Technical University of Denmark

Side by side tests of two SDHW systems with solar collectors with and without antireflection treatment

Kong, Weiqiang; Han, Jiangong; Perers, Bengt; Furbo, Simon; Fan, Jianhua

Published in:
Energy Procedia

Link to article, DOI:
10.1016/j.egypro.2015.02.148

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 70 (2015) 462 – 469

Energy Procedia

International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2014

Side by side tests of two SDHW systems with solar collectors with and without antireflection treatment

Weiqiang Kong *, Jiangong Han, Bengt Perers, Simon Furbo, Jianhua Fan

Department of Civil Engineering, Technical University of Denmark, Brovej, DK-2800 Kgs. Lyngby, Denmark

Abstract

Two low flow SDHW systems based on mantle tanks are tested side by side in a laboratory test facility for solar heating systems under the same weather and operation conditions. The systems are identical with the exception that one system is equipped with a solar collector with antireflection treated glass while the other system has a collector with a normal glass. Measurements of the thermal performance of the two systems have been carried out for a long measuring period. The thermal performances of the systems have also been calculated with a detailed simulation model. There is a good agreement between measured and calculated thermal performances for both systems. The extra thermal performance of the system with the solar collector with the anti reflection treated glass cover is a strong function of the solar fraction. In sunny periods with high solar fractions the percentage extra thermal performance gained by the antireflection treatment is low. In less sunny periods with low solar fractions the percentage extra thermal performance of the system with the antireflection treated cover glass is high, typically up to 8%.

Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG

Keywords: anti-reflection glass; SDHW system;side by side laboratory test; mantle tank; simulation

1. Background

The maximum efficiency of a solar collector is strongly depending on the solar transmittance of the glass cover of the solar collector. The higher the solar transmittance is, the higher the maximum efficiency will be. Usually a low iron glass is used as glass cover in solar collectors. Typically the absorptance for such a glass is about 1% and the

* Corresponding author. Tel.: +45 45250919; fax: +45 45931755.
E-mail address: weiko@byg.dtu.dk

Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.02.148

reflection is about 4% on both sides of the glass, resulting in a solar transmittance of about 91%, see Fig. 1. The absorptance can't be changed due to the material's property. The only way of increasing the transmittance is by reducing the reflection. This can be done by modifying the surface of the glass, which should have a refractive index of 1.22 after the modification [1].

Three methods are often used for antireflection glass treatment [2]. The first is to deposit material by a deposition process, i.e. the dip-coating method. The second is to remove materials from the glass surface by etching. The third is to first deposit a thin film and then take away a small part of the film by etching.

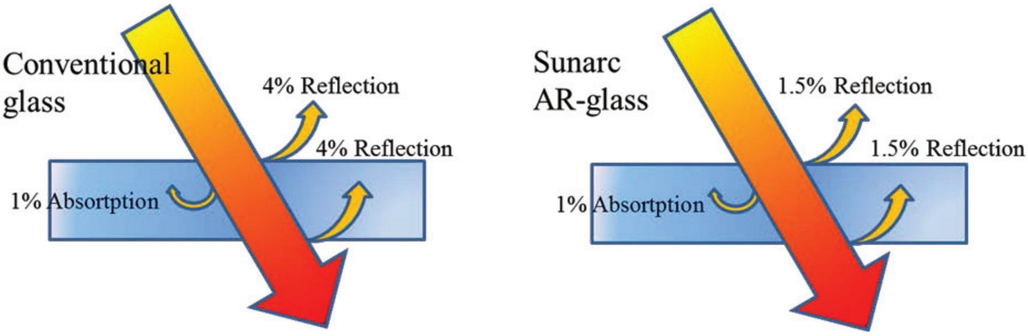

Fig. 1. The transmission of the conventional glass and the antireflection glass [1]

The antireflection treatment of the cover glass for the solar collector used in one of the investigated solar domestic hot water system is produced by Sunarc Technology A/S. The Sunarc antireflection glass is produced by an etching method. The antireflection surface is produced by subjecting the glass to a series of mild chemicals that produces a 100 nanometers thick layer on both sides of the glass, see Fig. 2. The layer has a refraction index of 1.24 and reduces the reflection of the glass to 1.5% which increase the solar transmittance by 5-6% and the total solar transmittance to 96%, see Fig. 1.

