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Use of Solar Collectors on the Example of a Water-Park Part 2: Economic Analysis

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Summary. The paper contains the economic analysis of the carried out modernisation of the facilities of a water-park consisting in fitting solar collectors for heating of tap hot water and central heating system. The article presents the data showing investment outlays, operating costs and the calculations concerning the payback time.
Key words: solar collectors, economic analysis, profitability, modernisation.

INTRODUCTION

Solar collectors impose no risk to the environment or human health. The savings associated with the use of solar collectors for heating top hot water and the central heating are very high, and the investment expenses pay off relatively quickly [1, 9, 13, 18].

After 2010, the use of energy from the sun is significantly increased, with a noticeable drop in consumption of conventional energy sources, including coal and oil [7, 14, 15]. It is predicted that after 2030 also a decrease in the consumption of natural gas will be seen. It is worth noting that virtually all the energy development scenarios predict that the energy from the sun will play a major role in meeting the energy needs of the world in the future [6, 11, 17]. Data on the number of existing and actively operating solar collectors are very divergent [3, 10, 20]. According to some authors, in Poland about 4000 solar installations for tap water heating are installed with the total area of solar collectors exceeding 40000 m².

The analysis of the water park investment options shows that the best solution for the water park is a supplementary system of energy supply from the solar collectors. In addition, the aim of the project was to recover energy irrecoverably lost from the venting system and from the warm waste water discharged into the sewer system. Electricity needed to power the facility and technological devices would be produced from the solar plant with the capacity of ~50 kW. The eventually selected variant made it possible to achieve the objectives along with optimising the investment costs. The aim of the whole project was the modernisation of the energy circuit in the water park ensuring use of renewable energy sources. The execution of the project enabled the optimal use of renewable energy in the global balance of the facility, reducing significantly the demand for conventional sources (conventional power plants). These actions were related to the optimisation, modernisation and thermal upgrading of the selected systems and obtainment of heat and electricity from both the renewable solar energy and waste energy from energy supply of the facility.

ASSESSMENT OF PROFITABILITY OF THE SELECTED VARIANT OF THE PROJECT CONSISTING IN REPLACEMENT OF WINDOWS AND DOORS AND IMPROVEMENT TO VENTING SYSTEM

The proposal covered the use of air handling unit, which would feature not only the exchange of air but also the heating and drying, with the following elements fitted in: high efficient exchanger, preferably asymmetric and made of plastic; at least two-level sensible and latent heat recovery, based on a cross-flow exchanger and a heat pump, for example adjustable internal bypass, capable of operating in a closed circuit and of operating in a mixed system, with the addition of fresh air and complete bypass of the recovery; active heat recovery system and active and passive humidity control both through air drying and by supplementing external dry air, fluent, automatic control of supply and exhaust airflow. It was important that the unit was fitted with specialised automatic controller with regulation algorithm adapted to the needs of pool halls and indoor swimming pool halls. Also a high degree of wear of the previous equipment and technology gap between them and the potential modern solutions should be noted (Table 1).

ASSESSMENT OF PROFITABILITY OF THE SELECTED VARIANT OF REDUCTION IN HEAT DEMAND FOR TAP HOT WATER PREPARATION

The use of solar thermal collectors was suggested and the system of partial recovery of heat from waste water and washings was introduced based on a heat pump [5, 8, 11].

