## Comparison Sheet
## Evacuated Heat Pipe Collectors
## Versus
## Flat-Plate Solar Panels

| Evacuated Heat Pipe Tubes | Flat-plate Solar Panels |
|---|---|
| The collector is hermetically sealed inside an evacuated glass tube, eliminating convection and conduction heat losses and isolating the collector from adverse ambient conditions. Therefore, no heat losses due to convection and conduction and no change of performance during the service life of the collector due to corrosion. | The collector is put in a casing with a glass shield to reduce heat losses. The air gap between absorber and cover pane allows heat losses to occur, especially during cold and windy days. Build up of condensation will in due course influence the collector greatly due to corrosion, reducing performance and durability. |
| Uses a heat-pipe for super efficient heat conduction. No water enters into the collector. | Circulates water inside insulated areas. Prone to leakage, corrosion and restriction of flow due to possible air lock. |
| The heat-pipe has a self-limitation of maximum working temperature through the physical properties of its special fluid (THS200 and THS250 models) resulting in safeguarding the system and system fluid (water and anti-freeze mixture). | Flat-plate collectors have no internal method of limiting heat build up and have to use outside tempering devices. When these safety or control devices fail the system and/or system-fluid can be destroyed. |
| Thermal diode operation principle. The heat pipe's thermal flows one way only; form the collector to the water and never in the reverse. | Flat-plates can actually rob the water of built up heat if the collector becomes colder than the water temperature. |
| Corrosion and freeze free; there is nothing within the evacuated tube to freeze and the hermetic sealing of each tube eliminates corrosion. | Flat-plate collectors contain water and unless well-protected can burst upon freezing. Corrosion can become a major problem reducing performance! |
| Easy installation and no maintenance. Lightweight individual collector tubes are assembled into the system at the point of installation. Each tube is an independently sealed unit requiring no maintenance. | Installation is difficult. Entire panels have to be hoisted onto the roof and installed. if one has a leak, the entire collector has to be shut down and removed. |
| Relatively insensitive to placement angle, allowing architectural and aesthetic freedom. | Requires accurate southern exposure and elevation placement. |

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# Flat Plate Collectors v. Evacuated tubes – a brief overview

Since their conception, the evacuated tube collector has been commonly heralded around the solar industry as the more efficient collector. This idea has been perpetuated mainly by manufacturers of evacuated tube collectors, but unfortunately their claims are often not backed up by any scientific data or independent testing results.

Efficiency in hot water collectors is predominantly influenced by Newton's Law of cooling which states that a hot object transfers heat to its surroundings (cools) at a rate proportional to the difference in temperature between the two – with hotter objects cooling faster than colder objects, given the same surrounding temperature. Applying this theory to a solar collector, when the difference in temperature between the heated water within the collector and outside temperature (delta T) is large, heat loses will be proportionally larger than when the delta T is lower. In domestic water heating, these heat loses can be high and degrade the efficiency of a collector significantly. Cooling cannot be prevented, but it can be retarded by insulating the body, either by glazing the collector or utilising a vacuum such as in evacuated tubes.

For example, unglazed polymer collectors are used for swimming pool heating over glazed designs because a collector in this environment will often be operating under ambient temperatures. That is, it will only be required to heat the water up to air temperatures or slightly above. In these cases, when the temperature of the water is the same as the outside air temperature, there will be no heat loss – nullifying the need for insulation. Polymer collectors actually have a higher efficiency than both flat plate and evacuated tube collectors for the delta T range they are employed in. Introducing glazing in this case would actually decrease their efficiency as the layer of glass will reduce light transmission to the collector plate.

As our needs move up the temperature scale, heat losses to air become an important consideration. For domestic hot water applications, water at up to 30-40 °C above ambient is required, and even more demanding are the thermal requirements of certain commercial processes and space heating systems. In such systems insulating the solar collectors against heat losses is very important. Glazing in flat plate collectors achieves good results in the mid range of temperatures, while the vacuum present in evacuated tube collectors does indeed prove to be superior in systems where the ambient temperature is very low (very cold climates) or where it is necessary to heat the water significantly higher than normally required for domestic hot water requirements.

