CALCULATIONS OF SEMI-SPHERICAL SOLAR COLLECTOR WITH REFLECTOR

Ilze Pelece
Latvia University of Agriculture
ilze.pelece@llu.lv

Abstract. As it was shown in our previous works, a solar collector with a semi-spherical absorber is suitable for gain of solar energy in Latvia and other northern countries. The main advantage of the semi-spherical solar collector is its ability to collect the solar energy from all sides to conform to the long path of the Sun in summer. As it has been shown, there are no spots on the semi-spherical absorber which would not receive the solar beam radiation. However, the northern side receives the solar energy only in the morning and evening. At midday it is much colder then the southern side and therefore diminishes the energy gain via excess cooling. Therefore, additional supply of solar beams to the northern side of the absorber by using a reflector would be useful. The main problem is that the reflector must not shadow the collector at any position of the Sun. An effort has been done in this work to calculate the right shape, size and position of the reflector for the maximal possible energy gain from the semi-spherical solar collector. Calculations have been done using the method of the effective area developed in our previous works. The calculations show that the reflector can increase the energy gain by 60 % at summer midday.

Keywords: solar collector, semi-spherical, reflector.

Introduction

Along with other renewable energy sources, solar energy has been widely used around the world. Also in Latvia solar energy is used [1], but there are some peculiarities in comparison with traditional solar energy using countries [2]. There is a long day in summer and therefore a long path of the Sun, small maximal height of the Sun and therefore small maximal irradiation, and considerable nebulosity. Therefore, a traditional flat-plate solar collector is not appropriate enough for use in Latvia (and also in other northern countries) and new constructions of solar collectors are necessary.

One of such new constructions of the solar collector suitable for the use in Latvia and other northern countries can be a semi-spherical solar collector [3]. Such collector has been made (Fig. 1) and measurements of the received energy have been carried out [4].

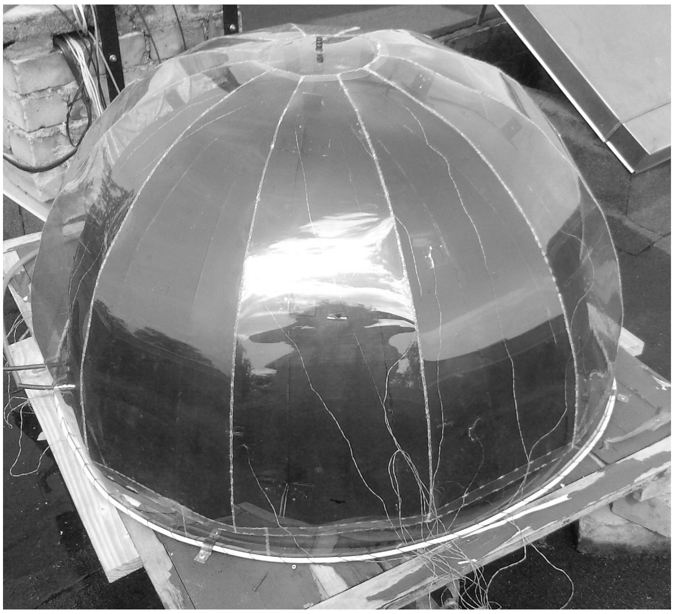

Fig.1. **Semi-spherical solar collector [3]**

The semi-spherical solar collector receives energy from all sides and there are no spots on it which would not receive direct solar energy [3]. However, the northern side receives direct radiation only in the morning and evening, at midday its temperature is considerably lower than the temperature of the southern side (Fig. 2).

