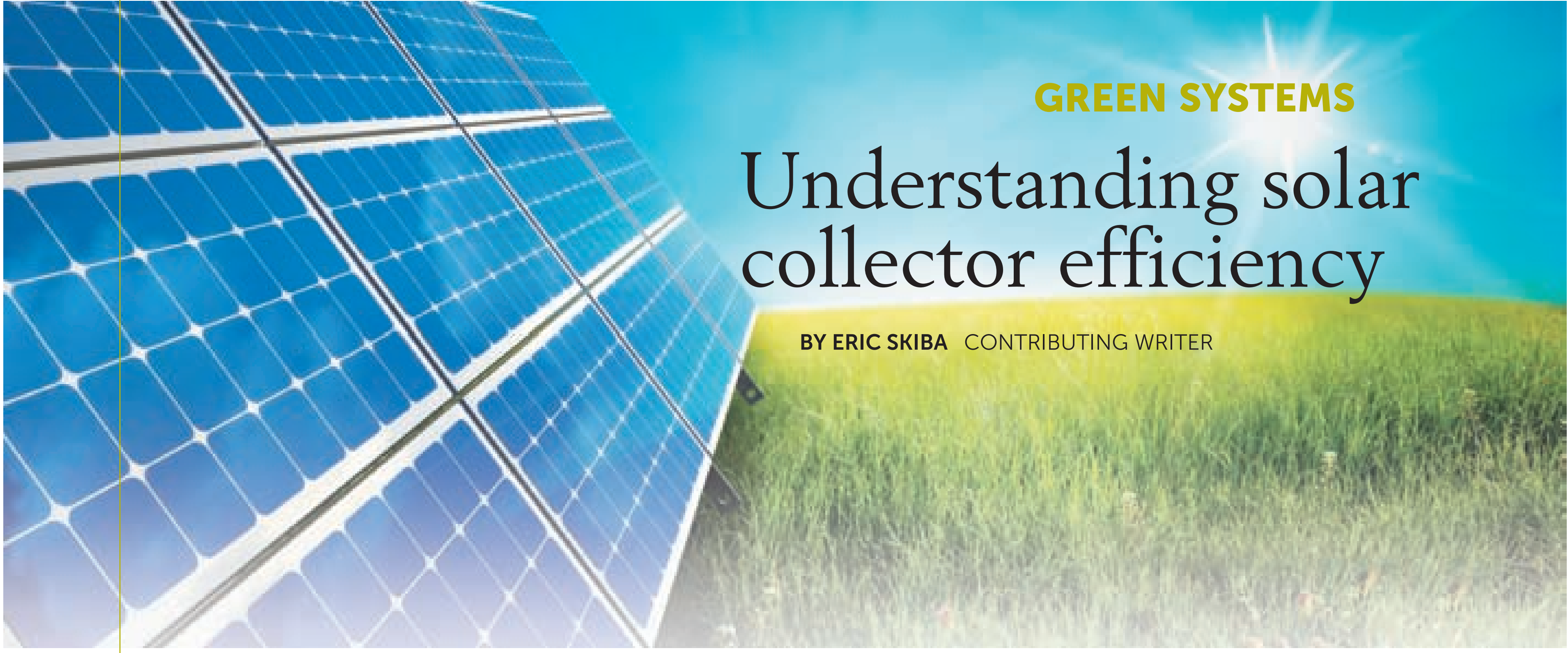

GREEN SYSTEMS

Understanding solar collector efficiency

BY ERIC SKIBA CONTRIBUTING WRITER

Efficiency is a topic that is much discussed throughout the plumbing and heating industry and solar thermal, with its increasing relevancy in the market, is no exception. Solar thermal, or hot water, collector efficiency is being used in marketing campaigns, engineering analysis and other situations where the performance of two products is compared head to head to decide which product is "better." Without a general understanding of what these numbers mean, one may be easily mislead into thinking one product is superior when that may not be the case.

Solar thermal collector efficiency is, at its core, no different than other efficiency numbers. It considers how much energy the collector can convert and transfer to a fluid from the amount of available solar energy (known as insolation). Trying to calculate, or rate, a collector's efficiency is complicated, since the conditions surrounding the collector are constantly changing. The fluid temperature, air temperature, amount of sunlight available and the angle of the sunlight striking the collector all affect the efficiency of conversion.

In order to calculate the efficiency, the area to be analyzed must first be defined. For flat plate collectors this is easy, since the total area and the area that absorbs the sun's energy are almost the same size. For evacuated tube collectors that have a round absorber and spaces between tubes, this becomes a bit more difficult, since the areas are different.

When evaluating a product, it is important to use an area that represents the end goal of the analysis. For example, if roof space is tight, then using the overall, or gross area, would be wise. If a pure analysis of the collector's efficiency is being completed then the absorber area may be more appropriate. In Europe, collectors are usually rated using absorber or aperture area; collectors in the North American market are rated using gross and aperture area by the Solar Rating and Certification Corporation (SRCC).

