of continuous supervision and fine tuning of the building's environmental systems. The results of his supervision is not clear to the building's users, including the head of the school Ewa Glinska, who was not given any written reports on its progress and outcome. Some problems that had been occurring persisted. An in-depth POE research is thus planned to start this year using PROBE investigation techniques developed by the UK's Usable Buildings Trust (Baborska-Narozny 2011). It is intended to deliver evidence-based evaluation and indicate ways for improvements. A three year contractor's warranty ends in June 2012, thus it is vital for the head of the school to trace and repair construction defects and systems malfunctions before that date. In result a thermo-graphic survey has already started. The presented evaluation is based on an in-depth knowledge of the building's design and procurement phases, semi structured interviews with crucial occupants (head of school, head of preschool, staff representatives, including the building technician responsible for the building maintenance), questionnaire survey mentioned above and detailed analysis of all records documenting the defects claimed by the users to DMD, who manages construction warranty.

1.5 Design targets and solutions as built

Comparison of early design stages and as built design solutions to lower the building's energy demand and environmental footprint is presented in Table 1.1. It is followed by selected usability issues. Table 2.2 includes preliminary and as built solutions concerning sustainable landscaping and the selection of construction materials.

Table 1.1 Design targets and solutions as built

Design solution	Competition entry	As built
Improved energy performance of the building's envelope		
Building's envelope thermal insulation exceeding building regulations requirements. (see point A following Table 1.1)	V	V
Building's air tightness	V	X
Outdoor staircases and glazed roofs covering entrance areas are separate from the construction of the building to avoid thermal bridging. (see point B following Table 1.1)	V	V
Additional insulation framing windows	V	V
Functional disposition to incorporate solar gains and losses		
Double glass facades on south-facing classrooms	V	X
Reduced heat loss through north-facing walls with smaller openings in the corridors	V	V
The use of exposed thermal mass	V	V
Excessive solar gain and glare protection		
Fixed horizontal brise solei above south-facing openings. (see point C following Table 1.1)	V	V
Skylights and east and west facing glazing of public areas and administrations facilities with external textile roller blinds	V	V
Use of renewable energy sources to cover energy demand for heating/cooling and hot water		
Heat recovery from a major municipal sewage collector that crosses the site underground	V	X
Heat pump with geothermal loop vertical	V	V
Earth tubes	V	X
Solar collectors for water heating (see point D following Table 1.1)	V	V
Floor heating in the preschool, dining and sport hall	V	X
Ventilation system		
Natural ventilation with the stack chimneys and double glass facades	V	X
Automatic controls to enhance natural ventilation	V	X
Mechanical ventilation with heat recovery to support natural ventilation when required, particularly in the summer and winter periods	V	X
Mechanical vent. with heat recovery (see point E following Table 1.1)	X	V
Energy management system		
Partly automated individual comfort management integrated with natural ventilation	V	X
BMS system with the possibility to make individual adjustments in most interiors (see point F following Table 1.1)	X	V
Use of daylight		
All interiors day-lit (excepts for school toilets)	V	V
Daylight entering classrooms from two sides: direct with views outside and	V	V

indirect through clerestory widows opening to the corridors		
In the preschool extensive glazing to the south and clerestory windows to the east, allowing daylight also to the toilets	V	V
In the two story communication zone daylight reaches the lower floor through openings in the floor slab under the roof lights	V	V
Controlled use of artificial lights		
Occupancy sensor control in the restrooms	V	V
Zoning of artificial lighting scheme according to the distance from the windows	V	X

The users' comments and faults which were reported concerning selected design solutions listed in Table 1.1 are as following:

A) A severe problem i.e. frost on the inside of wall and window occurred at one point during the first winter. A thermographic survey revealed a major gap in the thermal insulation layer that was soon repaired. A second thermographic survey carried out this winter revealed only one minor defect in the consistency of thermal insulation.

B) Thermography proved those details to be efficient (see Fig. 1.2).

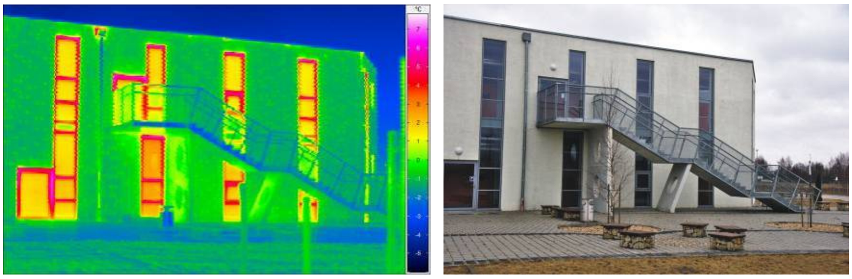

Fig 1.2 a) Thermographic picture taken at outside temperature -5 ºC, inside +19 º C, wind 1 m/s, at 11 p.m. on 27 Feb.2012, low moisture, dry surfaces, camera Varioscan 3021ST. b) Daytime view

C) Glare was an immediate problem in the classrooms from the early occupancy. Internal roller blinds were installed. The modeling of daylight performed at design stage proved to be insufficient.

D) The solar collectors are supplemented by electric water heaters. Even so there are persistent problems with warm water across the school. The problem is still to be solved.

E) Mechanical ventilation produces noise that is perceived by the teachers as disturbing and annoying. Limiting the air flows in turn lowered the air quality.

F) Precise measurements of air flows, internal temperatures and indoor air quality are yet to be taken. The overall evaluation indicates poor usability of the system. It was meant to be controlled by the BMS, but lack of facility manager and lack of competence of the users causes frustration. Separate controls of the air flow rates are provided for each classroom, however their location at the corridor at ceiling height and the need to use a screwdriver makes it impossible for the teachers to make adjustments in air flow rates. The need to call for technical assistance often results in asking for turning the ventilation off and opening the windows (see Fig. 1.3).

