British Renewable Energy: *the big picture*

Solar Water Heating: *best practice guide*

Barry Johnston, MSc, comments that solar water heaters can be surprisingly simple, comprising mainly panels, pumps and pipes, and that there is no magic involved in solar. Park your car in the sun and it gets hot. Double glaze its roof, insulate all the rest and it gets hotter still. Paint it black inside, put a pipe inside and you have a prototype solar heater. All you now need to do is to remove the heat and store it until you need it, in a well insulated container. He contends that solar best practice is a matter of opinion, but can include the following issues:

Sustainability and zero carbon design

Low or zero carbon solar? Solar water heating is now classified into two types of “carbon impacts”: low carbon solar or zero carbon solar. Cutting global warming and not having to use any mains electricity, even if it is derived from a “green tariff” in order to run a solar panel, is becoming important to many users of solar water heating.

Low carbon solar uses mains electric pumps, typically rated at 30-60 watts power consumption to circulate water, antifreeze or air between the hot cylinder and the solar panel. Low carbon solar consumes further additional electrical energy to control a small computer called a solar controller which switches this pump on or off, depending on whether the panel is hotter or colder than the cylinder. The “parasitic mains electricity consumption” of conventional solar water heating negates its carbon savings by around 20% according to data in a report published by the DTI in UK.

Zero carbon solar uses either a thermosyphon or a solar electric pump to move water from the panel, to the cylinder where it is stored. A thermosyphon solar water heating system relies on hot water being lighter than cold, so that it floats upwards. Thermosyphon requires the hot water cylinder to be located above the solar panel. This design, which is most appropriate to flat roofs in countries where there is little chance of freezing, is uncommon in UK and Ireland. Alternatively, solar electric (photovoltaic or PV) pump can therefore be used to pump water downwards when the sun shines. This uses no mains electricity and is therefore described as zero carbon solar. PV pumping is the usual approach to water pumping for zero carbon solar in UK and Ireland.

Sustainability, waste and business practice

Solar companies which survey by phone and use aerial photos where possible, rather than by driving off to make a site visit will result in your panel having a lower initial “carbon debt” to repay before it goes into carbon credit.

The use of unnecessary packaging for solar panels and their components should be minimised. Where it is used, it should be of recycled origin, or easily recyclable.

It may be environmentally preferable to re-use hot water cylinders. Many old cylinders contain CFC gases in their insulation foams. CFC’s damage the ozone layer. The UK is failing to enforce the EU “fridge mountain directive” on used hot water cylinders. The result is that when some cylinders become squashed, either in landfill dumps, or during copper recycling, these CFC’s are released to pollute the atmosphere for decades. Solar heating technologies which may permit re-use of existing hot water cylinders may be environmentally preferable to those which always require new cylinders, since new cylinders have several negative environmental impacts. These can be associated with their manufacture as well as with the disposal or recycling of the cylinders which they replace.

To counter this down side of cylinder replacement, there are two counter-arguments. One is that some new hot water cylinders may have larger heat exchangers for the “boiler circuit” than those that they replace. This may offer a slight increase in “summer hot water boiler efficiency”: however this benefit is likely to be small given that solar reduces boiler use for water heating most of all in summer. The other is that new solar cylinders can be larger that what they replace, and so they can offer the potential to “iron out the bumps” between sunny and gloomy days rather better, due to their larger volumes.

Four ways to prevent frozen pipes from bursting

There are currently four main ways of preventing freeze damage in solar panels. All are technically viable. A traditional solution is to use chemical antifreeze at a relatively high concentration of say 30%, as in a car radiator. This is the approach of older conventional solar panels. However, some antifreezes can degrade if not replaced regularly, which imposes a maintenance cycle on the installation. The three remaining solutions are:

1. fill the panel with air as a heat transfer medium, rather than with water, while also having larger surface areas of heat exchangers in order to allow for the lower heat capacity of air
2. automatically drain down the panel completely when it becomes cold, say 5C, or
3. use pipes made of silicone rubber which can simply freeze without cracking.

These three newer solutions tend to need less maintenance, since the antifreeze renewal cycle is not required.