It is for this reason, being that each collector design has its own merits, that no collector has dominated the solar hot water market.

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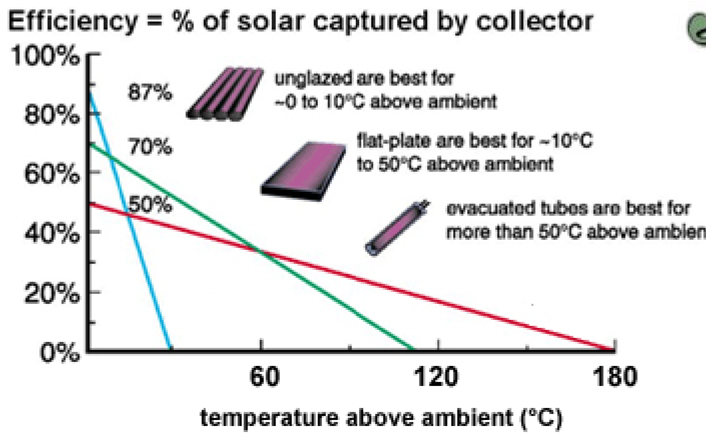


Source: Alternative energy store; www.learn.altenergystore.com

Notes on efficiency data:

When comparing efficiency data for different collectors it is important to check weather the efficiency stated is based on the collector total area, or the absorber area (area in which solar gain can be converted to heat energy). In the USA and Europe efficiency testing is mostly based on total collector area which is the space taken up on your roof. As we know, there is a significant area between the evacuated tubes which produces no energy, and drags down efficiency results.

Tests carried out on over 160 solar panels by the internationally acclaimed research organisation Solartechnik Prufung Forschung (SPF) found that in low to medium delta T conditions (temperature difference between the collector and air) evacuated tube collectors are actually less efficient than their flat plate cousins.

> *"The average gross efficiency of the 120+ flat plate collectors tested was about 70%, while the average efficiency of the 42 models of evacuated tubes was only 49%. In terms of range, the flat plates varied from 51% to 79% while the evacuated tubes varied from 31% to 62%. All but five of the flat plate collectors tested had a gross efficiency greater than 60%."*
>
> *Source: http://www.sustainability.ie/solar.html*

Collector Efficiency and cost

Of course, efficiency is not the only characteristic that should be looked at when purchasing a solar collector. The durability of a collector and the price are also very important aspects to consider. Apart from feeling good about the positive environmental benefits, most people are mainly interested in the financial savings they get on the money invested in a collector. This is where price comes into play. A collector that is 10% more efficient but 50% more expensive makes very little economic sense. Maximizing economic return is more about getting more collectors for less money than getting highly efficient, but more expensive, collectors.

Often it is easy to compare the energy output of one collector to another. Data is freely available from both the SFP webpage and from The Solar Rating and Certification Corporation (SRCC)[1] webpage. However, sometimes it may be difficult to take into account the price variations for different collectors and compare them on their economic return. One method to do this is to compare the energy output for each dollar spent on different collectors. That is, how much energy in Megajoules per day a dollar will buy if spent on collector #1 compared to collector #2.

Below is a table offering a comparison between two popular retrofit kits available in Australia. The Apricus 30 tube collector costing $1999 was compared to a Rheem two panel kit costing $1470. Both prices are not inclusive of any rebates which might be available. Performance data for the two panels was sources directly from testing results published in the Directory of SRCC Certified Solar Collector Ratings document**. The Solar Rating and Certification Corporation (SRCC) is the most common and reliable source in the USA for independent information about solar collectors – testing not only for efficiency but also durability and reliability.

In Table 1.1 the cost-effectiveness between the two collectors was compared in a variety of climatic conditions; Warm climates with a 20°C Delta T, Cold climates with a 50°C Delta T and a category for very hot water requirements with an 80°C Delta T. Each category was further divided into the three main sunlight conditions; clear, partly cloudy and cloudy.

