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A Study of Opportunities of Using Solar Energy Radiation for Under Floor Heating in a Pig-shed

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Abstract: **The opportunities to build under floor heating pig building with solar energy are considered. The energy yield per unit surface of solar collectors for various tilt angles is determined by different methods. The theoretical model for building collector heating system integrated into the floor coils in a real pig building is developed. The parameters of conceptual installation in a heating period (November-March) for Bulgaria are analyzed.**

Keywords: **Solar Energy, Under Floor Heating, Tilt Angle, Pig Building**

I. Introduction

In recent years underfloor heating is gaining in popularity in animal raising, especially in the area of industrial-scale pig raising. Its use in this subsector is associated with an increase in the average daily growth of adolescent animals, decrease of the rate of feed per kilogram of live weight, improvement of health status and general indoor micro climate [1].

In terms of applied thermal engineering, underfloor heating is a low temperature solution employing radiation heat release. The necessary energy can be supplied from conventional or renewable energy sources. Integration of underfloor heating modules in solar thermal installations gives a real opportunity to improve energy efficiency in modern animal raising farms. Achieving of widespread use of this approach involves a preliminary analysis of the potential annual energy output of solar collectors within particular installation and engineering parameters [2].

The efficiency of solar thermal systems is dependent in a very high extent on the orientation and tilt angle of the collector field [3][4], especially in those cases where the energy is used for heating of residential, public and industrial structures. Monthly or seasonal adjustment of the tilt angle of solar panels is mandatory in view of maximum energy output [5]. Precise values of this parameter are essential for the temperature potential of the thermal agent circulating inside each system [6][7].

These findings underline the need for analysis of the influence of collector field parameters on the operating mode of radiation underfloor heating integrated into a solar thermal system.

Aim and Objectives of the Study

The aim of this study is a theoretical exploration of the opportunities of using solar energy in a radiation underfloor heating system of a building for raising of adolescent pigs and the influence of collector field parameters on the monthly energy output. On the basis of the established relations, a schematic diagram of a solar collector system for operation with underfloor coils of a low-temperature radiation heating system has been proposed.

II. Materials and Methods

The experimental study and its analysis were based on a conventional pig-shed for raising of adolescent pigs in group pens with solid flooring. The general layout of the building is shown in the drawing of Figure 1.

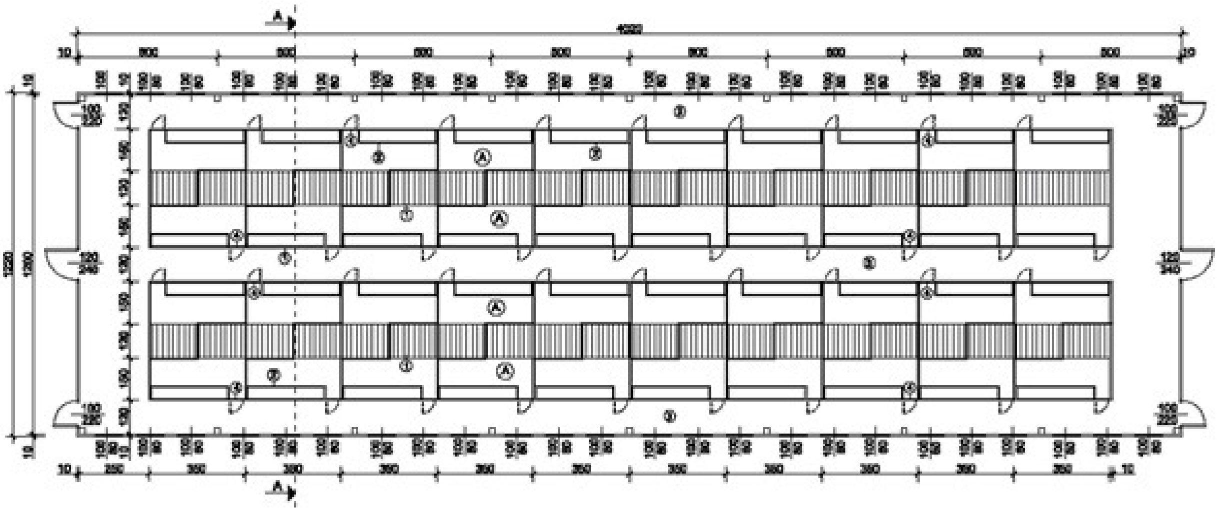

Fig.1. Pig-shed with solid floor pens for raising of adolescent pigs.