Narrow pipes make a significant difference

A lot of heat can be lost in a conventional solar water heating system because its pipes tend to be 15 mm or 22 mm wide. Issues to consider include both surface area and pipe volume. Reducing surface area means less thermal losses. Using narrow microbore pipes with an internal diameter of 6mm plus low flow pumps instead of wider pipes can cut heat loss from the surfaces of pipes by over 50%. In addition, the lower volumes of water contained in narrow reduces the energy lost in transit between the panel and the cylinder when a pump stops. These “dead leg losses” can be cut by 80% by using microbore pipe.

In summary, low volumes minimise energy losses when pump stops. Narrow flow and return pipes (plus low volumes of fluid in the panel itself) reduce the “standing ex-cylinder volume”.

Variable and slow speed pumping

Slowing the pump down at low light levels tends to produce hotter water sooner in the day than happens in lower cost on-off pump designs, particularly when used in direct solar water heating systems, since they stratify (float) the solar hot water over cooler water below.

Maintenance matters

Maintenance costs money, while the travel involved also takes a toll on the environment, not least in terms of CO2 emissions. Solar antifreeze typically needs checking every year and should be replaced every seven years, so solar water heating systems which do not need it may, for some installations, be preferable over systems which do. To balance this, direct solar heating systems may need internal flushing out at a similar interval.

Price confidence and warranties

No unforeseen shocks should occur when it comes to prices. This means that itemised fixed price quotes for clearly specified work should always be given in writing. Quotes must include all costs including delivery and taxes such as VAT Quotes should clearly state if roof access costs including scaffolding and lifting such as cranes are included or excluded, and if excluded, whether the customer or who, specifically, should supply this and to what standard. If work takes longer than expected, the installer should bear this in full.

Warranties should be clear, of a fixed period and inclusive. For commercial installations warranties of 12 months should be regarded as minima. Warranties of at least 3 years should apply to the performance of solar installations before additional payment for longer warranties are required. Warranties which offer different periods on different elements, such as 12 months on labour, 2 years for cylinders, 3 years for pumps and five for panels and pipes can cause difficulties, since if anything goes wrong, there can be “boundary disputes”. For example, it can sometimes be difficult to attribute a claim to one particular component, or to labour alone, especially when one element is out off warranty, while another is still covered.

Future proofing and customer service

Once the installation is complete, installers should take photographic records of installations for quality purposes unless the customer requests otherwise. Photos can include: pipe runs, pump positioning and panel positioning. This way if a query crops up, the company who installed will be able to gain an immediate picture of your installation. In addition, installers should keep complete, accurate and confidential records in compliance with data protection legislation of: customer contacts, installation photos, relevant plans or diagrams, original installation specifications plus any variations from these and written details of significant health, safety and environmental issues including Legionella risk assessment and recommendations. In addition, dates and times of important events such as installations or services need to be recorded and easily available.

Keep it simple

Simplicity is inherently better than complication, provided that this simplicity is reliable, safe and green. Fewer components are usually better than multiple components. Fewer not only means only lower cost (usually) but fewer also means there is far less likelihood of failures as well as unanticipated "component-component" interactions causing malfunctions. For example, eg using an existing simple vent pipe to vent a solar heating system is preferable to using a complex temperature/pressure relief valve, since valves contain moving parts and since moving parts are prone to leaks, corrosion and breakdown. In some social housing applications, direct solar technologies can allow for all plumbing to be concealed in the attic. In addition, they do not use any programmable control boxes at all, so they are never subject to incorrect programming. Direct solar, by not needing a heat exchanger, is not only simpler but inherently slightly more efficient than indirect solar in the cylinder, because heat exchangers need a temperature drop across them in order to function.

Maximise energy gain - start with cool water

The cooler your water is when it enters your panel, the more its temperature will rise, and so the more energy it will gain. So from an efficiency viewpoint, is best to design and to use solar hot water systems in ways that let the water start the day as cool as possible rather than hot.

Aesthetics

For some solar users, discreet looking panels may be preferable to shiny ones, or to conspicuously ugly ones. For others, panels which visually shout "look - I am up here" may be important. Flat glazing for panels may in some circumstances be considered better practice than curved surfaces since these are more likely to tie in with building aesthetics. Having the opportunity to order solar panel frames available in specific colours which are similar to the colour of nearby building components such as roof tiles, slates etc may be preferable on occasions where planning criteria are tight. For some people, beauty means complexity, for others it is simplicity: the choice of technologies caters for all tastes across this spectrum.