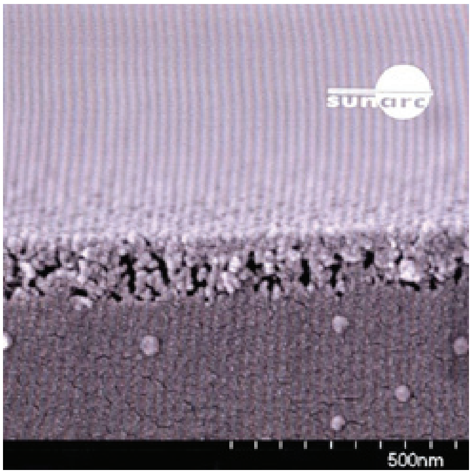

Fig. 2. The etched surface of glass in nanometre scale [1]

The solar transmittance of a glass cover is a function of the wavelength both for a glass with and without antireflection treatment, see Fig. 3. The effective wavelength regions for greenhouses (GH), PV modules (PV), and thermal collectors (TM) are illustrated in the figure.

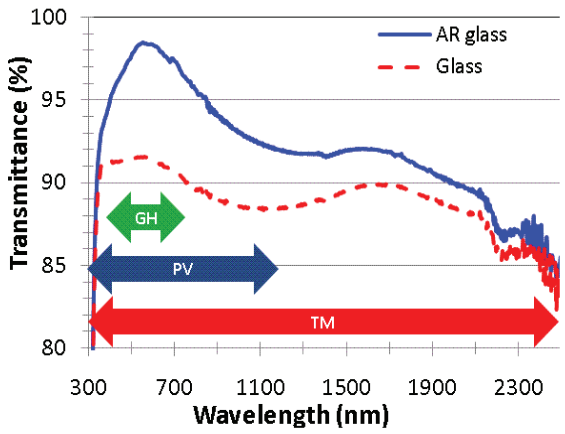

Fig. 3. The solar transmittance of glass before and after antireflection (AR) treatment [1]

The average solar transmittances for the three applications of greenhouses, PV modules and thermal collectors are shown in Table 1. The improvement of the transmittance for glass for solar collectors gained by antireflection treatment is 5.5% at an incidence angle of 0°.

Table 1 The average solar transmittance improvement for three applications at an incidence angle of 0° [1]

	T(GH)	T(PV)	T(TM)
Antireflection glass	97.6%	96.3%	95.9%
Conventional glass	91.3%	90.6%	90.4%
Improvement	6.3%	5.7%	5.5%

Furbo and Shah [3] investigated how a glass cover with antireflection treatment can improve the efficiency of a solar collector and the thermal performance of solar heating systems. The solar transmittances for two glass covers for a flat-plate solar collector were measured for different incident angles. One is normal glass and the other is antireflection glass from Sunarc A/S. The measurements were carried out for different incidence angles in an outdoor solar tracker. The results show that for all incidence angles, the glass with antireflection surfaces has a higher solar transmittance than the normal glass. For incidence angles between 0° and 70° the increases in the solar transmittance due to the antireflection surfaces are between 5 and 9%-points, and for incidence angles between 70° and 90°, between 9 and 0%-point. The maximum transmittance increase is found at an incidence angle of about 70°, see Fig. 4.

The efficiency measurements for collectors with and without antireflection treatment glasses at an incident angle of 0° were carried out according to ISO standards. 4-5%-points of efficiency increased due to the antireflection surfaces. The efficiencies were measured at incidence angles of 0°, 30°, 45°, 60° and 70° for the collector with the two glasses. The efficiency is higher for the collector with antireflection treated glass than for the collector with the normal glass. The incidence angle modifier is higher for the collector with the antireflection treated glass than for the collector with the normal glass, see Fig. 5. and Fig. 6.