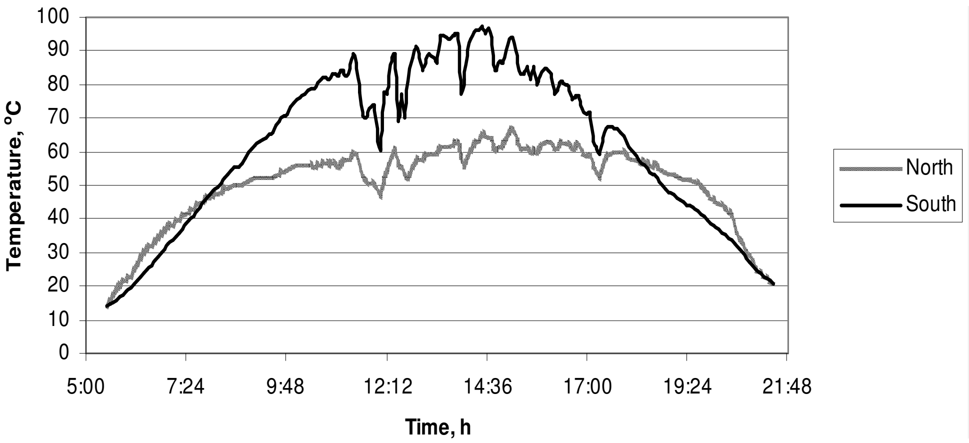

Fig. 2. **Daily courses of surface temperatures at northern and southern sides of the semi-spherical solar collector, 17 June 2009 [3]**

This colder surface results in additional cooling of the solar collector and therefore diminishes the energy gain. Therefore, it can be useful to avoid this temperature difference using the reflector. The aim of this article is to calculate the best shape, size and position of the reflector for maximum energy gain.

Materials and methods

The main problem is that the reflector must reflect solar beams as large part of the day as possible, but must not screen the collector at any position of the Sun.

Several shapes (concave, convex and flat) of the reflector have been considered.

The methods of calculations discussed in our previous works [5; 6] have been used.

Results and discussion

The concave reflector screens itself when the position of the Sun changes. The convex reflector gives reflected beams to the same spot as direct ones; therefore, it does not diminish unevenness of the surface temperature of the collector.

The calculations show, that the best is simply a flat reflector positioned vertically at the northern side of the collector. The position of the reflector is shown in Figure 3. The method of effective areas [2] gives, that in this case the amounts of direct and reflected radiation are equal if the coefficient of reflection is equal to 1.

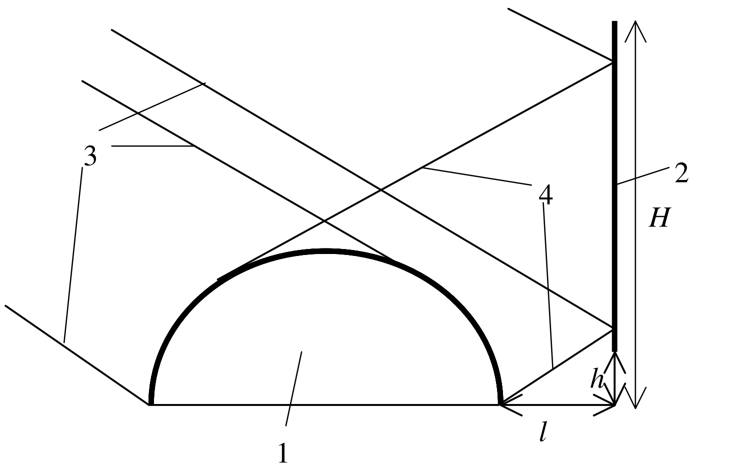

Fig. 3. **Semi-spherical solar collector with reflector:** 1 – collector; 2 – reflector; 3 – direct solar beams; 4 – reflected beams; *l* – distance between the collector and reflector; *h* – height of the bottom of the reflector; *H* – height of the top of the reflector

The optimal distance of the reflector from the collector is the smallest, at which the collector can receive the reflected radiation from the lowest part of the reflector, and it depends on the radius of the collector as given in formula (1).

$$l = \frac{R}{2\,\mathrm{tg}\,\delta_{\min}}, \tag{1}$$

where l – distance from the collector to the reflector, m;
R – radius of the collector, m;
$\delta_{\min}$ – minimal height of the Sun at midday (within season), degrees.

In our case the radius of the collector is 0.56 m, and if we consider the season of use of the collector from the 1st of March to the 31st of October then the minimal height of the Sun at the noon is on the 31st of October and it is 19 degrees. Then the optimal distance from the collector to the reflector is 0.82 m.

The bottom of the reflector can be not directly on the ground level; the maximal height of its bottom depends only on the radius of the collector and is equal to the half of it.

The minimal height of the top of the reflector is determined by the maximal height of the Sun as given in formula (2).

$$H = \left(R\sin\delta_{\max} + R + l\right)\cdot \mathrm{tg}\,\delta_{\max} + \frac{R}{2}, \tag{2}$$

where H – height of the top of the reflector, m.

The maximal height of the Sun is on the 21st of June, and it is 56.5 degrees. Then we obtain the height of the top of the reflector 3 m.