Table 2 shows the calculation of thermal power and heat demand for the preparation of tap hot water. A comparison of the calculated heat demand before and after modernisation is shown in Figure 1. Irregularity coefficient Nh: $9.32 * U^{-0.244} = 9.32$

Central hot water preparation was calculated according to:

$$Q_{dśr} = U * Q_c = 1 * 25.800 = 25.800 \quad (1)$$

$$Q_{hśr} = Q_{dśr} / \tau = 25.800 / 18 = 1.43 \quad (2)$$

$$Q_{hmax} = Q_{hśr} * Nh = 2.58 * 9.32 = 24.05 \quad (3)$$

whereby:
$Q_{dśr}$ – average daily heat water demand;
U – number of inhabitants;
Q_c – Specific hot water consumption by inhabitant per day;
τ – time of hot water use in hours per day (18 h are assumed);
Nh – hourly irregularity coefficient of water distribution;

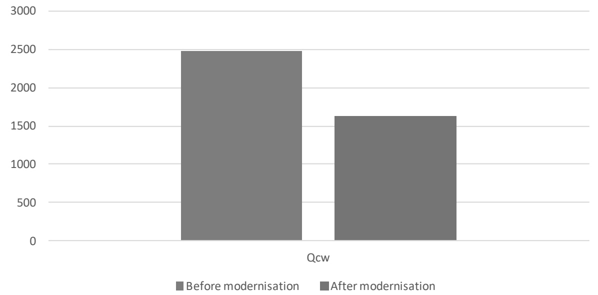

Fig. 1. Comparison of the calculated demand for heat Qcw before and after modernization [Author's elaboration]

Table 1. Assessment of profitability of the selected variant of the thermal upgrading of windows and doors and the venting system [16]

Modernisation: venting system with heat recovery			
Minimum ventilation air stream V: 44520.00/44325.00 m³/h			
		Before modernisation	After modernisation
Cost of 1 GJ	PLN/GJ	30.52	30.52
Cost of 1 MW	PLN/MW/month	8563.13	8563.13
Other costs, subscription	PLN/month	0.00	0.00
Factor V_{nom}	m³/h	---	---
Factor V_{calc}	m³/h	---	---
Factor $V_{n,sup}$	m³/h	40725.00	40725.00
Factor $V_{n,ex}$	m³/h	40920.00	40920.00
Factor $V_{calc,sup}$	m³/h	44325.00	44325.00
Factor $V_{calc,ex}$	m³/h	44520.00	44520.00
Factor β		1.00	0.70
Factor η_{oc}		32.16	85.00
Heat loss by penetration Q	GJ	167.83	25.98
Demand for heat power q	MW	0.0003	0.0001
Annual cost savings ΔO	PLN/year	---	28437.71
Simple payback time SPTB	years	---	19.84

Variant characteristics: Execution cost: PLN 564204.17 Simple investment payback time: 564204.17 / 28437.71 = 19.84 years.

Table 2. Calculations of thermal power and heat demand for the preparation of tap hot water. [16]

	Before modernisation	After modernisation
Number of users L_i	1.00	1.00
Specific use Vcw [m³/d]	25.800	25.800
Temperature of hot water at draw-off valve [°C]	45.00	45.00
Number of days per user t_{uz} [days]	300.00	300.00
User time during the day τ [h]	10.00	10.00
Heat source efficiency	0.920	0.920
Transfer efficiency	0.600	0.600
Heat accumulation efficiency	0.830	0.860
Irregularity coefficient Nh	9.32	9.32
Consumption per day $Q_{dśr}$ [m³/d]	25.80	25.80
Average hourly consumption $Q_{hśr}$ [m³/h]	1.43	1.43
Calculated heat demand Q_{cw} [GJ/a]	2477.436	1621.026
Max heat power q_{cwu} [MW]	3.5209	2.3038

EVALUATION OF PROFITABILITY OF THE MODERNISATION OF THE TAP HOT WATER SYSTEM (C. W. U.)

Submitted variant gives a relatively quick payback time, that is 5.62 years, along with large cost savings related to annual expenses (Table 3).