Inherent safety

For example, concerning lower rather than high solar collector stagnation temperatures. Stagnation temperature is approximately the temperature at which a solar collector will settle down in full sun if left there for an hour or more without heat being removed from it and with the pump switched off. Stagnation temperatures in solar collectors vary from 130C to over 200C above the air temperature in which this occurs. Lower stagnation temperatures are inherently safer and therefore better practice than high stagnation temperatures since they involve offer lower boiling risks and lower pressure risks.

In addition, low pressure solar water heating systems which typically operate under 0.5 bar pressure are inherently better practice than systems operating at higher pressures. Although the UK and Ireland do not currently insist on thermostatic blender valves being installed, solar installations which include a thermostatic blender valve to limit the water leaving the hot water cylinder to 60C (by blending it with cooler water) are inherently safer than ones which do not, even though scalding can occur at temperatures as low as 45C.

However, thermostatic blender valves may reduce the speed at which water flows from taps. This drawback can be reduced, but not eliminated, by selecting a blender valve which is designed for one pipe size larger than the pipes to which they will be fitted: for example on 22 mm pipes, a 28 mm blender valve can be fitted.

In all solar installations, heating the cylinder regularly to 60C, right to the bottom is advisable. Twin coil conventional solar cylinders, have an “exclusive solar volume” (of often tens of litres) at the bottom of the cylinder with the backup heating usually positioned higher up. Exclusive solar volumes may be inherently less safe, from a Legionella perspective, than conventional cylinders which have backup heating located closer to the bottom. This is because Legionella bacteria are killed at temperatures over 55C, however the bottoms of conventional twin coil solar cylinders may not reach this temperature for weeks at a time in winter, thus potentially allowing dangerous bacteria to proliferate to high levels. Avoiding solar cylinders with a separate pre-heat volume may be advisable in some circumstances, unless they can be regularly heated, right to the bottom to 60C, particularly in winter.

Solutions to the above, if considered important, can include using a destratification pump regularly, or having backup heating coils which reach the bottom of the cylinder, which are, perhaps, intertwined with the solar coil, or using direct solar water heating in a normal cylinder which has its backup heating at the bottom. It should be noted here that in domestic installations the UK’s DTI do not require any of these particular Legionella control measures as part of grant aided solar.

Panel weight can be a safety issue. When retrofitting solar panels to a roof, heavier panels are more likely to need structural calculations and roof reinforcement, so many panels are designed for lightness. Weight also has health and safety implications when it comes to lifting and handling panels on the ground and on the roof.

Energy and panel performance

Solar fraction. Over a year, homeowners can expect 30-70% of their hot water to be heated by the sun. Better positioned panels in low occupancy homes may approach this 70% "solar fraction", while the same size panels which are less well positioned, or in homes with 3-4 people may achieve the lower solar fraction.

The exact location of panels on roofs is, however, far less critical than many people think. Almost every home in the UK has a roof which is positioned within 20% of optimum, when it comes to collecting sunlight. Even a west facing roof at 30 degrees pitch collects around 85% of an maximally positioned panel, which is typically due south at 30 degrees pitch. It is worthwhile seriouslyconsidering panel performance and how much sun it intercepts: but one should be prepared to compromise and to bear in mind that maximising annual panel gain is different from maximising usable energy gain, given that a panel which may collect the most energy over a year may not necessary deliver 100% usable energy, because you may have an excess of energy arriving in summer.

Therefore, where possible, it may sometimes be important for solar suppliers to position panels steeper than "annual optimal" to gives customers more useful energy over the year, particularly in spring and autumn, at the expense of a summer surplus.

Convenience

Having hot water relatively early in the day may matter to some customers. Systems which deliver hotter water earlier in the day by the significant use of hot water stratification, such as direct solar heaters, may, in some applications, be preferable over indirect systems. Stratification is where hot water floats above cold.

Rapid installation. Simple solar water heating systems which can be installed in 3-5 hours and which will give the user hot water the same night may be preferable to more complex systems which may take 2-3 days to fit and which may leave the customer without hot water during one or more nights.

Homegrown or imported?

For some people, the big picture that includes supporting jobs by buying locally manufactured products can be important. In addition, it is worth examining whether or not a solar collector has been specifically designed for the rapidly changing climate of the British Isles. Lightweight collectors, variable speed pumps, and low volume pipes within them tend to make the best of our short sudden bursts of sunshine.