The building was of floorage 480 m^2, of which 148 m^2 with thermal insulation for underfloor heating. The area of windows was 72m^2, enclosing walls 248 m^2, and roof 497m^2. Heat transfer coefficients of walls, roof and windows were 1,92; 2,25 and 3,38W/m^2K, respectively. The building had a forced ventilation system and a radiation underfloor heating system. The building was used to raise 360 adolescent pigs in the average (maximum capacity being 400 pigs). Calculations made are applicable for the climatic zone of Central Southern Bulgaria.

The total thermal energy demand for provision of micro climatic comfort for animals in the shed (E_{dmd}) was determined from the following general model:

$$E_{dmd} = Q_1 + Q_2 + Q_3 - Q_4, kWh \quad ...(1)$$

where:
Q_1 – heat transfer trough building enclosure;
Q_2 – heat loss through floor;
Q_3 - heat loss from ventilation;
Q_4 – heat flow release by animals.

Calculations of the components Q_1, Q_2 and Q3 were made using standard thermal engineering methods [8] which are not subject to discussion in this study. The value of ingredient Q_4 was assumed in accordance the current animal hygiene standards.

Energy to be supplied from the underfloor heating coil was calculated from the formula:

$$E_{coil} = \frac{E_{dmd}}{r_{ng}}, kW \quad ...(2)$$

where:
E_{coil} –thermal energy required from coil, kWh
r_{ng} - relative thermal resistance of the layers under floor heating system (determined in accordance with the thermal engineering methods (Stamov St., 2001).

Solar energy utilized by the collector field per month of the heating period shall be:

$$E_m = E_{dy}.\eta.D, kWh/m^2 \quad ....(3)$$

where:
E_m– energy utilized within a specific month of the heating period;
E_{dy}– total solar radiation for a specific day of the month recorded at a specific angle to the sun. Calculated as a statistical parameter from a climatological guide (Stamov St., 2001), kWh/m^2 .day.
η – efficiency of solar collectors of flat design and with selective coating, being an integral value of the interval 0.20÷0.75.
D – number of days of the month considered.

The required area of solar collectors integrated with an underfloor heating coil was determined from the formula:

$$F_{sc} = \frac{Q_{coil}.\tau}{\eta.E_{dy}}.k, m^2 \quad ...(4)$$

where:
F_{sc}– required collector area, m^2
Q_{coil} - coil thermal power rating, kW;
τ - duration of effective solstice per typical day of the specific month, h.
k – coefficient allowing for heat loss in the solar system, of assumed fixed value k=1.1.

Coil thermal power rating was obtained from:

$$Q_{coil} = \frac{E_{dmd}}{r_{ng}\,\tau\,.3600}, kW \quad ...(5)$$

Analysis of the influence of the tilt angle "β" of the collector field was made on the basis of the unspecified type of functions:

$$E_m = f(\beta), kWh \text{ per month} \quad ...(6)$$

$$F_{sc} = f(\beta), m^2 \quad ...(7)$$

Results of energy output of the solar collector field at β =40°,45°50°,55°,60° for the months of November, December, January, February, and March were considered.

III. Results and Discussion

Data from Table 1 clearly suggests the possibility of real thermal energy output from solar radiation. The potential was of close values for all months of the discussed period. The lowest energy output at all tilt angles were for December and January. This finding was quite reasonable in view of the solstice duration and general climatic conditions in these two months.

Table 1. Energy output per 1 m2 collector area as a function of tilt angle within the heating season.

Value of tilt angle β, °	Monthly energy output per 1 m^2 collector area, kWh					Annual energy output, kWh	Average monthly energy output, kWh
	XI	XII	I	II	III		
40	26.5	17.4	18.5	28.2	49	139.5	27.9
45	31.7	20	18.5	28.2	49	147.5	29.5
50	31.7	20	21.2	28.2	49	150	30
55	33.1	20	21.2	29.4	49	152.7	30.6
60	33.1	20	21.2	28.2	47.4	150	30

Regardless of the small differences in energy output among the individual gradations of the table parameters, it is worth noting that the potential of collector area increased with the increase of the tilt angle from 40 to 55°, and at 60° decreased.

