
REPORT TITLE:	Case Study 2: Comparison of different solar technologies for use within an aged care facility
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WRITTEN BY:	Dr Faisal Ghani Mechanical Design Engineer Solimpeks Australia
APPROVED BY:	Daniel Barber (Director, Solimpeks)
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Executive Summary

A computational analysis has been carried out on a 100 person aged care facility located in South East Queensland. Using the commercial software package Polysun, annual simulations were carried out on an hourly basis for three solar energy systems:

1) A flat plate collector system with 20kWp of PV modules.
2) An evacuated tube system with 20kWp of PV modules.
3) A hybrid PVT collector system rated at 20kWp of photovoltaic output.

Systems 1 and 2 were designed to provide a high solar fraction (circa 90%) where the solar fraction is the percentage of solar contribution to the total thermal energy load. The size of the hybrid PVT system was dictated by the photovoltaic power rating which was chosen in this work to be 20kWp.

It was found that all three systems were able to meet the thermal energy loads of the facility which was approximated to be 5000L of water at 48 degrees Celsius. The hybrid PVT collector was found to provide the greatest energy output per unit area of roofing while also matching the photovoltaic output of the conventional photovoltaic array with minor deviation.

Furthermore, it was found that the less expensive Wunder ALS1809 flat plate collector was able to provide the equivalent solar fraction as the evacuated tube system while using less roofing. This result can be explained by the high performance selective surface coating applied to the absorber fin of the collector which significantly reduces thermal radiation heat loss. The tropical climate of Queensland does not take advantage of the minimal heat loss characteristics of the evacuated tube collector.

Based on the results of this work, two engineering recommendations can be made:

1) If the goal is to minimise the roofing area consumed by the collectors, the hybrid PVT collector is the obvious choice as it will provide 75% of hot water from the sun while also providing 30MWh of electricity from PV.
2) If roofing area is not an issue, a combination of high performance flat plate collectors and 20kWp of high quality Winaico photovoltaic panels will make a substantial contribution to the hot water load (almost 90%) while also producing approximately 30mWh of electricity generation from PV.

1.0 Introduction

Conventional solar collectors have traditionally been split into two technical categories; a) photovoltaic (PV) and b) solar thermal. The PV collector is a solid state device capable of converting incidental sunlight into direct current electricity. The solar thermal collector on the other hand is able to convert incidental sunlight into thermal energy via an absorption process. Although the absorption process is fundamental to the solar thermal collector, both collector types (PV and solar thermal) are subject to this phenomenon due to the absorption characteristics of their materials. Consequently, the temperature of the collector, whether it is solar thermal or PV, will inherently increase from prolonged exposure to sunlight. For the case of the solar thermal collector, fluid channels placed in direct thermal contact with the absorber contain heat exchange fluid to transport this energy away from the collector for storage. By circulating fluid through the absorber of a solar thermal collector and relocating thermal energy to the storage tank, the transient rise in temperature is reduced. The situation, however, is quite different for a PV module.

The PV panel will absorb a significant portion of the total solar spectrum which it is exposed to. Only a small portion of this energy may be utilised to facilitate the production of electricity. The remaining portion, greater than 50% [1], is absorbed and sunk as heat by the PV cell, thereby elevating its operating temperature. The negative impact of temperature is well documented [2-4], with the principal effect an approximate linear drop in photovoltaic conversion efficiency [5] (commonly known as ‘degradation’). A reduction in PV performance can therefore be expected during the operation of any terrestrially installed PV panel. The severity of this is dependent on the environmental conditions (irradiance, ambient temperature), PV cell type and the type of installation (free standing, rack mounted, building integrated, etc.). Generally speaking, PV modules may operate at temperatures greater than 50 degrees Celsius resulting in a 10-15% drop in conversion efficiency. Over the typical 10-20 year operational life of a photovoltaic system, the electrical losses due to temperature can be significant. Using Polysun simulation software for an off the shelf mono-crystalline PV panel, the module temperatures were calculated under Brisbane weather conditions. The results for the first week of the year are shown in Figure 1, from which we can see that a module can reach temperatures greater than 60^{o}C. Over the year, a maximum temperature of 72 ^{o}C was obtained.