The thermal performance of low flow SDHW systems with normal glass and antireflection glass solar collectors were calculated. The yearly thermal performances of the system with the solar collector with the antireflection treated cover glass were compared to the yearly thermal performance of the system with the solar collector with the normal glass for different solar collector areas, collector tilt angles, collector orientations and solar fractions. The investigation showed that the system with the collector with the antireflection treated glass has a 4% -10% higher thermal performance than the system with the collector with the normal glass.

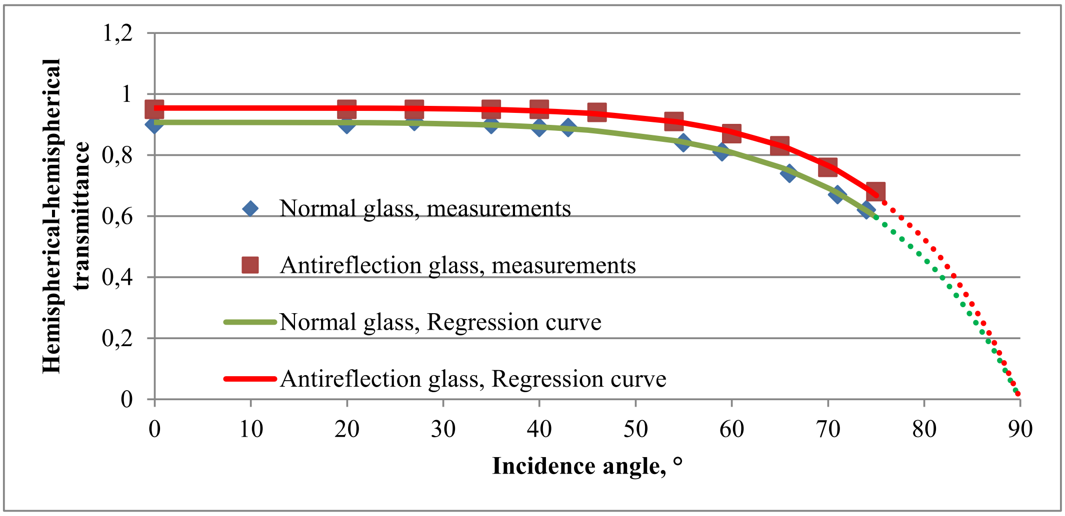

Fig. 4. Measured hemispherical –hemispherical transmittance for the two glasses [3]