Fig 1.3 a) Classroom with MV ducts visible, b) Corridor with MV ducts visible, c) Location of the control gear for MV at ceiling high

Table 1.2 Sustainable materials and landscape design targets and solutions as built

Design solution	Competition entry	As built
Sustainable water management		
Water retention ponds as a landscape feature	V	X
Rain water for watering the plants on site	V	V
Gray water for flushing toilets	V	X
Using water permeable surfaces	V	V
Time-limited taps	V	V
Sustainable landscaping		
Local plants	V	V
Shading the building through proper planting	V	V
Experimental garden for the pupils	V	V
Extensive green roof	V	X
Light color of roof membranes and landscape surfaces for heat island effect reduction	V	V
Local materials with low embedded energy where possible		
Use of wood for facades	V	X
Use of wood and wood products for structure and interior, mineral wool for thermal insulation	V	V
Gabions filled with local stones as the base for outside benches	V	V

The school was commissioned and designed as a highly innovative building, making use of renewable energy sources, thus lowering its environmental footprint. It is equipped with sophisticated installations that were to deliver healthy indoor environment while being energy efficient. The change form preliminary design stages towards the built result brought a shift form a co-existence of passive and active methods of IAQ control towards focusing on active ones. What seems to be missing from the user's perspective is a lack of handover stage that would leave them with awareness of the systems installed and the technical skills for their control. There is no professional facility manager employed. Lack of proper fine-tuning of systems installed during the early occupancy and lack of awareness of the expected results in terms of overall comfort result in staff frustration. Detailed measurements of building energy performance are yet to be taken however at this stage of data collection and problem solving it is probable that the building is not yet making full use of its potential in terms of energy efficiency and user's comfort.

1.6 The building's total energy consumption and CO_2 emissions as compared to two other schools in Wroclaw

A robust check whether the aim to reach energetically and environmentally efficient building is met can be performed by comparing the bills for media of school at Suwalska Street (see Fig. 1.4a), with two other schools in Wroclaw. The bills for water are not included as there are too many factors to take into account to explain the results. The focus is on energy consumption and CO_2 emissions (see Table 1.3). The two other schools selected represent two building types. The school at Rumiankowa Street is a recently retrofit building from the seventies of the XX century to meet "highest European standards" (Hussak 2012) (see Fig. 1.4b). It is heated with local gas heating. The school at Aleja Pracy is a historical building built in 1934 (Harasimowicz 1998) that is not yet retrofitted (see Fig. 1.4c). It is heated with co-generation. The first type indicates what can be achieved through retrofitting of the existing building stock and the second represents the many historical buildings before any major modernization. Data on type and amount of energy used by each school were collected and shared by the City Council Office.

Reference carbon emissions for electricity production in Poland is 0,812 Mg CO_2/MWh = 225.44 kg CO_2/GJ (as in June 2011 – applicable for calculations in the year 2012) (KOBiZE 1 2011). It is among the highest in Europe. CO_2 emissions factor for co-generation heat in Poland is 93.97 kg CO_2/GJ, and for gas it is 55.82 kg CO_2/GJ (KOBiZE 2 2011).

Table 1.3 Comparison of total energy consumption and CO_2 emissions for three selected schools in Wroclaw

	2009	2010	2011	Average

1. Suwalska **5800 m²** **450 pupils**	1626 kWh (Sep-Dec) (5.8 GJ)(*)	182,817 kWh (658 GJ/pa)	252 130 kWh (908 GJ/pa)	0.12 GJ/m^2/ pa
Annual CO_2 emissions	1320 kg CO_2/pa	148 371 kg CO_2/pa	204 625 kg CO_2/pa	26 kg CO_2/m^2/pa
2. Rumiankowa **5000 m²** **407 pupils**	1842 GJ	1813 GJ	1286 GJ	0.33 GJ/m^2/ pa
Annual CO_2 emissions	143 555 kg CO_2/pa	139 027 kg CO_2/pa	110 797 kg CO_2/pa	17.6 kg CO_2/m^2/pa
3. Aleja Pracy **3567 m²** **165 pupils**	2 744 GJ	3 478 GJ	2 721 GJ	0.84 GJ/sq.m/pa
Annual CO_2 emissions	298 478 kg CO_2/pa	348 kg CO_2/pa	365 278 042 kg CO_2/pa	88 kg CO_2/m^2/pa

(*) The electricity meter for the school was faulty in 2009 and underestimated the energy demand. The difference between the real and the calculated energy consumed was added to the bills for 2011 hence the substantial difference in energy demand shown in the bills for 2010 and 2011. Source: Energy consumption based on unpublished data shared with the authors by the Municipal Department of Education, Wroclaw (Municipal Department of Education, Wroclaw 2011)

Fig 1.4 a) School complex at Suwalska, b) School complex at Rumiankowa, c) High school at Aleja Pracy

1.7 Conclusions

The analyzed school in Wroclaw is built according to energy standards well exceeding even current building regulations. It is equipped to make use of renewable energy sources. Its environmental impact was a major decision factor for the architects. The novelty of many design solutions proposed together with the feasibility study performed were the main reasons for changes introduced to the initial scheme for the building's energy management. A comparison of the resulting building's energy demand and CO_2 emissions with data for two other selected schools in Wroclaw proves it's excellent quality in terms of energy efficiency and at the same time relatively high CO_2 emissions due to coal-fired electricity covering 100% of the building's energy demand. Retrofit school heated by gas, though consuming almost three times more energy, produces 32% less CO_2 emissions than the analyzed building heated by ground heat pump. A more detailed evaluation of the whole building's performance must wait for the results of the planned POE research.

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