Table 3. Evaluation of the profitability of tap hot water system modernisation [16]

	Before modernisation	After modernisation
Cost of 1 GJ [PLN/GJ]	30.52	30.52
Cost of 1 MW of ordered heat power for heating tap hot water [PLN/MW]	8563.13	8563.13
Other costs, subscription [PLN]	0.00	0.00
Annual cost savings ΔO [PLN/a]	---	151204.32
Modernisation cost Nu [PLN]	---	849686.50
Simple payback time	---	5.62

Simple payback time: Nu / ΔO = 849686.50 / 151204.32 = 5.62 years

EVALUATION OF THE PROFITABILITY OF THE SELECTED HEATING SYSTEM MODERNISATION OPTION

Within the modernisation the second, independent source of thermal energy based on thermal collectors was postulated. It was found out that the installing of solar thermal collectors mounted on a free-standing structure located above the car park is the optimum solution. The scope of the investment covered the installation of collectors with the area of 571.2 m². Solar collectors are positioned on special structures at the angle of 40 °. They are mounted on the structures along with hydraulic batteries, each containing 4 units. Cables from such a battery are led through a special base. Each battery has its regulation and de-aeration system. Three systems of solar collectors in the overall quantity of 120 units are assumed. Flat collectors type Vitosol 200F are provided as the heat source. Each battery of collectors has a control valve AB-QM Plus that allows precise flow regulation. In addition, each battery has an air separator installed. Solar installation cables are carried out partly on the outside and fixed to the proposed structure and partly through the pre-insulate. The equipment associated with the designed solar collector installation is located in the basement of the building and in the free space under the pool.

Heat from the collectors is received through solar fluid, e.g. Ergolid-Eko, (with freezing temperature of – 35 °C – mixture of propylene glycol, water and improvers) and transferred to the water through a plate heat exchanger to two buffer cylinders, each with the capacity of 10 m³. Then the heat is released by plate heat exchangers to the cylinder of preliminary heating of tap hot water with the capacity of 5 m³ or by pool exchangers to the pool water. If necessary, usable hot water is pumped from the preliminary heating cylinder and additionally heated by the existing system of tap hot water preparation. Also a pump conveying water from preliminary heating cylinder to the existing tap hot water cylinder, activated during reheating (elimination of Legionella) was also designed. The system is controlled by a freely programmable controller. The water flow in the installation both at glycol side and water side is ensured by the circulation pumps. The installation is protected against overpressure by diaphragm safety valves, and the increase in the volume of water in the installation is taken over by the expansion vessels at the solar side through a cooling tank. Discharge pipe from the safety valve leads to the supplementary fluid tank. A pump fed from the supplementary tank is provided for supplementing solar fluid.

With optimal weather conditions, that is, sunny sky, in the middle of the day, the value of the energy of the total solar radiation is from 900 kWh/m² per year to 1200 kWh/m² per year. An average of 1000 kWh/m² per year was assumed. Annually in Poland the insulation typically ranges from 1390-1900 hours, depending on the region. On average, the insulation of 1600 hours is assumed [4, 12, 19].

Simple payback time: Nu / ΔO = 680299.50 / 32420.76 = 15.14 years

The use of solar thermal collectors as renewable energy sources for powering the facility is a reasonable solution from the point of view of the energy economy and the impact of the installation and the entire facility on the natural environment (Figure 2 and Figure 3).

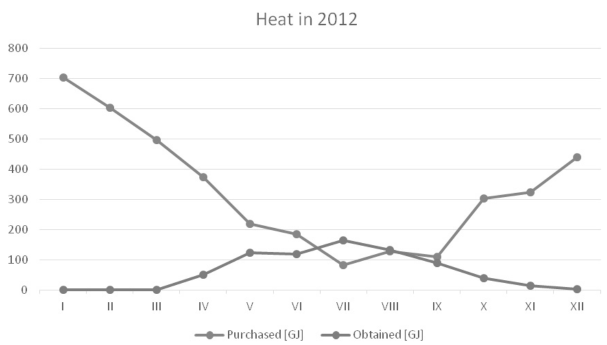

Fig. 2. Thermal energy purchased and obtained in 2012 [Author's elaboration]