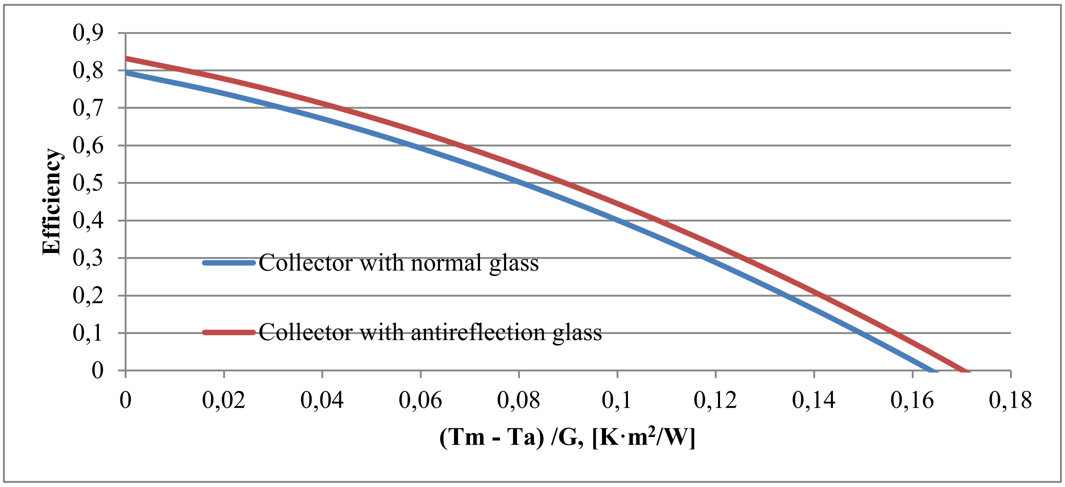

Fig. 5. Solar collector efficiency at an incidence angle of 0° and a solar irradiance of 800 W/m^2 [3]

2. System introduction

Previously theoretical investigations on the advantage by using solar collector with cover glass with antireflection treatment in solar heating systems have been carried out[3]. In order to investigate the thermal advantage of a SDHW system with a solar collector with antireflection treated glass in practice, two low flow SDHW systems were established side by side in a test facility for solar heating systems at the Technical University of Denmark. The systems are identical with the exception that one of the systems has a solar collector with an antireflection treated cover glass from Sunarc A/S, while the other system has a solar collector with a normal cover glass. The solar collectors, which are from Wagner & Co Solartechnik GmbH, have a solar collector area of 2.37 m^2, see Fig. 7. The top right photo shows the solar collector with the antireflection treated glass at the left and the solar collector with the normal glass at the right. The system schematic at the left hand side includes the solar collector loop and the hot water draw-off loop. The circulation pump is installed at the hot side of the solar collector loop aiming to utilize the pump energy in the best possible way. The circulation pumps are controlled by differential thermostats measuring the temperature difference between the outlet from the solar collectors and the bottom of the mantles. The pump start temperature difference is 10 K and the stop temperature difference is 5 K. The solar collector fluid in the collector loop is a 40% (weight %) propylene glycol/water mixture. The bottom right photo in Fig. 7. shows the two mantle tanks with insulation and cabinets. The tanks which are produced by Solrvarmebeholderen.dk, have a hot water volume of 165 l and an auxiliary volume in the top of the tank heated by an electric heating element of 53 l. The auxiliary volume is heated to 54 °C by the electric heating element if the solar collector is not able to heat the volume to this temperature level. The tanks are made of stainless steel. The tests are carried out with the same daily hot water consumption of 100 l. Hot water is drawn off at 7 am, at noon and at 7 pm in three equally sized volumes of 33.3 l and the hot water consumption is 4.6 kWh per day, heated from 10 °C to 50° C.

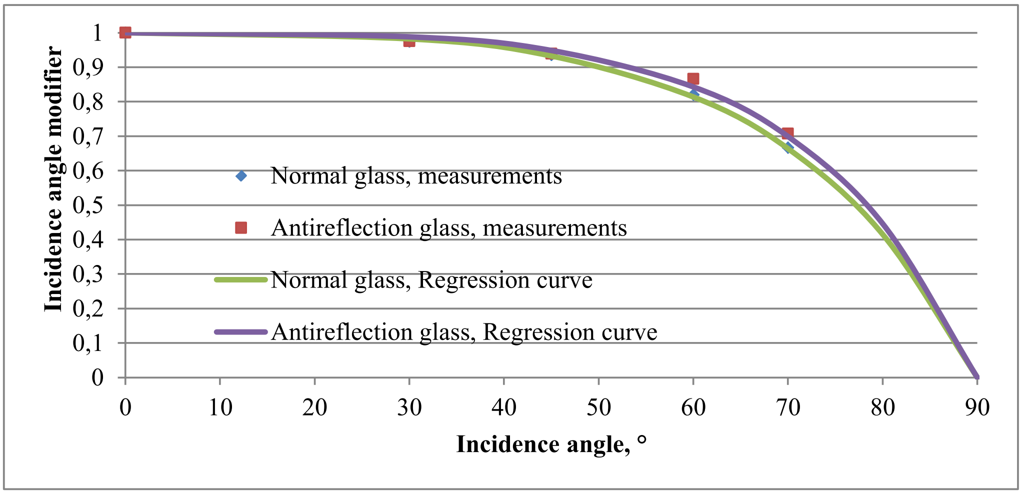

Fig. 6. Incidence angle modifier for the collector with the two glasses [3]