The above pattern was similar for each month within the period considered.

In Figure2 is shown a graphical profile of the total and average energy output at different values of β for better visualization of the dependence of the collector field parameters on the tilt angle.

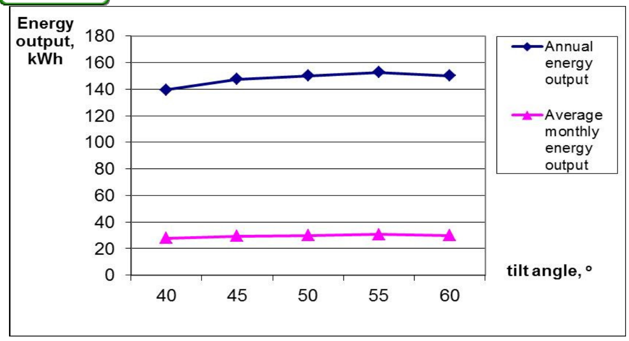

Fig. 2. Annual and average energy output at different values of the tilt angle.

Graphic interpretation clearly leads to the conclusion that energy performance was best at tilt angle β=55°. This angle value provides a total energy output of 152.7 kWh/m^2 and respectively an average of 30.6 kWh/m^2 for November and March of the period discussed.

Table 2 was constructed on the basis of the results from formula (4). The required collector area to supply adequate energy to the underfloor heating coils was highest for December and January. The interval was in the range of 119-145 m^2. That result is in full measure in line with the above pattern of the lowest energy output and corresponding reasons for those two months.

Table 2.Required area of the collector field as a function of tilt angle.

Value of tilt angle β, °	Required collector area by months, m^2					Average value, m^2
	XI	XII	I	II	III	
40	105	145	136	92	66	108.8
45	88	140	136	92	66	101.6
50	88	136	119	92	66	100.2
55	84	136	119	88	66	98.6
60	84	136	119	88	66	98.6

On examination of the values of the required collector area with relation to the angle β, it is evident that 55° was the most suitable tilt angle for the collector field. At this tilt angle the average collector area calculated for the period considered was the lowest at F_{sc} = 98.6 m^2.

The graph in Fig. 3 highlights the relation established. In addition, it should be noted that March was excluded from the above patters. The required collector area within March was the same at 66 m^2 for all values of the tilt angle. This was reflected in the similar average values of the collector areas at angles 55° and 60°.

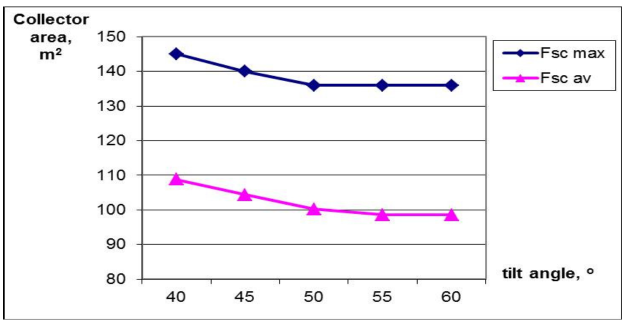

Fig. 3. Influence of the tilt angle on the required collector area.

Summarizing these results leads to the conclusion that in terms of the minimum collector area the most appropriate tilt angle was 55°. The established relation is entirely consistent with the analysis of Table 1 and the graph in Figure 1.

Irrespective of the conclusions made so far, there arises the question as to the practical sizing of the collector field with a view to the energy needs of the building and the corresponding underfloor heating system. Should the average required collector area of 98,6 m^2 at tilt angle 55° be applied as a criterion, then there will be a risk of energy shortage during certain days of December and January. In view of completely ensuring of the required heat release performance of coils (and their corresponding floor surfaces)throughout the heating period, the actual size of the collector field should match the maximum required 136 m^2 at a tilt angle 55°.

In Fig. 4 is shown the schematic diagram of aunderfloor heating system for adolescent pigs, powered by a solar collector system.

