An Introduction to the Hybrid Solar Solution

a report by

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The Hybrid Solar Solution

This British-designed and -built solution is the first in the world to combine three different renewable energy technologies into a single efficient and reliable system. It can provide all of the annual central heating and hot water requirements of well-insulated homes and generate more than enough electricity to do so carbon-neutrally.

In order to explain how the hybrid solar solution generates efficiencies in both financial and environmental terms, it is useful to take a step back and look at the three component technologies involved.

1. Photovoltaic Panels

Photovoltaic (PV) panels have been available for decades; the introduction of electricity feed-in tariffs has made them an economically viable producer of both electricity and revenue. A little-mentioned drawback with PV is that as the surface temperature of the panel rises the output drops, as electrical conductivity is impaired by heat. This can result in disappointing operational output in periods of sustained hot and cloudless conditions when one would otherwise expect PV panels to perform at their best.

2. Solar Thermal Collectors

Under direct sunlight, traditional solar thermal installations collect the sun's heat and convert this into hot water, typically meeting the large part of a property's summer hot water requirements. A major drawback is that in times of little or no sunlight there is little or no hot water. In winter, solar thermal collectors can be rendered essentially useless for long periods.

3. Heat Pumps

Heat pump technology has been available for many years and installations of both ground- and air-source systems are meeting heating demands worldwide. However, while these devices are potentially greener than burning fossil fuels directly for heat, they use large amounts of electricity to power compressors that upgrade latent heat to a useful temperature. The lower the temperature of the latent heat source, the less efficient the heat output.

Advantages of the Hybrid Solar Solution

The hybrid solar solution combines all three of the above technologies in such a way that the aggregate system output is far greater than those produced by the individual components.

How is this achieved? PV panels, as already mentioned, have a linear drop-off in electrical efficiency as the surface temperature of the panel rises. Given that PV panels are typically dark-coloured and mounted in such a way as to receive maximum exposure to the sun, this rise in panel temperature is inevitable. PV panels typically lose up to 0.5% in efficiency per degree rise in panel temperature.

However, with the hybrid solar solution, the PV and thermal elements are combined on a single panel – a photovoltaic thermal (or PV-T) collector. A flat-plate solar thermal collector is bonded with thermal conductive glue on to the back of the PV panel, thereby directly drawing heat away from the panel surface.

This has two main advantages: first, by reducing the panel surface temperature the electrical output is maintained at a higher level for a longer period, and second, with the PV and thermal elements combined on a single panel less roof area is required, allowing for greater electrical and thermal output than could be achieved by separate PV and solar thermal installations on the same amount of roof space.

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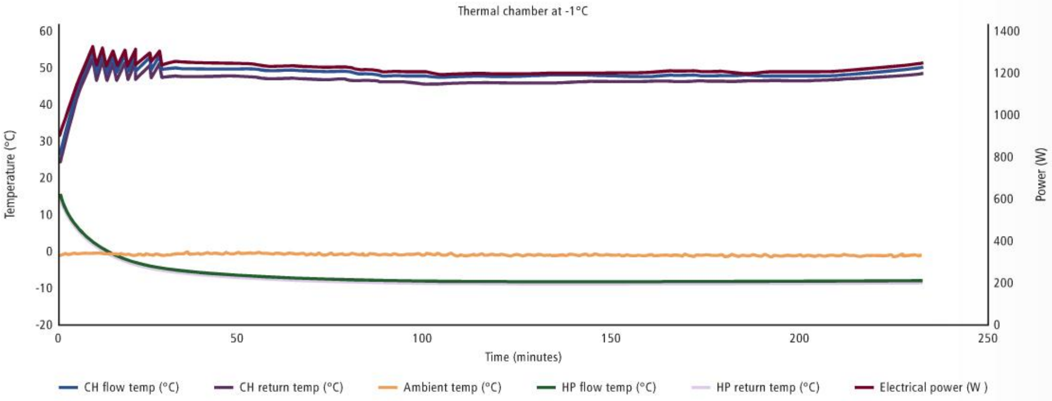
In the UK, electrical output from a PV-T panel is generally more than 20% higher over the course of a year than that achieved by the same wattage of good-quality monocrystalline PV panels. The uplift in electrical output is counteracted by a decrease in thermal output per unit area when compared with more traditional solar thermal collectors. This is a benefit in that it increases the area of roof that can usefully be used by PV-T.

Solar thermal output is dependent on direct sunlight, so for half of the day in summer and for most of the winter a solar thermal collector operates very inefficiently, if at all, and the heat collected is often at a much lower temperature than that required for use in a house. However, with the hybrid solar solution, the liquid loop in the solar thermal collector is connected both to the hot water cylinder and also to the heat pump.

With the integration of the heat pump, the output of the thermal collector is no longer directly related to the intensity of the sun and therefore a reasonably constant output temperature can be achieved irrespective of solar input – at times in summer when there is strong direct sunlight the solar thermal component of the PV-T will typically generate sufficient heat to cater for a household's hot water requirements and the output is therefore directed straight to the hot water cylinder.

Figure 1: PowerVolt Panels Absorbing Energy at -10°C in the Dark



The ability of the panels to absorb energy in such conditions demonstrates that the system will perform at higher efficiency than air-source heat pumps in the same environment.