Realistic expectations when it comes to solar space heating

Solar space heating / central heating? The shortage of sunlight is precisely the *reason* why it is colder at night and in winter. This is a meteorological reality, from which we cannot escape. In June in UK, there is typically six times more sunlight available than in December. Six times! So solar can do space heating extremely well provided that you are happy to have most of the heat arriving when you don't want it: by day and in summer. But...

The main solar central heating exception is large scale "interseasonal solar hot water storage". This is where the rocks deep beneath your homes become a giant storage heater, to be emptied in winter. This proven technology is used very successfully in parts of Scandinavia. It is practical but inherently very large scale, needing communities of 100 to 1000 homes to participate, because of what engineers call "constraints due to the ratio of surface loss to storage volume". Surprisingly, no interseasonal projects exist yet in UK / Ireland.

Other claims that solar may offer cost-effective contributions to solar space heating should be treated with caution, unless the technology is low cost. The further north you go the longer becomes the "central heating season". This means that Scotland is a better candidate for solar central heating than southern England. One sensibly priced new air heating solution is MacGregor Solar's "Solar Slates". Even in solar water heating applications where the water is used for washing and bathing, between 30-70% of your energy may still need to come from other sources. The key points are that solar water heating gets rid of fuel, but not boilers and that solar water heating usually offers better value for money than solar central heating.

Water quality

Best practice in water hardness control is more important for direct than for indirect solar water heating systems. Direct solar water heating systems may need robust hardness control: and water softeners may be difficult to install in a few properties. Unless they are plumbed "indirectly", water harness control for direct solar is usually achieved by polyphosphates where the water hardness is 100-200 ppm $CaCO_3$ and by the use of an ion exchange softener above this figure. Ion exchange water softeners are thus regarded as essential best practice. Lower cost, but less effective hardness control options such as "physical water conditioning" may be feasible for indirect solar thermal plumbing.

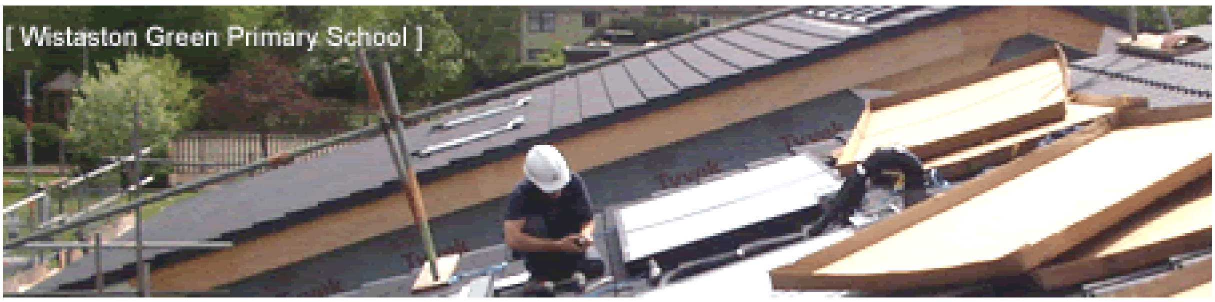
Value for money

Electricity or heat? It is noteworthy that energy from solar electricity (PV's), which is otherwise not covered here, costs, per unit, about 3-5 times more than solar hot water. However, the maintenance of PV's costs less than the maintenance of antifreeze based solar water heating systems. Since over 70% of energy in the home is used in the form of heat, rather than electricity, it makes sense, from the energy engineering perspective, to collect energy in the same form in which it will be used, rather than in another form. This is one of several reasons why solar water heating tends to be considerably more cost effective than solar electricity. Some people also look at value for money from a carbon saving perspective, rather than just a money saving viewpoint. This brings in the interesting but very detailed subject of "environmental valuation" with respect to energy, a subject that is not covered here. The EU's Externe Project is an interesting introduction.

The common (financial) denominator for many solar customers starts with the initial cost of their solar heating installation, minus any grant. It is worth noting here, that zero carbon solar is likely to cost slightly more to buy, since zero carbon solar includes its own miniature solar electric power station, rather than just a length of cable. Additional costs over 20 years or so, of maintenance and electricity (if any) to run the system also need to be estimated.

