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APPLICATION OF RENEWABLE ENERGY SOURCE IN DOMESTIC HOT WATER SYSTEM IN ENERGY EFFICIENCY ASPECT

ZASTOSOWANIE ODNAWIALNEGO ŹRÓDŁA ENERGII W DOMOWYM SYSTEMIE OGRZEWANIA WODY W KONTEKŚCIE OSZCZĘDNOŚCI ENERGII

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A b s t r a c t

The paper is devoted to solar energy use as a renewable energy source in the application of solar thermal hot water system in relation to energy efficiency ranking. The aim is mutual comparison and evaluation of energy efficiency, of hot water for 3 alternatives under the existing legislation of the SR and the relevant technical standards.

Keywords: renewable energy source, solar collectors, hot water preparation system

S t r e s z c z e n i e

Artykuł poświęcony jest energii słonecznej używanej jako odnawialne źródło energii, zastosowane w słonecznym systemie ogrzewania wody, w relacji do rankingu oszczędności energii. Celem jest wzajemne porównanie i ocena oszczędności energii przy 3 alternatywnych systemach ogrzewania wody w świetle istniejących uregulowań prawnych SR i odpowiednich norm technicznych.

Słowa kluczowe: odnawialne źródło energii, kolektor słoneczny, system ogrzewania wody

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1. Introduction

The domestic hot water system within energy certification is part the assessment of any building type according to Ordinance of MCRD SR. No. 311/2009 Coll SR. The methodology for assessing the energy performance is based on the content of standards STN-EN 15316-3 (Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies, parts 1–3). Currently, the most common, and well known among the population form the use of renewable energy (solar radiation) is the installation of solar collectors with the device for preparing hot water. The energy potential of solar energy in thus designed system is determined according by standard STN-EN 15316-4-3 (Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies, parts 3–4: Space heating generation systems, thermal solar systems). Standard analytical calculation procedures in the standard will be in following sections applied to model example of family house with storage tank water heating.

Variants of the domestic hot water system:
- without the use of solar energy,
- using solar energy with flat collector,
- and using solar energy through a vacuum tube collector.

They are evaluated in terms of their energy balance and impact on the final classification system to energy class A–G.

2. The domestic hot water system with solar collectors

As a model example was chosen single-floored family house – bungalow type, with a sloping roof. Residential building with four rooms and accessories is determined for 4 persons. Preparation of hot water is designed with storage tank water heating, where the primary source are the solar collectors and gas condensing boiler works as an supplementary source.

Liquid solar system consists by 2 collectors in variants:
- flat plate collectors,
- vacuum tube collectors,

with bivalent hot water storage tank, volume of 300 litres, connecting pipes and solar station with accessories. Solar collectors are installed on the roof of the building under the inclination 25° and oriented south. Distribution system of hot and cold water is designed from polybutylene tubes, which are stored in the floor, heat-insulated with pipes from polyethylene foam. Due to the remote location of kitchen sink from the hot water storage is in this part designed circulating pipe with circulation pump (Fig. 1).