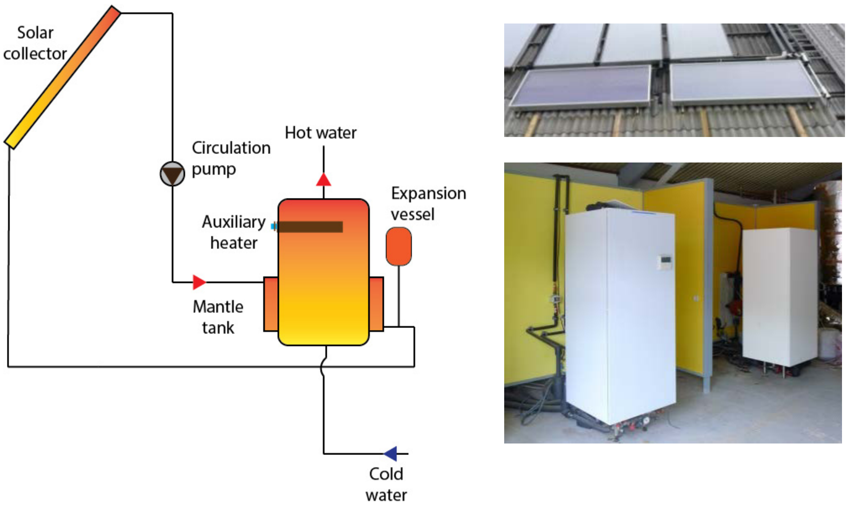

Fig. 7. System schematic with photos of solar collector and tank

3. Comparison of simulated and measured results

The detailed mantle tank simulation model MANTLSIM which was developed and validated by Knudsen and Furbo [4] and Knudsen [5] was used to simulate the thermal performance of the SDHW systems applying the weather data of the Danish Test Reference Year (TRY) [6]. Calculations were carried out with the used solar collectors with the normal glass and with the antireflection glass. The 12 diamond points in Fig. 8. show the 12 months performance ratios of the system with the collector with the antireflection treated glass as a function of the monthly solar fraction of the system with the collector with the normal glass. The performance ratio is defined as the ratio between the net utilized solar energy of the system with the antireflection treated glass and the net utilized solar energy of the system with the normal glass. The net utilized solar energy is the tapped energy minus the auxiliary energy supplied to the mantle tank. The solar fraction is the ratio between the net utilized solar energy and the tapped energy. The simulation results show that the performance ratio of the system with the collector with the antireflection treated glass decreases for increasing solar fraction of the system with the collector with the normal glass.