On the plus side, annual savings come from fossil fuel saved, plus the fact that boilers last longer and may need less maintenance because less fuel will be put through them when solar is used to displace fuel. Where water softeners are fitted, they have running costs which may be offset by increased efficiency in hot water cylinders and savings on cleaning materials such as detergents, scourers and soap.

Capital cost or whole of life costing? So rather than looking only at initial capital costs, the above "whole of life" approach towards solar, examines total capital cost, less running costs, maintenance costs plus fuel and other savings. In general, this big picture approach can favour zero carbon solar and solar which requires low maintenance over older technologies.



I'm implementing solar across a range of homes? How do I select them?

You will be spoilt for choice: Of the 24 million homes in UK, under 0.1 million use solar water heating. Of the remainder, over 90% have a suitable roof and over two thirds have suitable plumbing. This means that approximately 15 million homes could have solar.

If you are in the fortunate position of being a manager in social housing who has a budget to install say fifty solar panels across a thousand homes, this poses a very taxing question: Which houses to start with? The answer will depend on how you want to maximise the benefits, be they social, financial and environmental. The key questions to ask are: how many occupants?, What is the displaced energy?, Is there fuel poverty?, and What will be the lowest cost (usually the simplest) installations?. Here is a quick look at each in turn and an example of a "points" system. I hope this approach, or some variant of, it might help you to prioritise the best candidates first and also help to weed out the lower priority homes. The more points the better the candidate is for solar. Here goes...

How many occupants? When it comes to looking at how many people live in a home, those with more people in them will usually gain a higher priority, when it comes to installing solar. This is because more people will make more use of the hot water, thereby saving more energy and more money and cutting global warming more (than if, say, only one person were using hot water). If a simple points system were to be used to work out which homes were best candidates for solar, you might want to give one point for a single occupied home, two for a home with two people in it, and so on, with a maximum of four.

What is the dirtiest "displaced energy"? Environmentally, although around 50% of UK homes use mains gas for heating water, this fuel has a much lower "global warming impact" than higher carbon fuels such as: electricity, coal, oil and bottled gas. So it makes environmental good sense to install solar water heating into homes where the occupants heat their water with electricity and coal, and then to work down the list to the lower carbon fuels, only installing solar in homes which use mains gas as the lowest priority. This approach can let you more than double the CO2 savings compared to what would happen if you started first by installing solar into homes of users of mains gas. The general rule is again to look at the big picture and offer the high carbon homes solar first of all. Again, if a points system were to be used, to work out, in terms of carbon displacement, which homes were best candidates for solar, you might want to do this: Give five points for where electricity was the fuel which is saved by using solar, four for coal, three for oil, two for bottled gas and one for mains gas. Add this figure to the score from the above.

What about fuel poverty? In addition, homes which use costly fuels can be treated as priorities from the point of view of cutting fuel poverty, which is defined as when more than 10% of household income is spent on energy. If the case of fuel poor homes you may want to add one or more points.

Finally, start on the simple jobs and on the low cost jobs first. Give the costly or complex installations low priority, unless money is no object. Complex plumbing and high, inaccessible roofs bring the main cost hikes here. The lower the roof, the lower the cost of installing solar. If the home is more than two storeys to the gutter of the roof, then, roof access costs are likely to very high. Consider installing solar in tall homes as a low priority, unless safe, low cost access to the roof is easily available.

Similarly, installing solar hot water (of any technology) into combi boilers, is not always technically feasible. Survey and design time costs money! Combi boiler solar installations typically cost 50% more than installing solar into homes where hot water cylinders already exist. Plus even if the home has a technically suitable “solar ready combi” it is well known that the occupants of combi boiler homes can sometimes be rather reluctant to give up about a square metre of their floor or precious cupboard space for the inevitable large heat store cylinder and pipework which combi boilers always require. In homes where combi boilers are used, it may be wise to cherry pick the simpler installations first and leave the combis until last.

In summary, prioritising high carbon fuels, high occupancy homes and fuel poverty households will show your funders that you are both strategic and serious about optimising the social environmental and economic benefits of using solar. It will also enable you to stretch your precious budget the furthest!

So how does your ***own*** home rate on this “points system”?

The planners want 10% of my new building's energy to come from "onsite renewable sources". Is this achievable?