The main variable remains the width of the reflector. The wider it will be, the longer the time of the day when it works. But if it will be too wide, it would screen the collector in the morning and evening. The daily course of solar power received by the collector with or without the reflector is shown in Fig. 4. The width of the reflector is 6 m, reflectance of the reflector has been taken 0.6 in these calculations.

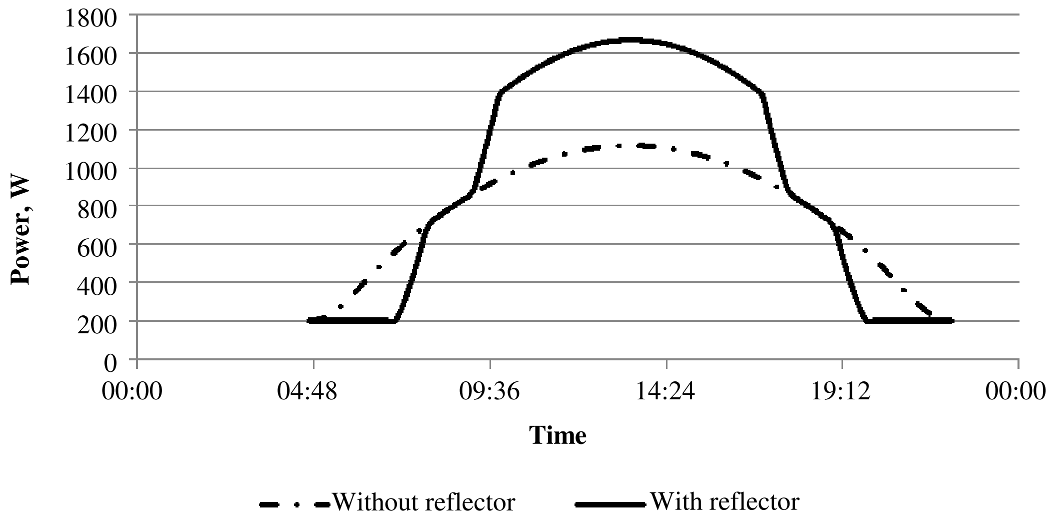

Fig. 4. **Daily course of solar power received by collector with or without reflector**

Fig. 5 shows the dependence of seazonal (from the 1-st of March till the 31-st of October) energy gain from the solar collector on the width of the reflector.

The energy gain from the same collector without the reflector calculated by the same methodics is 6220 MJ. It can be seen from Fig. 5 that rather a small reflector gives big increase of energy gain, while at the width of the reflector approximetly 5-6 m further increase becomes negligible. Therefore, the optimal width of the reflector (for collector with radius 0.56 m) is approximetly 6 m.

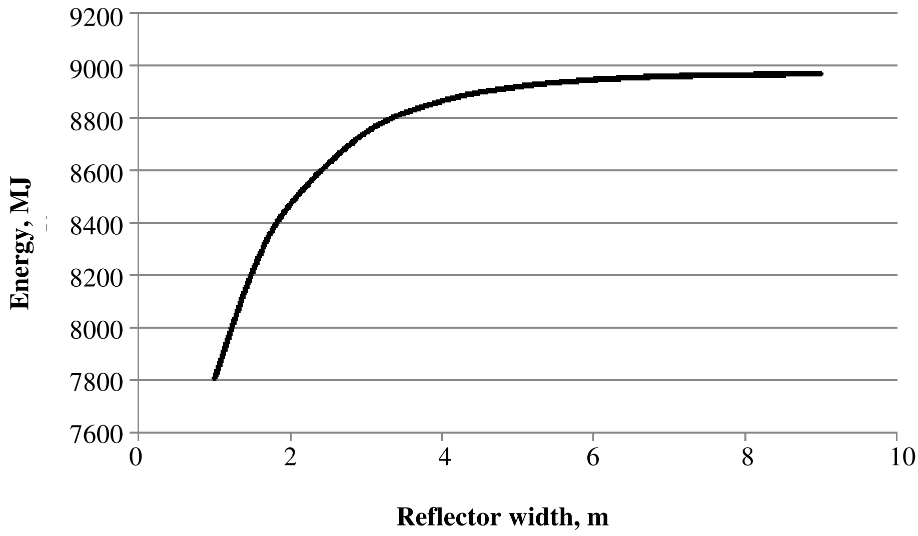

Fig. 5. **Dependence of seazonal (from the 1st of March till the 31st of October) energy gain from solar collector on width of reflector**

Comparison of yearly course of energy gain from a semispherical solar collector with 6 m wide reflector and without the reflector is show in Fig. 6.