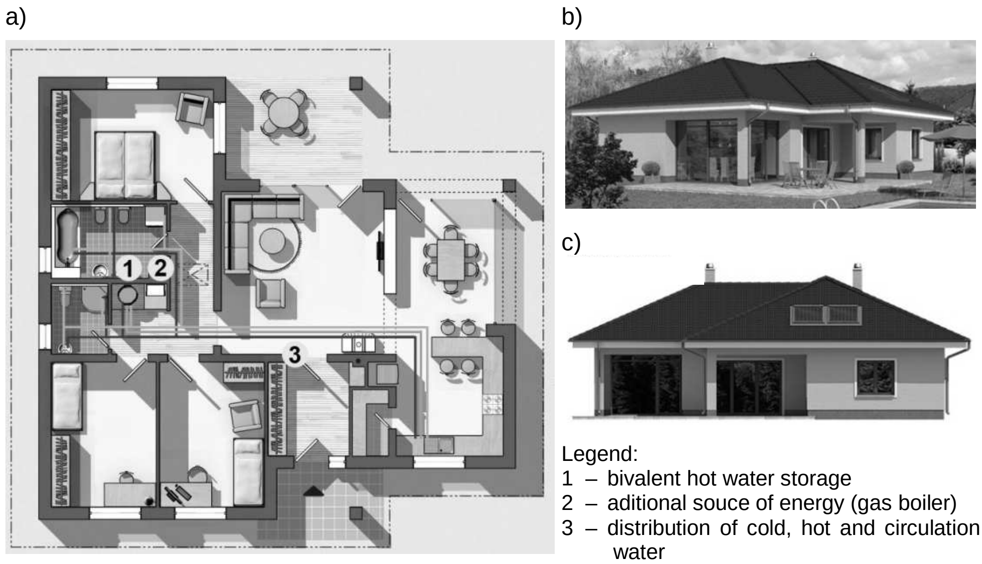

Fig. 1. Model of family house: a) layout, b) mounting the object, c) view from the south of installed solar collectors

Rys. 1. Model domu rodzinnego: a) plan, b) osadzenie obiektu, c) widok od południa na zainstalowane kolektory słoneczne

T a b l e 1

Technical parameters of solar collectors (Source: producer or STN EN 15 316-4-3)

Technical parameter	Symbols [units]	Flat collector	Tube collector
Angle of collector	[°]	25	25
Orientation of collector		south	south
Collector aperture area	A [m^2]	4,52	5,12
Efficiency factor (zero – loss)	η_0 [–]	0,77	0,665
First order heat loss coefficient of solar collector	a_1 [W/(m^2·K)]	3,6810	0,721
Second order heat loss coefficient of solar collector	a_2 [W/(m^2·K^2)]	0,0173	0,006
Heat loss coefficient of the collector	a [W/(m^2·K)]	4,37	0,961
Overall heat loss coefficient of all pipes in the collector loop	$U_{loop,p}$ [W/(m^2·K)]	7,26	7,56
Heat loss coefficient of the collector loop	U_{loop} [W/(m^2·K)]	5,98	2,44
Efficiency factor of the collector loop	η_{loop} [–]	0,9	0,9
Collector incidence angle modifier	IAM [–]	0,911	1,0
Storage tank capacity correction factor	f_{st} [–]	1,24	1,28

3. Energy balance of domestic hot water system

Within the frame of energy certification of domestic hot water system must be evaluated the energy of delivered domestic hot water, the energy requirements of distribution sub-system, accumulation sub-system and the additional energy for power of the equipment. In determining the energy of delivered domestic hot water for the chosen family house is proceed according to STN EN 15 316-3-1, which defines the required volume of hot water in litres per functional unit. In this case, functional unit is the building floor area [1]. Based on detailed analysis of individual sub-system of domestic hot water system was obtained all the necessary outputs to generate a graph of energy balance system without solar collectors (Fig. 2).