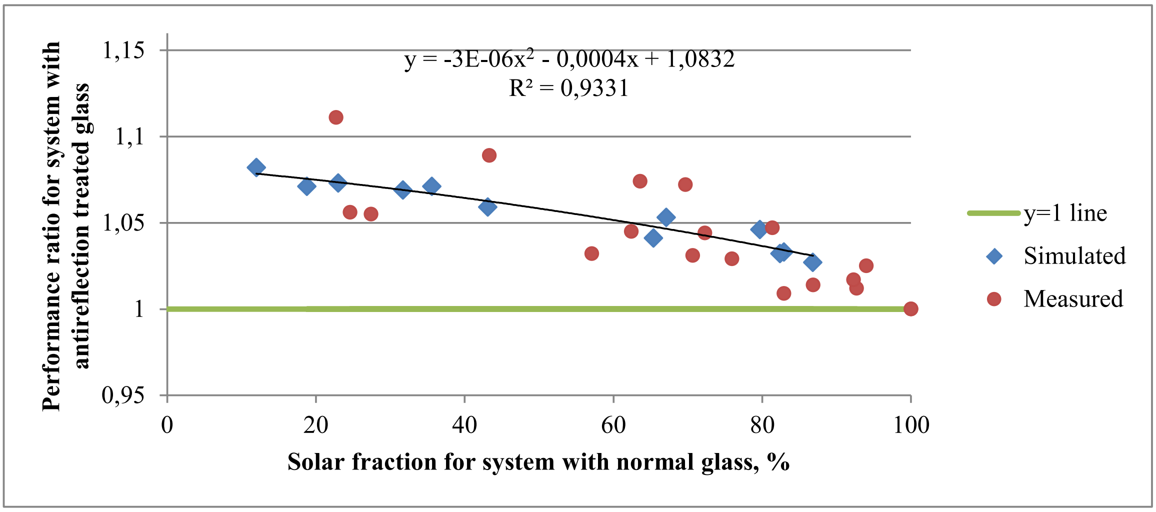

Fig. 8. Performance ratio for the SDHW system with the antireflection treated glass as a function of solar fraction for system with the normal glass

The two SDHW systems have been tested under the same weather conditions since March, 2014 and the measurements will be continued till the end of 2014. The tapped energy, the auxiliary energy, the solar heat transferred to the heat storage, the fluid flowrate and the system temperatures were measured during the whole test period.

The weekly performance ratios can be seen as the round points in Fig. 8. The measured results show the same trend as the theoretical calculated values. For increasing solar fraction the system performance ratio is decreasing. The black curve in Fig. 8 is the trend curve of the simulated points. In addition, the equation of the trend curve and the coefficient of determination are also illustrated in the figure.

It can be seen that the simulated results and the measured results have the same trend. The higher solar fraction is, the lower the performance ratio will be. In periods with 100% solar fraction which means no auxiliary energy is used, the two systems have the same tapped energy and net utilized solar energy. Therefore the performance ratio is 1. The highest performance ratio, typical up to 12% can be found for low solar fractions less than 20%. It is seen that differences between the trend curve and the performance ratios are larger for the measurements than for the calculations.

Further calculations of the difference between the measured results and the calculated results by using the regression equation under the same solar fractions are carried out. The comparison can be seen in Table 2. The difference of the performance ratios between measured and calculated results are also plotted in Fig. 9. All the absolute differences are below 4% which shows the good agreement between the simulation and the experimental results.

Table 2 Comparison of measured and calculated results

Week	Solar fraction for solar heating system with collector with normal glass	Measured extra thermal performance of system with collector with antireflection treated glass	Calculated extra thermal performance of system with collector with antireflection treated glass	Difference
week 10	22.7	11.10%	7.26%	3.84%
week 11	82.9	0.90%	2.94%	-2.04%
week 12	27.4	5.50%	7.00%	-1.50%
week 13	43.3	8.90%	6.03%	2.87%
week 14	62.4	4.50%	4.66%	-0.16%
week 16	72.3	4.40%	3.86%	0.54%
week 17	63.6	7.40%	4.56%	2.84%
week 18	100	0.00%	1.32%	-1.32%
week 19	24.6	5.60%	7.15%	-1.55%
week 20	57.1	3.20%	5.06%	-1.86%
week 21	92.7	1.20%	2.03%	-0.83%
week 22	100	0.00%	1.32%	-1.32%
week 23	70.66	3.10%	4.00%	-0.90%
week 24	94.01	2.50%	1.91%	0.59%
week 25	81.38	4.70%	3.08%	1.62%
week 26	75.91	2.90%	3.55%	-0.65%
week 27	86.85	1.40%	2.58%	-1.18%
week 28-31	100	0.00%	1.32%	-1.32%
week 36	92.27	1.70%	2.08%	-0.38%
week 38	69.67	7.20%	4.08%	3.12%