Once a collector is certified to the SRCC OG-100 standard, it is listed with an accompanying certification sheet. This is a great resource when comparing technologies, since the test conditions for each collector are more or less the same. On the lower portion of a rating table (section A in the picture) is a list of technical information; the right column lists values for Y-Intercept and Slope. These two numbers can be used to build the collector's efficiency graph

SRCC Column	Insolation (Btu/sq.ft/day)
Clear	2,000
Mildly Cloudy	1,500
Cloudy	1,000

by using the following formula:

Efficiency = Y Intercept + Slope * ((Inlet Temperature - Ambient Temperature)/Insolation)

The value in parentheses is a ratio of the available sunlight and the difference in temperature between the fluid and air (ambient) during

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Section C

COLLECTOR THERMAL PERFORMANCE RATING

Kilowatt-hours Per Panel Per Day				Thousands of BTU Per Panel Per Day			
CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY	CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY
A (-5 °C)	13.5	10.2	6.9	A (-9 °F)	46.1	34.8	23.5
B (5 °C)	12.9	9.6	6.3	B (9 °F)	44.0	32.7	21.4
C (20 °C)	11.9	8.6	5.3	C (36 °F)	40.6	29.3	18.0
D (50 °C)	10.0	6.7	3.5	D (90 °F)	34.2	23.0	11.8
E (80 °C)	7.9	4.7	1.7	E (144 °F)	27.1	15.9	5.9

A- Pool Heating (Warm Climate) **B**- Pool Heating (Cool Climate) **C**- Water Heating (Warm Climate) **D**- Water Heating (Cool Climate) **E**- Air Conditioning

Original Certification Date: 24-AUG-09

COLLECTOR SPECIFICATIONS

Gross Area: 4.158 m^2 44.76 ft^2

Dry Weight: 96.2 kg 212. lb

Test Pressure: 1103. KPa 160. psig

Net Aperture Area: 2.98 m^2 32.05 ft^2

Fluid Capacity: 1.0 liter 0.3 gal

COLLECTOR MATERIALS

Frame: Stainless Steel

Cover (Outer): Glass Vacuum Tube

Cover (Inner): None

Pressure Drop

Flow		ΔP	
ml/s	gpm	Pa	in H_2O
20.00	0.32	105.00	0.42
50.00	0.79	524.0	2.1
80.00	1.27	1257.00	5.05

Absorber Material: Tube - Copper / Plate - Aluminum

Absorber Coating: Aluminum Nitride

Insulation Side: Vacuum

Insulation Back: Vacuum

TECHNICAL INFORMATION

Efficiency Equation [NOTE: Based on gross area and (P)=Ti-Ta]

SI Units: η= 0.456 -1.35090 (P)/I -0.00381 $(P)^2/I$

IP Units: η= 0.456 -0.23796 (P)/I -0.00037 $(P)^2/I$

Section A

Y INTERCEPT	SLOPE
0.458	-1.579 $W/m^2.°C$
0.458	-0.278 $Btu/hr.ft^2.°F$

Incident Angle Modifier [(S)=1/cosθ - 1, 0°<θ<=60°]

Kτα = 1 1.306 (S) -1.034 $(S)^2$

Kτα = 1 0.23 (S) Linear Fit

Section B

Test Fluid: Water

Test Flow Rate: 20.0 ml /s.m^2 0.0294 gpm/ft^2

Example of a SRCC Rating Sheet

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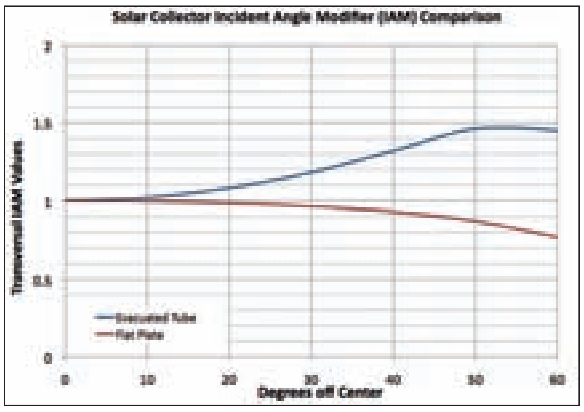
operation known as the fluid inlet parameter. The closer to 0, the more "ideal" the environment (a hot summer day, for example) and the higher the efficiency will be. Temperature difference between the fluid and the air is one of the most important values to