Table 1: Technical Specifications of the Volther PowerVolt Panel

	PowerVolt W190/460
Dimensions	828x1,655x90mm
Weight	24.4kg
Liquid content	1.2l
PV efficiency	17.5%
Absorber panel	Mono-crystalline
Number of cells	72
Cell dimensions	125x125mm
WP (W) nominal power	190W
IMP (A) nominal current	5.2A
Isc (A) short circuit current	5.6A
Vmp (V) nominal voltage	36.5V
Voc (V) open circuit voltage	45.2V
Heat exchanger	Copper strip
Internal piping	Copper
Flow (L/H)	65
Test pressure bar	20
Operating pressure bar	10
Cover glass hardened	Low iron tempered
Sealing	EPDM & silicon
Housing	Aluminium
Rear side	Aluminium
Product warranty	10 Years
Quality guarantee	90% <10 years/80% <20 years

EPDM = ethylene propylene diene monomer (M-class) rubber.

Table 2: Thermal and Electrical Output of the PowerVolt Panel at Varying Temperature Outputs

	Radiation ΔT=10°C	1,000 Q=55l/h/m_2	W/m_2	n (%)
Powervolt	T out	Wth/m_2	We/m_2W/m_2	
	10°C	>600	178.7	>77
	20°C	510	171.2	68
	40°C	317	156.2	47
	60°C	113	141.2	25
	80°C	-71	126.2	6

Table 3: 50°C Output Temperatures

Water Temperature (Cold Side)	Duty (kW)	COP
19°C	5.96	3.94 *
20°C	6.05	3.98 *
21°C	6.17	4.04 *
22°C	6.35	4.15 *
23°C	6.55	4.28 *

** The coefficient of performance (COP) cited above are for the heat pump in its most basic form. By incorporating electricity frequency regulation and intelligent control systems it is anticipated that operating efficiency will improve by about 12%.*

However, when such heat is insufficient to meet requirements, the solar thermal output is redirected to the heat pump and upgraded to meet heating and hot water requirements. This has two major advantages: heat can be collected from the panel at night as the surface of the panel will act as a thermal absorber rather than solar collector (see *Figure 1*) and the temperature of water in the house can be set and achieved irrespective of levels of irradiance (sunshine).

Heat Pump Component

The efficiency of a heat pump is typically shown as a coefficient of performance (COP). This is a simple calculation of electrical energy input versus thermal energy output. The COP of a heat pump changes throughout the year as a direct result of seasonal variations in source temperatures. Simply put, as the input temperature of the source reduces (colder ambient ground or air conditions), and the temperature differential between latent heat input and upgraded heat output widens, the COP falls.

Air-source heat pumps are most susceptible to this; when the ambient temperature drops to below freezing the COP will drop off dramatically. Due to the relative constancy of the energy source, ground-source heat pumps are more stable and do not have such a wide COP range.

The hybrid solar solution maximises the advantages of air-source (namely low cost) with the downside of inefficient performance in freezing conditions. In winter, under direct sunlight the solar gain will ensure input several degrees above ambient air temperature, and generally above ground-source heat at the end of a harsh heating season when ground loops are likely to be at or below zero.

Over the course of a winter, the operating COP of the hybrid solar solution should therefore comfortably surpass that of domestic air-source heat pumps and compete reasonably well with ground-source heat pumps. Optimal winter weather is high pressure conditions with cold, bright and windless days.

Technical Specifications (see Table 1)

The hybrid solar solution uses a Volther PowerVolt Hybrid PV-T collector, which is the only Microgeneration Certification Scheme

(MCS)-accredited PV-T panel available in the UK (with the exception of its sister product, PowerTherm), providing the owner with revenue from both the feed-in tariff and renewable heat incentive systems for its respective electrical and thermal production (note that PowerVolt is currently listed as a transition product under the MCS).

The PowerVolt collector has been developed to maximise the electrical return of the panel, essentially making it an enhanced PV collector that also produces a reasonable amount of heat in the summer. Peak panel outputs are 190W electrical and 460W thermal.

When correctly installed, the panel will produce >20% more electricity than the equivalent wattage of good-quality monocrystalline PV over the course of a year in the UK. When the heat pump is running, electrical output will increase noticeably in sunny weather conditions – this is a result of the cold return from the heat pump being fed back into the PV-T array, thereby force-cooling the panels to a greater extent than the solar thermal component can achieve. This is a perfect solution for customers looking for a year-round heating and hot water solution and also wishing to maximise the electrical energy returns from a given roof area.

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The hybrid solar solution, with PowerVolt panels installed on a house with 28m^2 of available south-facing roof area, will produce the equivalent annual electrical output from 34m^2 of conventional monocrystalline photovoltaics. The same area of PowerVolt collectors will offset approximately the same amount of thermal energy as 8m^2 of conventional solar thermal collectors (without any contribution from the heat pump). Using separate PV and solar thermal systems would therefore require 42m^2 to generate the same electrical and thermal energy produced by 28m^2 of PowerVolt thermal collectors.

A hybrid solar solution system with the panel array size shown in *Table 2* and a heat pump of nominal 4.5 kW output would be capable of producing approximately 8,000 kWh at a COP of 3.6 or better during the cold winter months. Additional heat could be produced if required, albeit at lower COP as this would require the heat pump to run extensively during periods of darkness when no solar gain could be achieved from the PV-T. Eight thousand kWh would be sufficient to provide for a large part of the winter heating and hot water needs of a family of four living in a modern well-insulated and draught-proofed house of approximately 150 square metres floor space, with efficient low temperature heating systems. However, a further heat source would be required to meet peak heat load requirements: this can be provided in all circumstances by an immersion element in the heating