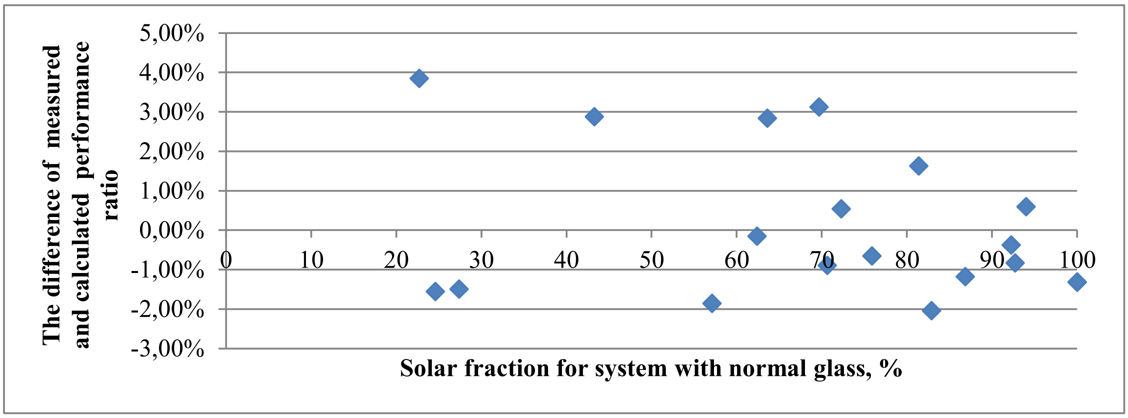

Fig. 9. The difference of the performance ratio for the SDHW system with the antireflection treated glass as a function of solar fraction for system with the normal glass

Table 3 shows the summed thermal performance of the two systems during the whole test period including the tapped energy, the auxiliary energy, the net utilized solar energy and the total performance ratio. 2.4% extra thermal performance was gained by the system with collector with antireflection treated glass compared to the system with collector with normal glass.

Table 3 Summed thermal performance of the two systems during the whole test period

System	Tapped energy (kWh)	Auxiliary energy (kWh)	Net utilized solar energy (kWh)	Solar fraction	Performance ratio
System with collector with normal glass	731	181	550	75.2%	1.024
System with collector with antireflection treated glass	731	168	563	77.0%	

4. Conclusion

Side by side tests of two small SDHW systems with solar collectors with and without antireflection treatment have been carried out. The measurements show that the extra thermal performance gained by the antireflection treatment is strongly influenced by the solar fraction. The lower the solar fraction is, the higher the extra percentage thermal performance for the system with the solar collector with the antireflection treated glass will be. Measurement for 23 weeks resulted in an extra thermal performance of the system with the solar collector with the antireflection treated glass of 2.4% and a solar fraction of 75% for the system based on the collector with normal glass. There is a good agreement between measured and simulated thermal performances for both the low flow SDHW systems. The good agreement is a good basis for further calculations with the used model MANTSIM to simulate similar systems with other weather conditions and locations.

References

[1] http://www.sunarc.net/index.php/ap-processing/argenerelt.
[2] Nostell P., Roos A., and Karlsson B. (1998) Antireflection of glazings for solar energy applications. Sol. Energy Mat. Sol. Cells, 54, 223-233
[3] Furbo, S., and LJ Shah. Thermal Advantages For Solar Heating Systems With a Glass Cover With Antireflection Surfaces. SOLAR ENERGY 74.6 (2003): 513-523.
[4] Knudsen Søren, Furbo Simon. Thermal stratification in vertical mantle heat exchangers with application to solar domestic hot water systems. Applied Energy.2004; 78(3): 257-272
[5] Knudsen Søren. Investigation and optimisation of heat storage tanks for low-flow SDHW systems. Ph.D. Thesis, Department of Civil Engineering, Technical University of Denmark, report R-075, 2004.
[6] Statens Byggeforskningsinstitut, Vejrdata for VVS og energi. Dansk referencear TRY.1982.