TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

3-B/2014

JOLANTA FIEDUCIK*, JAN GODLEWSKI**

THE LOW ENERGY HOUSE USING AN AIR SOLAR COLLECTOR – A CASE STUDY

DOM ENERGOOSZCZĘDNY WYKORZYSTUJĄCY SŁONECZNE KOLEKTORY POWIETRZNE – STUDIUM PRZYPADKU

A b s t r a c t

The main aim of this paper is to present the prospect of heating and cooling a house using solar air collectors. An analysis made of an energy-efficient house, for which the energy requirements for heating shall not exceed 40 kWh/m^2/a. The calculations used air collectors with an area of 60 m^2 and performance efficiency of 70%, which are available commercially. In the analyzed building the solar heating system provides almost full coverage of energy needs throughout the year, with a small shortfall occurring in December and January. The above-mentioned deficits at the beginning and end of the year can be supplemented with other alternative energy sources.

Keywords: *low energy house*, *solar air collector*, *heating and cooling system in buildings*

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

Celem tego artykułu jest przedstawienie możliwości ogrzewania i chłodzenia domu jednorodzinnego przy wykorzystaniu słonecznych kolektorów powietrznych. W analizie uwzględniono dom energooszczędny, którego wskaźnik sezonowego zapotrzebowania na ciepło wynosi 40 kWh/m^2/a. Do obliczeń przyjęto kolektory powietrzne dostępne na rynku o powierzchni 60 m^2 i wydajności wynoszącej 70%. W analizowanym budynku występuje prawie pełne pokrycie potrzeb na energię grzewczą w ciągu roku z powietrznych kolektorów słonecznych, oprócz niewielkich braków w tym względzie występujących w grudniu i styczniu. Wspomniane w tym przypadku pewne braki ciepła w końcu i na początku roku można uzupełnić z innych alternatywnych źródeł ciepła.

Słowa kluczowe: *dom energooszczędny*, *słoneczne kolektory powietrzne*, *system grzania i chłodzenia w budynkach*

* Ph.D. Jolanta Fieducik, Faculty of Technical Sciences, University of Warmia and Mazury in Olsztyn.

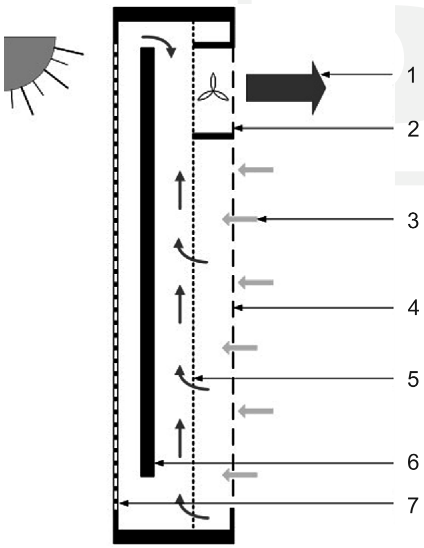
** Ph.D. Jan Godlewski, Faculty of Applied Physics and Mathematics, Gdańsk University of Technology.

1. Introduction

The use of solar energy for heating and other energy-producing purposes is becoming more and more of a topical issue as the supply of fossil fuels diminishes [3, 4]. This is especially important for small buildings which take up enough space, that the solar energy that reaches them would, in theory, be sufficient to cover the building’s full energy needs. A single family house is such an example. The aim of providing the energy from solar supplies can be realized in various ways [1–4]. The goal of this article is to analyze the possibility of using solar collectors to obtain the thermal energy to heat a low energy house throughout the whole year. Additionally, an analysis regarding using the collectors to cool the building is included in the article. The analysis is carried out using the climatic conditions of the city of Olsztyn and commercially available air collectors as an example. As part of the evaluation the energy balancing task is to be carried out without giving any particulars of the control systems used during the utilization of the building.