Usually yes, usually easily. How to establish a 10% renewables capability goes like this... First identify your renewable energy resources. Ask precisely what renewable energies, such as solar and wind, are available on site. Then list the technologies (such as turbines) which could realistically harvest some of this energy. Next, ask how much energy is available. Then choose your renewable energy technology or technologies, if you are going for a mix. Now you need to "size" each technology appropriately. Then you need your costings. On the basis of a "lifetime costing" (usually mainly installation costs plus say 20 years running costs) you can then examine the costs-benefits - usually net money in, compared to net energy out.

In more detail, your first step is to list the renewable energy resources available in quantity. For example for a new-build government office building in a city, these might be wind and solar. If it were in the country, there might be other available energies such as geothermal (hot rocks) or hydro available from a stream nearby. Now you have your list of energy resources.

Step two. Identify the collection technologies for each energy resource. For example, within the wind technologies there may be a choice between one large turbine or several smaller ones, with differing planning or cost implications for each. Within the solar technologies, options include electricity or hot water. Since, besides being lower cost, solar hot water systems are often 4 times more efficient per square metre than solar electric systems, solar hot water tends to be a worthwhile technology to examine. Please also do a "seasonality analysis", by asking, for example: does the wind, sun (or whatever resource) actually arrive when the building is occupied, and when there is a demand for its energy. You may also need to examine backup fuel options, such as gas, electricity or wood chips.

Step three is system sizing. Work backwards from the building's estimated total annual energy demand. Say you are considering solar hot water as an option. Say the designers of the project estimate that the building will use 400,000 kilowatt-hours of energy a year. 10% of this is 40,000 kWh. But how much energy can one Solartwin panel deliver? This depends on a range of factors but is typically in the range of 600-1200 kWh per year. If we estimate its delivery as being 800 kWh per year, then by calculation, 50 solar panels would be required.

Reality checks. What would an installation of 50 panels cost? Typically £150k (i.e. £3k per panel) +/- 20% depending on issues such as how the panels are attached to the roof, scaffolding costs and the type of plumbing required to pipe and to store the hot water once you have collected it. How much roof or wall area would this require compared to how much you actually have? To allow for unused edges of roof, ready-reckon on 5 sqm of roof per panel provided the roof is pitched and in the range of E, S or W facing. Or you may use S (+/- 30 degrees) facing walls. Say you have 500 sqm of *available* roof. This could hold 100 panels, so with 50 planned, you fit the comfort zone. Now pass all your figures / assumptions to your financial / technical bean-counters for cross-checking! They usually confirm that 10% onsite generation of energy is achievable, and that solar hot water wins on costs-benefits.

Old solar chestnut: the efficiency non-question

Is it worth paying 30% extra or £1000 extra in order to be able to see an extra row of roof tiles? OK, those tiles may be particularly pretty, would you not prefer to spend this money on a framed painting, to view indoors, or maybe even some other energy efficiency investments? The presumption of having to maximise energy delivery per square metre of solar panel is, perhaps surprisingly, not always important. The key fact to remember is that over 95% of users of solar are not short of roof space. This "component by component" approach to solar can be useful in its way, but focussing on the big picture of total health safety, environment and customer satisfaction issues may be at least as useful.

Standard history

Most solar standards and best practice guides offer old, historical perspectives. The European and International solar standards are virtually obsolete because they only represent a limited range of older technologies. Despite recent advances in solar thermal technology, an apparent dominance of the standard-setting processes by individuals and research establishments who are conversant mainly with older forms of solar, appears to be contributing to regulatory inertia.

The wide range of low and zero carbon solar water heating technologies

Low carbon solar water heating includes the following. If air is used as a heat transfer medium, there is one main supplier in UK. If water, containing antifreeze, is the heat transfer medium, there are many suppliers using either vacuum tubes or flat plate collectors to catch the sun.

Zero carbon solar water heating solutions tend to use water as the heat transfer medium. They include technologies such as Solartwin, which uses low flow pumps and microbore pipes, coupled with variable speed pumping. Other water based solar technologies use a drainback system when frost threatens, in order to avoid freezing causing damage to their metal panels. This approach requires very diligent plumbing. An alternative to metal pipes is flexible polymer ones which simply freeze without cracking - throughout the solar installation. Solartwin's panel contains food grade flexible pipes like these. It plumbs directly into existing cylinders to maximise panel efficiency and stratification, and it can also be plumbed indirectly.

Whichever technology you choose will be a good choice: the big decision is deciding to to go solar in the first place. Enjoy!

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