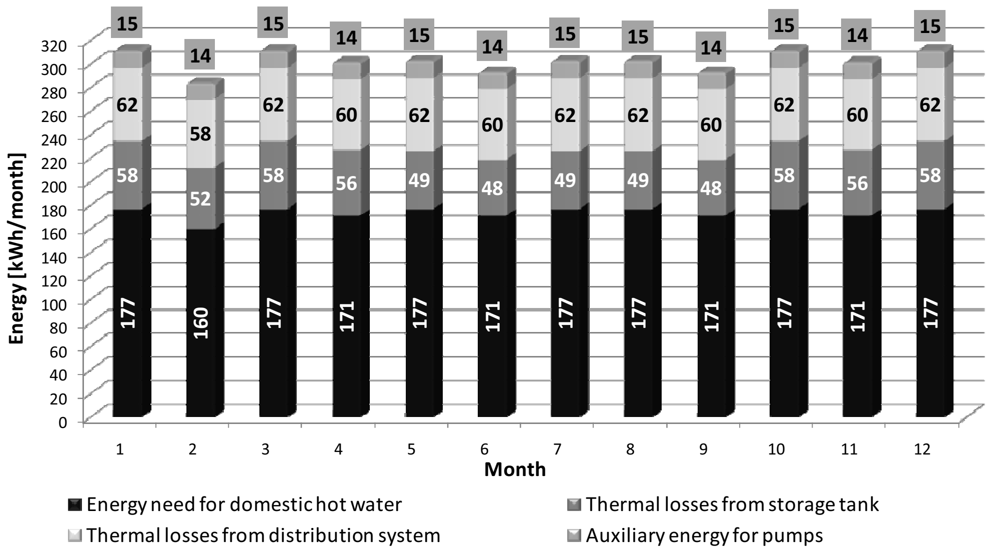

Fig. 2. The energy balance of domestic hot water system without solar collectors

Rys. 2. Bilans energii domowego zużycia ciepłej wody bez systemów solarnych

Effect of solar collectors in domestic hot water system is expressed in the value of total energy output of the solar system. This depends primarily on the input parameters characterizing the applied system of the solar collectors with accessories and of course on the assumed energy of delivered domestic hot water.

$$Q_{w,\mathrm{sol,out},m} = (a \cdot Y + b \cdot X + c \cdot Y^2 + d \cdot X^2 + e \cdot Y^3 + f \cdot Y^3) \cdot Q_{w,\mathrm{sol,us},m} \tag{1}$$

where:

$Q_{w,\mathrm{sol,out},m}$ – monthly energy output of the thermal solar system [kWh/month],
$Q_{w,\mathrm{sol,us},m}$ – monthly energy need for the domestic hot water [kWh/month],
a, b, c, d, e, f – correlation factor, STN EN 15316-4-3, Table B.1 [–],
X and Y – dimensionless factors [–].

Non dimensional numbers that enter into a relationship for calculating the energy output of the solar system in itself account the technical parameters themselves collectors and specifically solution of the solar system in the house. Factor, that have significant weight in their determination, are the monthly value of energy need for domestic hot water, the average intensity of sunlight at the time of sunshine and the time interval duration of sunshine in the month.

Model of family house is situated in the locality of the city Kosice, for which was determined the availability of direct and diffuse solar radiation (global radiation) at a clear sky by using analytical methods. Duration of a clear sky during the month is given, so called the mean relative sunshine that is determined by dividing the actual duration of sunshine at the site and possible astronomical sunshine. The average intensity of global radiation acting on the collector array at the time of sunshine was determined for each month of the year based on the actual surface density energy of the global solar radiation.

Table 2

Average intensity of solar radiation at the time of sunshine I_m [W/(m^2·month)]

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
279	387	458	482	522	531	524	479	467	421	315	251

Solar energy is transformed to the thermal energy by using solar collectors, either flat or tube vacuum. This energy is used in the domestic hot water system on cover of energy needs and thermal loss in individual sub-system. The Fig. 3 shows the coverage rate of calculated energy need for domestic hot water system in each month obtained the energy output of installed thermal solar system. Surplus heat, generated during the summer months, can be used for other purposes (pool heating, solar cooling, etc.).

The energy output of the thermal solar system is at average taller by 10 kWh in the case of tube vacuum collectors in comparison with the flat collectors in the winter months of the year (November-February), and by 20 kWh in the last months of the year. The equal balance between the energy need for domestic hot water system and energy output of the installed solar system is reached in May and August for flat collectors and in April and September for vacuum tube collectors. Therefore, the thermal solar system with vacuum tube collectors cover the energy need in full extent in the period April to September, about two months longer than thermal solar system with the plate collector. However, for using of incurred gains is need to operate further technological systems (swimming pool, solar cooling, etc.).

The following graph shows the balance of delivered energy per year to the domestic hot water system for individual variations, without taking into account the recovered energy. On the basis of delivered energy and net of recovered energy, system is classified into the energy class A–G (Table 3).