2. The construction and parameters of air collectors

In air collectors, the solar energy passes into the absorber, in which the air is heated. Solar collectors can be uncovered, in which the solar energy hits the absorber directly, or covered, in which the absorber is covered by a transparent screen. Depending on the construction of the collector, the air stream can either flow over or under the absorber, and in more advanced constructions, over and under or through the absorber. In the collector, the air stream flows



1 – Fresh and heated air is blown inside.
2 – Fan.
3 – Air is sucked through the perforated aluminium cover over the whole of its surface.
4 – Perforated aluminium.
5 – Black felt mat.
6 – Cover.
7 – Photovoltaic module.

Fig. 1. A diagram and the working principles of an air collector

through specially shaped channels. The channels can have a rectangular, triangular or oval cross-section. The absorber can be flat, or it can be bumpy or porous, which highly increases the surface area and efficiency of the heat exchange between the absorber and the passing air. A diagram of an air collector is shown in Fig. 1.

Air collectors are characterized by both a very efficient rate of exchange from solar to thermal energy [1–5], and the fact that the working element is air. In temperatures typical for the Earth's climate, air does not undergo changes of state, so the use of air collectors is not hindered by difficulties related to temperature changes. Additionally, air heated in collectors can be used directly to heat the building, without the use of any intermediary systems. The use of the air flowing through the collector can also provide very good ventilation of the heated space. An undeniable advantage of air collectors is the ease with which the air stream can be controlled and the thermodynamic space monitored, and also the speed with which the temperature can be changed. A diagram of a collector produced by SolarVenti is shown in Fig. 2.

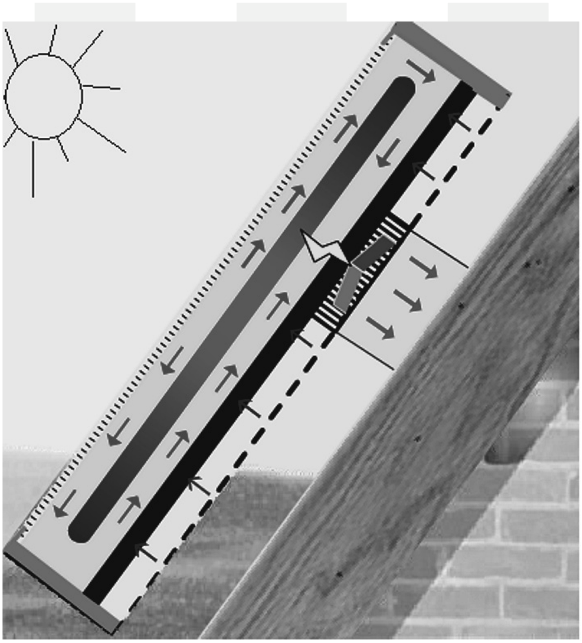


Fig. 2. A working diagram of a SolarVenti air collector during a heating cycle [7]

One disadvantage of air collectors is that, if changing the working element from air to any liquid, to heat a house or any other building, the heat exchanger needs to be more complicated than in the case of a liquid-liquid exchange [2]. There is a variety of manufacturers of air collectors of various types and purposes. Table 1 below presents the technical parameters of a typical air collector produced by SolarVenti.

Table 1

Specifications of the SolarVenti SV30X [6] air collector

Air manifold surface area	3 [m^2]
Maximum air flow	200 [m^3]
Total time to exchange all air in the room	2 [hours]
Efficiency	70 [%]
Average energy production	2100 [kWh/year*]
Increase in temperature in the intake manifold, in relation to the outside temperature	c. 40 [ºC] (eg. from 10 [ºC] to 50 [ºC])
Manifold dimensions in mm: length x width x depth	3000 × 1020 × 75 [mm]
Solar PV power	38 [Watt]
Fan power	5.1 [Watt]
Weight (panel)	22.5 [kg]
Maintenance-free period	Up to 15 [years]
Product warranty	5 [years]
Collector housing	Aluminum
Cover (transparent)	Polycarbonate
Can also be used as a cooling system	Yes