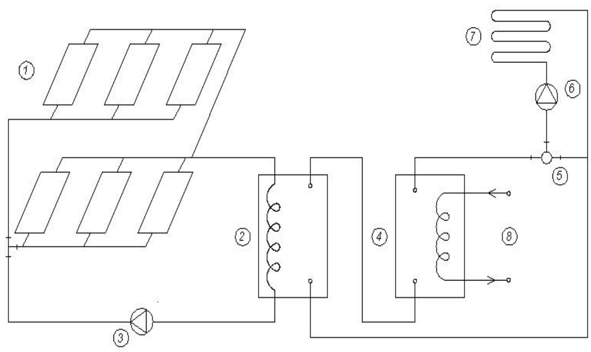

Fig. 4. Schematic diagram of integrating a solar collector field with radiation underfloor heating system for raising of adolescent pigs.

1- Collector field of tilt angle 55^o; 2 – heat accumulator with inner heat exchanger of collector field; 3 – recirculation pump of solar collector field; 4 – heat accumulator for additional heating up of thermal agent; 5 – three-way module with motorized valve and PID control; 6 – recirculation pump of underfloor heating; 7 - underfloor heating coils; 8 – heat exchanger for additional heating up by standby resource (for example, pellet boiler).

The collector field (1) should be constructed by selective collectors of total area 136 m^2 (corresponding to 68 single modules). These were connected in parallel and installed at an angle of 55° to the horizontal plane. Heat accumulator (2) and recirculation pump (3) provided reserve energy and indirect heating up of the thermal agent in the coils (7) of the underfloor heating system. The second heat accumulator (4) was connected in series to the collector system. It was designed for standby heat up of the heat agent on days with insufficient solar radiation and at hours when the heat accumulator (2) was of exhausted capacity. The three-way mixing module (5) ensured a constant temperature (about 30°C) of the heat agent to the coils (7) of the underfloor heating system. The hydraulic flow though it was regulated by PID controlled motorized valve as a function of the heat agent temperature.

Recirculation pump (6) provided mechanical energy to transfer the heat agent through the coils, accumulators and three-way mixing module.

IV. CONCLUSION

Solar collector systems can successfully provide low-potential heat for radiation underfloor heating in pig-sheds.

Average monthly energy output and total energy output throughout the heating period depend on the value of the tilt angle. During winter months the highest energy output was obtained at tilt angle 55°.

Angle tilt affects the solar collector area required for a building. The smallest solar collector area can be obtained at tilt angle below 55°.

Actual installed collector area shall comply with the maximum required area for the heating period at tilt angle β =55°.

REFERENCES

[1] Peychev K., An opportunity for underfloor heating for livestock building without a low-temperature mixing module, Union of Scientists, Stara Zagora, Scientific conference with international participation, 7-8.06.2007, http//www.sustz.com, Animal Husbandry and Veterinary Medicine, 2007,pp151-158.

[2] Georgiev R., K. Peychev, Energy output of flat thermal solar collector – a theoretical study, Union of Scientists, Stara Zagora, Scientific conference with international participation, 5-6.06.2008.

[3] Hartley L.E., Martinez-Lozano Y.A, The optimization of the angle of inclination of a solar collector to maximize the incident solar radiation, Renew Energy,17, 1999, pp. 291-309.

[4] Oloketuyi S. Idown, Oyewola M. Olarenwaju and Odesola I. Ifedayo, International Journal of Energy and Environmental Engineering, 2013.

[5] Keshavarz S., A.P. Talebizadeh, S. Adalatia, M.A.Mehrabian, M. Abdolzadeh, Optimal Slope-Angles to Determine Maximum Solar Energy Gain for Solar Collectors Used in Iran, International Journal of Renewable Energy Research, vol.2, No 4, 2012.

[6] Peychev K., R. Georgiev, D. Dimitrova, Theoretical study of absorption refrigeration system thermally activated by a vacuum pipe solar collector, Agriculture science and technology, vol. 2, N3, 2010, pp. 163-166.

[7] Peychev K., R. Georgiev, Development and experimental study of the maximum temperature potential of a solar thermal module for driving of an absorption air-conditioning machine, Agriculture science and technology vol.3, 2011, pp.240-245.

[8] Stamov St., A guide to heating, air conditioning and cooling, Part 2: Heating and gas supply, Tehnika Publishing House, Sofia, 2001.

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