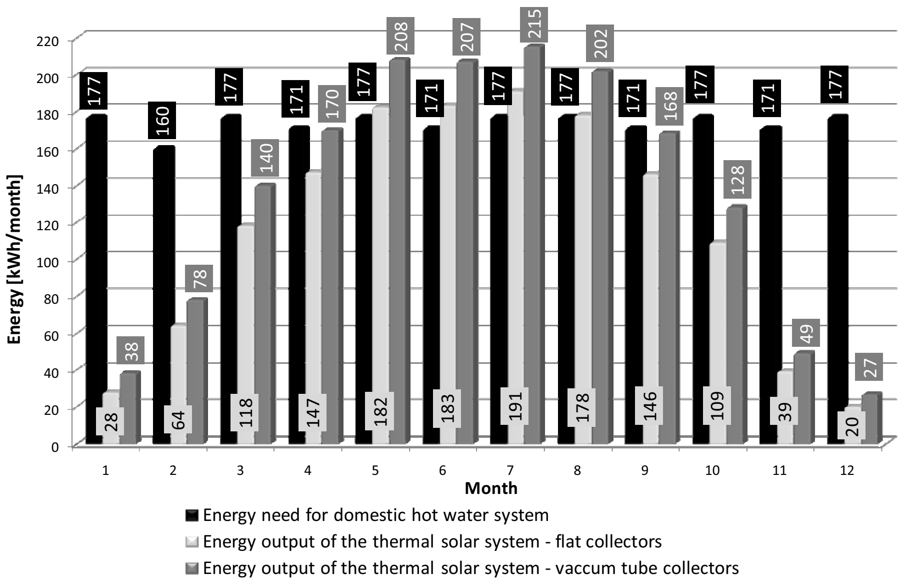

Fig. 3. Coverage of the monthly energy need for domestic hot water system with energy output of solar system

Rys. 3. Rozróżnienie miesięcznej energii potrzebnej do domowych systemów ciepłej wody z wydajnością systemów solarnych

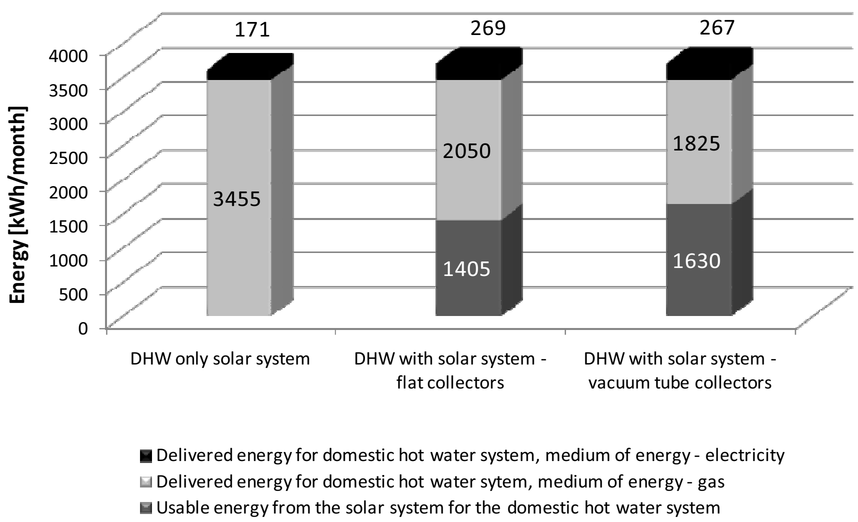

Fig. 4. Energy balance of domestic hot water system for individual variants according by delivered energy – not taking into account the recovered energy

Rys. 4. Bilans energii domowych systemów ciepłej wody dla wariantów indywidualnych zgodnie z dostarczoną energią + bez energii odzyskanej

Table 3

Energy class of domestic hot water system for evaluated variants

Parameter	DHW without solar system	DHW with solar system – flat collectors	DHW with solar system – tube collectors
Total delivered energy [kWh/year]	3626	2319	2092
Recovered energy from domestic hot water system [kWh/year]	131	186	186
Floor area [m^2]	116,9	116,9	116,9
Total delivered energy per 1 m^2 of floor area [kWh/(m^2·year)]	30	18	16
Energy class of domestic hot water system	**C**	**B**	**B**

4. Conclusions

Based on the presented results about the energy performance domestic hot water system in the model example of family house and for the following variants:
– without using solar collectors,
– using of flat solar collectors,
– and using vacuum tube solar collectors,
it's possible to clearly express the energy benefits of solar collectors. Total delivered energy for 1 m^2 of floor area is reduced by 40% in the case of flat collectors, and by 47% in the case of vacuum tube collectors. Content contribution is devoted exclusively to issues of energy and opportunities for reducing energy needs for the operation of buildings, which also stems from the adoption of legislative standards on energy performance of buildings. The question remains, however, a confrontation of entry investments, economic savings, and time of return (not rough return), what this contribution does not solve.

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