* the value given is for Danish atmospheric conditions

3. Energy conditions

As indicated in the subject of this thesis, there will be an analysis of the energy conditions related to the demand for thermal energy for heating purposes in a single family house, under the assumption that the area of the house is 150 m^2, while the dimensions of the house at its base are 10x10m. The demand for heat in the house is 40 kWh/m^2/a in accordance with the NF40 standard. For the purpose of this analysis it has been assumed that the roof is at a 45 degree slope, and that one side of the roof has an area of 60 m^2 and is completely covered in solar collectors. Based on the meteorological data for the city of Olsztyn, using the program GetSolar Professional [5], for each month the following values of solar energy per square metre of the collector are obtained (labelled radiation – column 2, Table 2). Other figures are also given in Table 2 which are necessary for the calculations.

As has been assumed previously, the radiation energy hits an array of collectors with a surface area of 60 m^2. For the calculations the demand for thermal energy for a 150 m^2 house has been set at the rate of 6000 kWh/year, in accordance with regulations for a low energy house. From Table 2 and Fig. 3 it can be seen that for the house parameters specified above and a collector array of 60 m^2, there is a surplus of heat, especially during the summer. Heat deficits only exist for two months in winter, specifically November and January. During the months in which there is an explicit energy surplus, the total value of this surplus is approximately 40 000 kWh. Relatively speaking, the deficit during the winter months is small – 771 kWh. The energy missing during the winter months could be covered by other sources of energy, if energy is not stored. In [8] it has been shown that the energy necessary to heat the house during the winter can easily be stored during the summer.

Table 2

The energy balance for solar energy obtained from the sun and energy necessary for heating purposes for a single family house on a month-by-month basis

Month	Radiation per [m^2] of the collector	Energy necessary to heat a 150 [m^2] NF 40 standard house	Total radiation on a 60 [m^2] collector	Solar gain from a 60 [m^2] collector – efficiency 70%	Surplus or deficit of energy from a 60 [m^2] collector
1	2	3	4	5	6
	[kWh/m^2]	[kWh]	[kWh]	[kWh]	[kWh]
January	24.4	1310	1464	1025	–285
February	37.2	886	2232	1562	+677
March	77.9	700	4674	3272	+2572
April	119	379	7140	4998	+4619
May	152	184	9120	6384	+6200
June	165	45	9900	6930	+6885
July	168	0	10080	7056	+7056
August	144	13	8640	6048	+6035
September	100	160	6000	4200	+4040
October	61.6	532	3696	2587	+2055
November	25.6	575	1536	1075	+500
December	17.4	1217	1044	731	–486
Total	1092	6000	65526	45868	39868

The table has been created using data from the program GetSolar, for Olsztyn – latitude 53.5 and longitude 20.3. The results are presented in graphical form in Fig. 3.

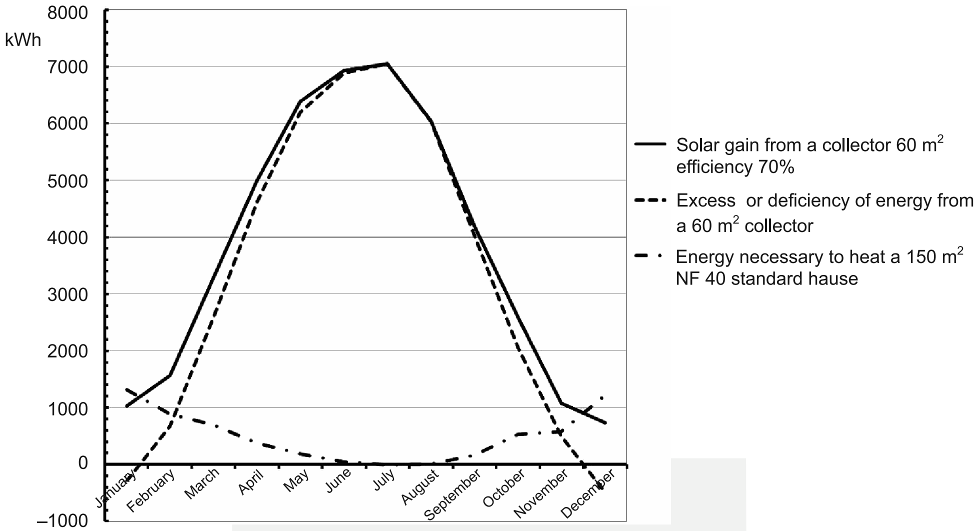


Fig. 3. Energy balance obtained from collectors and the energy necessary to heat the house