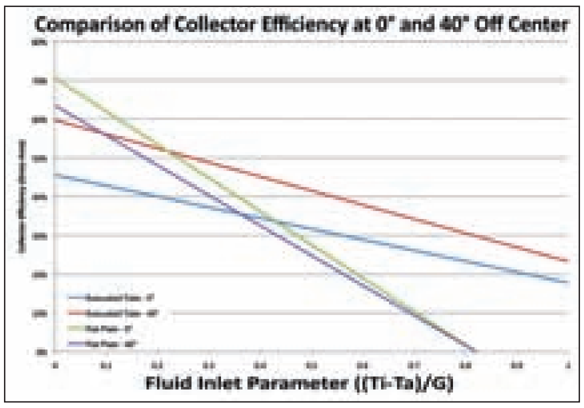


keep in mind when comparing collectors or evaluating efficiency. For example, a solar thermal system running at 180°F will have a completely different performance than the same system operating at 120°F due to the difference in fluid temperature. The Y Intercept from the certification sheet will tell you the maximum efficiency a collector can achieve, while the slope will tell you how fast the efficiency will decrease as conditions worsen.

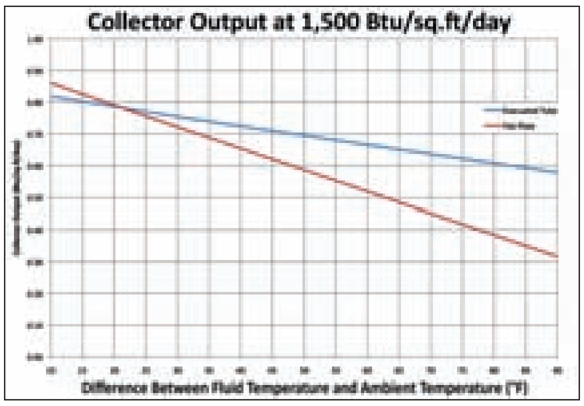
Efficiency values are taken during testing and represent the performance of the collector with a light source directly perpendicular to the collector (i.e. midday). It does not, however, take into consideration the changes in geometry, which, throughout the day, month and year, affect how efficiently a collector performs.

Each SRCC rating sheet has a table that shows how changes in the sun's angle affects performance (section B). These values can be used to build graphs that show how a collector's efficiency reacts to changes in the sun's angle in the sky. Known as incidence angle modifiers (IAM), the values can be used, along with the following equation, to produce a graph that shows how the sun's path through the sky affects efficiency. The higher the IAM value, the higher the efficiency will be at that time of day when compared to midday. This relationship is shown by the first line of IAM values. The second line is used to calculate the relationship in the other direction; for example, when the sun is lower in the sky during the winter months. This value is used when the relationship between installation angle and time of year is being evaluated.

The IAM value multiplies the efficiency curve that was previously discussed and gives a "geometry corrected" value for efficiency. For flat plate collectors the benefit is not substantial, since the testing of the



collector with a perpendicular light source correlates to peak efficiency, at midday. For collectors with round absorbers, however, the inclusion of an IAM value can increase the standard



efficiency values by as much as 25%.

Since the geometry can play a large role in a collector's performance throughout the day it is useful to use the instantaneous efficiency equations and the IAM values to average out a collector's performance over a day. This type of analysis is also done as part of a collector's SRCC OG100 certification and is provided in a ratings table near the top of a collector's certificate (Section C). These values take into account both the instantaneous efficiency and the IAM values.

The table has 15 values that represent a range of conditions and applications that are typical for the United States. Each of the rows (A – E) represents a different temperature differential (fluid - air) and lists a typical application underneath the table for a quick reference (Section C). The columns are labeled Clear, Mildly Cloudy and Cloudy which are different values of daily insolation levels. These insolation values can be compared to locations throughout the United States.

These daily production values can be used to compare how two collectors will perform under certain conditions. Unlike instantaneous efficiency values, however, the numbers in the rating table are related to the size of the collector. It is important to keep this in mind when looking at how much energy a collector produces per day. It is recommended that the ratings be normalized by dividing the output by the collector size to give an energy/area/day rating. This will give the best representation of how well a collector will perform.

The data can be analyzed in two ways by fixing the amount of sunlight or the temperature difference and then creating a graph to have a visual representation of how two collectors compare. In the graph, it is clear that there is a point where one collector becomes more efficient than the other. It is then up to whomever is doing the analysis to determine how much time the collectors will operate on either side of the cross-over point.

When making a decision on which type of collector is best for the application, a cost analysis would be the next step in comparing two products. Based on the information graphed above it is clear that there is a point where one product outperforms the other, but at what cost? Small increases in efficiency may cause a large increase in cost. Dividing the cost by the energy/area/day number above will yield a number that can be used to compare the overall value of a product by showing how much money must be spent for the efficiency or output. This would provide a picture of a product's overall performance value, not just efficiency.

Beyond efficiency and cost, much can be said for a company's ability to support their product and support a customer. Saving a few dollars on a product may not be worth the headaches later if an issue arises and a company is not able to support its product. Installation costs should also be taken into consideration. Using the methods above can help one understand a collector's performance and value and allow someone to make an informed decision about which product is right for them.

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