Calculations are quite simple. Take for example the Apricus collector on a clear day in a warm climate. In these conditions 23 Megajoules of energy is received from the sun per square metre of area. From this, the Apricus collector manages to produce 37 Megajoules of energy per day. The output per dollar spent is:

*Energy produced / Price*
*37 MJ / $1999*
*.0185 MJ per dollar spent*

The higher the number of MJs (Megajoules) per dollar, the more cost-effective the collector is – all other things being equal. It is important to remember though that the design and quality of the rest of the hot water system are critical when considering overall system efficiency – not just the collector.

| Table 1.1 | Warm Climate ( 20 Delta T) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Make and Model* | Size | Collector Cost* | *Clear Day* 23MJ/ m² .d Solar energy Produced | | *Mildly Cloudy* 17MJ/ m² .d Solar energy Produced | | *Cloudy Day* 11MJ/ m² .d Solar energy Produced | |
| | | | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** |
| Apricus AP-30 Retrofit Evacuated Tube Collector Kit | 4.053 m² Gross Collector Area | $1999 | 37 MJ/panel/day<br>Total = 37 MJ.D | **.0185 MJ / $** | 27 MJ/panel/day<br>Total = 27 MJ.D | **.0135 MJ / $** | 17 MJ/panel/day<br>Total = 17 MJ.D | **.0085 MJ / $** |
| Rheem 2RTF Retrofit Flat Plate Collector Kit | 1.98 m² x 2 panels in Kit<br>= 3.96m m²<br>Gross collector Area | $1470 | 24 MJ/panel/day<br>X2 panels<br>Total = 48 MJ.D | **.0326 MJ / $**<br>76% more cost effective | 17 MJ/panel/day<br>X2 panels<br>Total = 34 MJ.D | **.0231 MJ / $**<br>71% more cost effective | 9 MJ/panel/day<br>X2 panels<br>Total = 18 MJ.D | **.0122 MJ / $**<br>44 % more cost effective |
| **Cold Climate ( 50 Delta T)** | | | | | | | | |
| Make and Model | Size | Collector Cost | *Clear Day* 23MJ/ m² .d Solar energy Produced | | *Mildly Cloudy* 17MJ/ m² .d Solar energy Produced | | *Cloudy Day* 11MJ/ m² .d Solar energy Produced | |
| | | | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** |
| Apricus AP-30 Retrofit Evacuated Tube Collector | 4.053 m² Gross Collector Area | $1999 | 32 MJ/panel/day<br>Total = 32 MJ.D | **.016 MJ / $** | 22 MJ/panel/day<br>Total =22 MJ.D | **.011 MJ / $**<br>2 % more cost effective | 12 MJ/panel/day<br>Total = 12 MJ.D | **.006 MJ / $**<br>222 % more cost effective |
| Rheem 2RTF retrofit Flat Plate Collector | 1.98 m² x 2 panels in Kit<br>= 3.96m m²<br>Gross collector Area | $1470 | 15 MJ/panel/day<br>X2 panels<br>Total = 30 MJ.D | **.0204 MJ / $**<br>26 % more cost effective | 8 MJ/panel/day<br>X2 panels<br>Total = 16 MJ.D | **.0108 MJ / $** | 2 MJ/panel/day<br>X2 panels<br>Total = 4 MJ.D | **.0027 MJ / $** |
| **Industrial applications/space heating (Very high 80 Delta T)** | | | | | | | | |
| Make and Model | Size | Collector Cost | *Clear Day* 23MJ/ m² .d Solar energy Produced | | *Mildly Cloudy* 17MJ/ m² .d Solar energy Produced | | *Cloudy Day* 11MJ/ m² .d Solar energy Produced | |
| | | | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** | Energy output of panel | **Output per Dollar spent** |
| Apricus AP-30 Retrofit Evacuated Tube Collector | 4.053 m² Gross Collector Area | $1999 | 27 MJ/panel/day<br>Total = 27 MJ.D | **.0185 MJ / $**<br>70 % more cost effective | 17 MJ/panel/day<br>Total = 17 MJ.D | **.0185 MJ / $**<br>685 % more cost effective | 8 MJ/panel/day<br>Total = 8 MJ.D | **.0185 MJ / $** |
| Rheem 2RTF retrofit Flat Plate Collector | 1.98 m² x 2 panels in Kit<br>= 3.96m m²<br>Gross collector Area | $1470 | 8 MJ/panel/day<br>X2 panels<br>Total = 16 MJ.D | **.0109 MJ / $** | 2 MJ/panel/day<br>X2 panels<br>Total = 4 MJ.D | **.0027 MJ / $** | N/A | N/A |