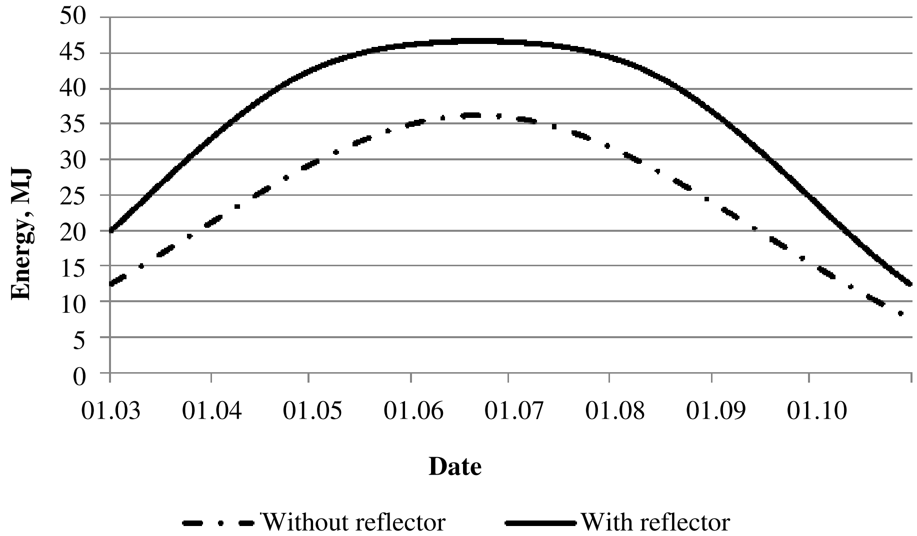

Fig. 6. **Year course of energy gain**

Of corse, a 6 m wide and 3 m high reflector is rather big, expensive and inconvenient in use. But one way how practicaly these obtained results can be used is that it is not necessary to bring the collector up on the roof, it can be simply placed on the ground near the south wall of the building, and the wall can serve as a reflector. Further studies must be carried out to find out the coefficient of reflectance of the wall, and to get to know about better finishing of the wall for greater reflectance.

Conclusions

1. A flat reflector is more convenient for use with a semi-spherical solar collector.
2. A reflector of the size 3x6 m with the coefficient of reflectance 0.6 gives increase of daily energy gain 1.3 to 1.6 times; increase of year energy gain is 1.43 times.
3. It is not necessary to bring the collector up on the roof, it can be simply placed on the ground near the south wall of the building, and the wall can serve as a reflector

References

1. Ziemelis I., Iljins U., Navickas J. Economical Comparison of Some Parameters of Flat-Plate Solar Collectors. Proceedings of International Research Conference "The Role of Chemistry and Physics in the Development of Agricultural Technologies", 2004, Lithuania, Kaunas, pp. 23-25.
2. Pelēce I. Modelling of new constructions of solar collectors. Proceedings of the 4th international scientific conference "Applied information and communication technologies", April 22-23, 2010, Jelgava, Latvia. Latvia University of Agriculture, Faculty of Information Technologies, pp. 200-207.
3. Pelece I., Ziemelis I., Iljins U. Surface temperature investigations of semi-spherical solar collector. Proceedings of the 4th International scientific conference "Rural Development 2009", 15-17 October, 2009, Akademija, Kaunas region, Lithuania. Lithuanian University of Agriculture. Kaunas: Akademija. Vol.4, Book.2, pp. 370-373. ISSN 1822-3230.
4. Pelēce I. Semi-spherical solar collector for water heating. Proceedings of 9th International scientific conference "Engineering for rural development", May 27 - 28, 2010, Jelgava. Latvia University of Agriculture. Faculty of Engineering. Institute of Mechanics. Jelgava; LLU. Vol.9, pp. 211-215.
5. Pelēce I., Iljins U., Ziemelis I. Theoretical calculation of energy received by semi-spherical solar collector. Agronomy Research, Vol.6: Engineering of Agricultural Technologies: International Scientific conference, Special issue, pp. 263-269. ISSN 1406-894x.
6. Pelece I., Iljins U. Improoved method of calculation of energy gain from solar collector. Proceedings of 7th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics, 2010, Antalya, Turkey, pp.1935-1938.