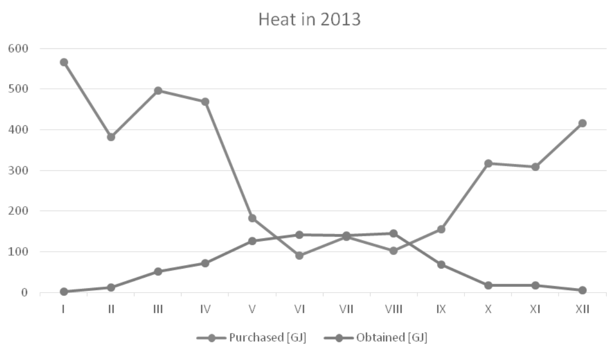

Fig. 3. Thermal energy purchased and obtained in 2013 [Author's elaboration]

OPERATING COSTS

Operating costs are a natural consequence of the status of a water park, so they are related to the use of the building. Various ways of use exist, leading to different definitions of costs.

The profitability of the investment in photovoltaic panels can be determined by comparison of energy obtained from the installation with energy purchased in the year 2012 (Fig. 4) and 2013 (Fig. 5).

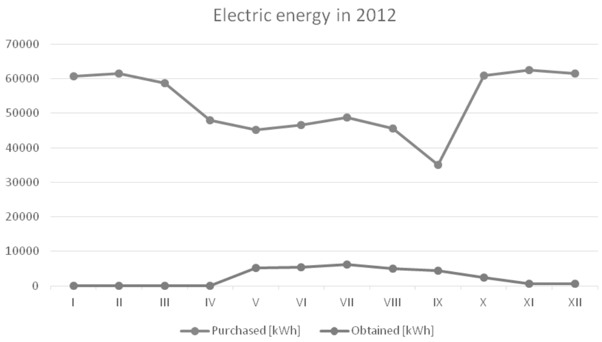

Fig. 4. Electric energy purchased and obtained in 2012 [Author's elaboration]

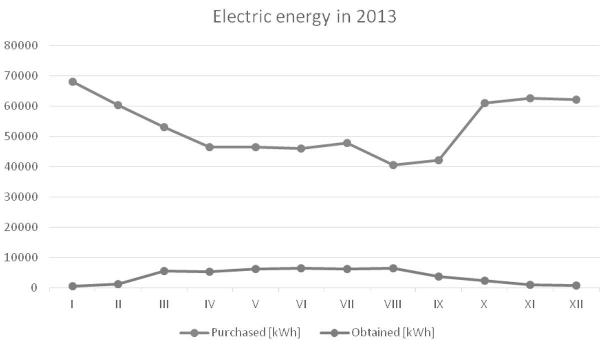

Fig. 5. Electric energy purchased and obtained in 2013 [Author's elaboration]

CONCLUSIONS

The implemented option, that is, the execution of the project consisting in the modernisation of energy installation, supplementing conventional sources of energy, such as heat supplied by the heat energy company, with modern systems of obtaining solar energy using cutting-edge solutions, has contributed to a significant reduction in costs. Maintenance of the facility after modernisation has become a lot cheaper and the used technologies and solutions have ensured safety and adequate durability of products from entry into service. All the adopted solutions ensure the achievement of the planned results with the intended and available financial resources.

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WYKORZYSTANIE KOLEKTORÓW SŁONECZNYCH
NA PRZYKŁADZIE PARKU WODNEGO
CZ. 2.: ANALIZA EKONOMICZNA

Streszczenie. Praca dotyczy analizy ekonomicznej przeprowadzonej modernizacji obiektów parku wodnego z wykorzystaniem kolektorów słonecznych na potrzeby podgrzewania ciepłej wody użytkowej i centralnego ogrzewania. W artykule zawarto dane ukazujące nakłady inwestycyjne, koszty eksploatacyjne oraz przeprowadzono obliczenia dotyczące czasu zwrotu inwestycji.
Słowa kluczowe: kolektory słoneczne, analiza ekonomiczna, opłacalność, modernizacja.