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We can see that for warm conditions, flat plate collectors are more cost effective in all sunlight conditions, up to 76% on clear days. In colder conditions Flat plates win out in clear skies, just about break even with evacuated tubes in mildly cloudy conditions, but are significantly less efficient in cloudy weather. For systems that require very a very high temperature rise evacuated tubes outperform flat plates in all conditions.

The final step is to determine which climate best describes your location. If you often have cloudy or overcast days, especially in winter, evacuated tubes might be worth considering. However to maximise cost-effectiveness evacuated tubes should only be chosen if they can offset the savings you give up by not using Flat plates in summer conditions. If winters are mostly sunny, flat plate collectors tend to be the most cost effective overall.

Some Flat plate systems do have frost protection using a frost dump valve as well as smart controllers which will circulate some hot water through the collector when it senses the water temperature approach freezing. This might work well where mild frosts are observed, but is not sufficient in locations prone to more severe frost or freezing conditions. In these conditions evacuated tubes provide an advantage in that they don't require a closed-loop system with glycerol to cope. This saves money in initial installation costs compared to Flat plate systems, as well as maintenance costs every few years.

*Retrofit Kit model names and prices were sourced from the solar hot water section of the Sustainability Victoria webpage: www.sv.sustainability.vic.gov.au
**Data using in the comparison was taken directly from the Directory of SRCC Certified Solar Collector Ratings document accessible on the SRCC webpage; www.solar-rating.org
***Please note: Solavis does not guarantee the accuracy of these calculations and will not be held liable or responsible for any activities relating to their use or any inaccuracies present.

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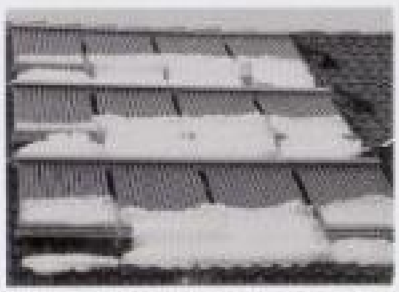
# SOLAR FLAT PLATE VS. EVACUATED TUBE COLLECTORS

## PERFORMANCE IN COLD CLIMATES

The main advantage for evacuated tubes is its low heat loss at high temperatures relative to ambient temperature. However in actual cold, snowy conditions, this poses a problem.

Where ambient temperature is very low, snow and frost play a important role in collector performance. Snow melts and can slide easily down the smooth, warm surface of the glass on a flat plate collector but gets stuck in the gaps between the cold tubes of an evacuated tube collector. The German Centre of Excellence for Solar Engineering at Ingolstadt University of Applied Sciences performed an independent study of a typical European home with both evacuated tube and flat plate collectors mounted on the roof. The following pictures taken of the home in January show dramatic photos of how snow and frost can collect on evacuated tube yet slides off and settles at the bottom of flat plate collectors.



*pictured above: evacuated tube collectors with snow and frost accumulated*
*photo courtesy of Center of Excellence For Solar Engineering at Ingolstadt University*

*pictured above: snow that has slid down the surface of a solar flat plate collector*
*photo courtesy of Center of Excellence For Solar Engineering at Ingolstadt University*

## INSTALLATION

The argument over which type of collector is easier to install is subjective. Both collectors have their advantages and drawbacks in terms of installation.