4. Using sun collectors for cooling purposes

Sun collectors also have, if in a limited scope, the ability to cool buildings. Certain types of collectors have specially adapted streaming systems that can be used for a cooling effect. Obtaining a cooling effect, however, requires that the whole building has been specially

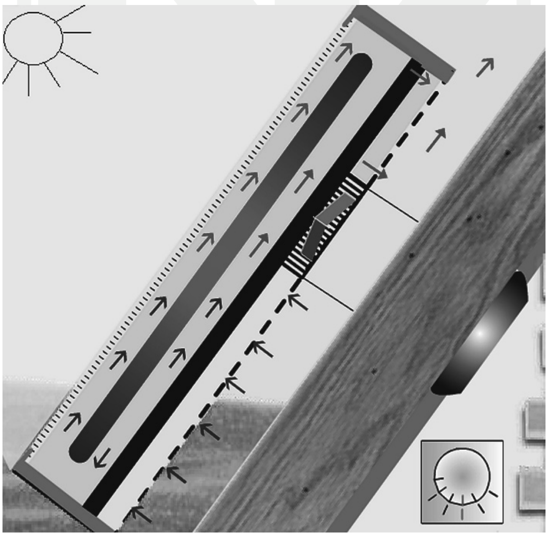


Fig. 4. A working diagram of a SolarVenti sun collector during a cooling cycle [7]

adapted for that purpose. In the case of a single family house, the part of the building that is exposed to sunlight should be covered in air collectors, and the rest of the building's surface should be made of a material that significantly reflects electromagnetic radiation of different wavelengths (for example metal foil). The heated air should be sucked away from the part of the building exposed to sunlight, or else kept for storing heat. This would result in a temperature only a couple of degrees higher than that of the ground – approximately 20 Celsius degrees. Cooling with the use of a collector is a relatively cheap method, though, this cooling system would not be sufficient in hot climates. In such conditions, a more sophisticated cooling system based on sun collectors should be used. Such systems have been described in [2]. A diagram of a SolarVenti collector is presented in Fig. 4.

5. Conclusions

New potential uses of solar air collectors have been introduced. Due to the simple construction, relative cheapness and the fact that the working element is air, these collectors are excellent for heating and cooling houses in temperate climates. Air collectors can also be used for the ventilation of buildings, which is an important consideration in low energy architecture. The use of sun collectors for heating, cooling and ventilation purposes should be accounted for when the building is being designed.

References

[1] Kalogirou S.A., *Solar thermal collectors and applications*, Progress in Energy and Combustion Science 30, 2004, 231-295.
[2] Kim D.S., Infante Ferreira C.A., *Solar refrigeration options – a state – of-the-art review*, International Journal of Refrigeration, 31, 2008, 3-15.
[3] Smolec W., *Fototermiczna konwersja energii słonecznej*, PWN, Warszawa 2000.
[4] Timilsina G.R., Kurdgelashvili L. Narbel P.A., *A review of solar energy; Markets, economics and policies*, Policy Research Working Paper 5845, Soc. Sci. Res. Netw., 2011, 49 pages.
[5] GetSolar software author: Dipl.-Ing Markus Maier. version 10.1.1. 21.12.2009.
[6] http://www.ventilacionsolarcanarias.com
[7] http://www.galileaenergy.com/kolektory-powietrzne-systemy-solar-venti.php
[8] Fieducik J., Godlewski J., *Storing thermal energy from solar collectors for the needs of a detached house*, Polish Journal of Environment Studies, 2014 (in print).