Proponents of evacuated tube argue that because they come unassembled, one person can easily carry the evacuated tube components onto the roof without needing any special equipment. Proponents of flat plate argue that because they are fully assembled, once hoisted onto the roof, no assembly is required thus greatly reducing installation time. Which type of collector is easier to install is therefore based on the installer's personal preference.

## DURABILITY & LONGEVITY

Nearly all evacuated tube and flat plate collectors sold in the U.S. carry a 10 year limited warranty. Generally speaking both types of collectors are designed to last 20 years or more. However, evacuated tubes are prone to more maintenance and repair for 2 reasons:

1. A quality flat plate collector will use thick (usually 4 millimeters), tempered glass which can take quite a beating under harsh weather conditions such as hail storms. Evacuated tubes use thinner glass (usually 1.6 millimeters) which is more susceptible to breaking and needing to be replaced.

2. Evacuated tubes rely on a vacuum seal to prevent heat loss. Over time this seal can be lost, again requiring the tube to be replaced.

Flat plate collectors very rarely need repairs done to them. A common misconception is that because fluid travels through it, the tubing in a flat plate collector will corrode or leak over time. As long as proper installation and the appropriate fluid is used, this will not happen. The main drawback of flat plate is that if something does break (such as the glass), the installer will usually need to replace the entire collector. Though evacuated tube collectors are more prone to breaking, the tubes can be replaced individually without having to replace the entire collector.

## SUMMARY

- **Performance:** Flat plate gives better year round performance
- **Efficiency:** Flat plate is best at delivering temperatures needed for the most common hot water applications
- **Cost & Value:** Flat plate is generally less expensive and gives more energy per dollar spent than vacuum tube
- **Cold Weather Performance:** Vacuum tube does not carry an advantage over flat plate because snow build up hampers its performance
- **Installation:** Vacuum tube collectors take more time to assemble while flat plate collectors take more effort to hoist onto the roof
- **Durability:** Vacuum tube collectors are fragile and prone to more maintenance

## REFERENCES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# SOLAR FLAT PLATE VS. EVACUATED TUBE COLLECTORS

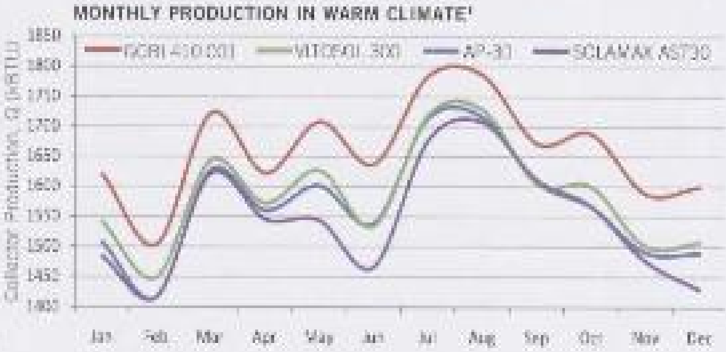
This document has been created to objectively highlight differences and performance characteristics between flat plate and evacuated tube collectors. It addresses concerns and corrects fallacies and assumptions regarding the two collector types. Information was gathered from various independent third parties which have been noted when applicable.

## YEAR ROUND PERFORMANCE

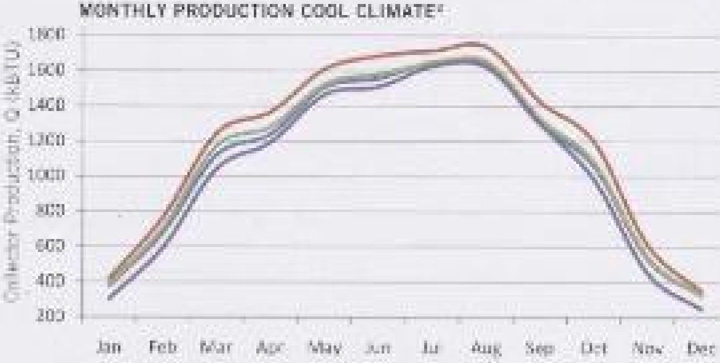
The graphs below show calculated year round energy output for 1 flat plate collector (the Heliodyne GOBI 410 001) and 3 vacuum tube collectors (the Apricus AP-30, Thermomax Solamax AST30 and Viessmann Vitosol 300). All 4 collectors are of comparable size. Graph 1 demonstrates collector performance in a warm region. Graph 2 shows performance in a cool, cloudy region. Graph test data was obtained by the Solar Ratings & Certification Corporation (SRCC), the industry's governing independent testing authority. Detailed results and numbers can be found at www.solar-rating.org.

As one can clearly see, energy production (measured in thousands of BTUs) is greater with the flat plate collector compared with 3 competing brands of evacuated tube collectors of comparable size.

MONTHLY PRODUCTION IN WARM CLIMATE[1]




MONTHLY PRODUCTION COOL CLIMATE[2]

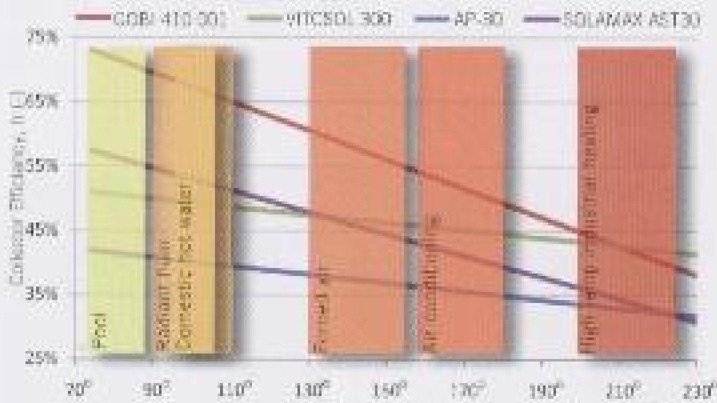



1. Collectors adjusted to total aperture area of 60FT², tilted to 35°, due South with 60.3 gallons per day and 125°F set temperature.
2. Same parameters as (1) above but with 45° tilt.

## EFFICIENCY

The efficiency curves of the GOBI flat plate and 3 vacuum tube brands are shown in the graph below as a function of the system operating temperature. Plotting the operating temperature ranges of the most common solar system applications shows flat plate collectors as a better option. It's only at system operation temperatures above 210°F that some vacuum tubes become a viable alternative.

COLLECTOR EFFICIENCY PLOT*




*At ambient temperature = 74°F; insolation = 317 Btu/hr·ft² (1,000 W/m²)

## COST & VALUE

The manufacturing process, mechanical complexity and material selection of evacuated tube collectors make them more expensive than flat plate collectors. This plays an important role when determining the cost efficiency of the collector. The table below shows how much average daily energy (measured in BTUs) per dollar spent on the collector is produced. To calculate this, we simply divided energy output (data provided by SRCC) of the 4 collectors by their list prices*. Comparison of the collectors shows the GOBI as the best value.

**BTU Per Dollar Comparison For Climate Categories A-D****

| Climate Category | Gobi 410-001 MSRP [illegible] | Solamax AST30 MSRP $1,920 | Vitosol 300 MSRP [illegible] | AP-30 MSRP [illegible] |
|---|---|---|---|---|
| A (Warm climate pool) | 30.30 | 8.72 | 8.60 | 16.11 |
| B (Cool climate pool) | 27.22 | 7.69 | 8.38 | 15.55 |
| C (Warm climate DHW) | 22.27 | 5.89 | 7.56 | 13.88 |
| D (Cool climate DHW) | 11.77 | 3.33 | 6.26 | 11.56 |

*List prices obtained direct from manufacturers or dealers (See reference list). Prices cannot be guaranteed 100% accurate and are subject to change.

**SRCC "mild cloudy day" energy collector test output used for categories A-D.