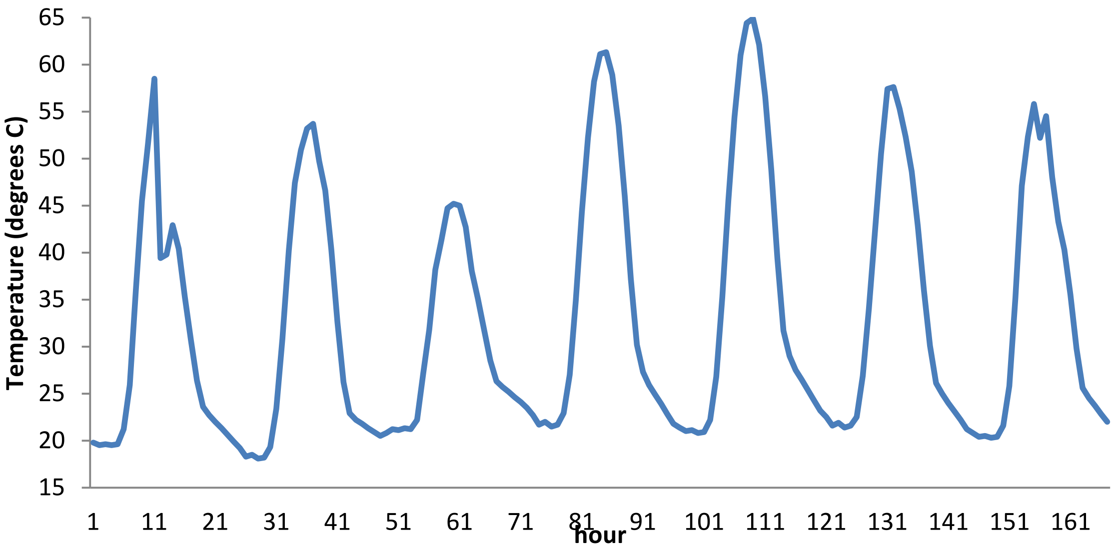

Figure 1 Module temperature for a generic mono-crystalline module for the first week of January in Brisbane, QLD. Data obtained from a simulation study using Polysun software.

Taking into account the absorption characteristics of the PV cell, a third type of collector has been developed which incorporates the performance characteristics of both photovoltaic and solar thermal collectors into a single integrated package. This collector, referred to as a hybrid photovoltaic/thermal collector, or PVT collector, utilises the standard PV cell for conversion of sunlight into electricity, but also as a thermal absorbing surface. The cells are laminated directly onto a fin and tube type absorber commonly utilised to fabricate a solar thermal collector which contains the necessary means to circulate the coolant and transport thermal energy away from the PV/absorber assembly to thermal storage. All major components are identified in Figure 2.

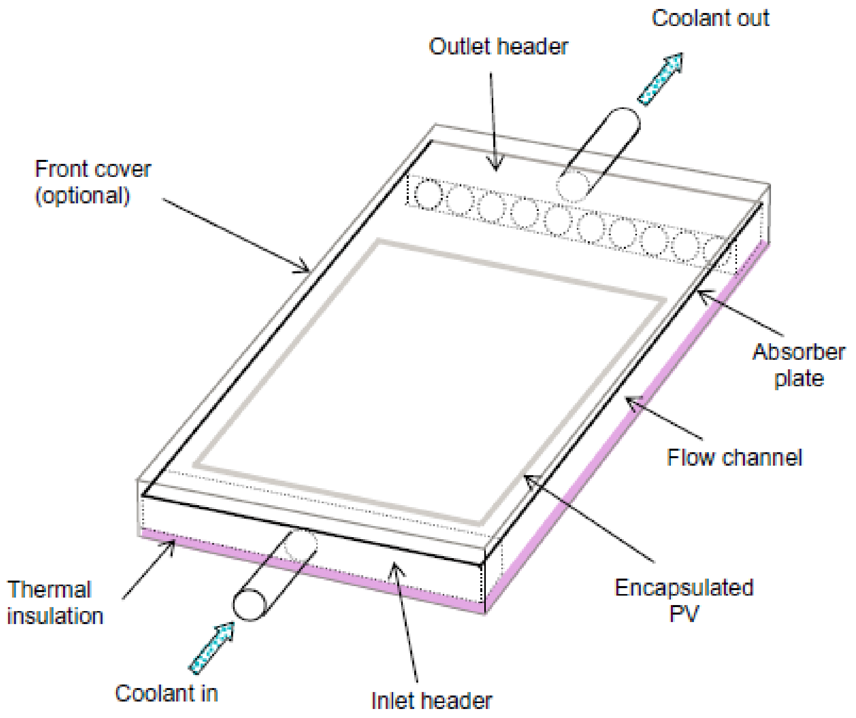

Figure 2 Diagram of the PVT collector with main components and fluid flow directions identified [1].

The hybrid collector offers a number of advantages over the conventional solar thermal and photovoltaic collectors with key advantages listed below [6-8].

1. Improved energy output per unit area of roofing used. This is a particular advantage for applications where roofing is limited relative to energy demands.
2. Possible reduction in installation cost and time. As only one collector is installed, the process of installation in comparison to individual photovoltaic and solar thermal collectors is faster and easier to manage.
3. The hybrid collector provides improved aesthetics and architectural uniformity as it avoids the mixing of collector types.

2.0 Problem statement

An aged care facility is currently under construction at South East Queensland, QLD. The facility is occupied by approximately 100 people with an assumed water temperature requirement of 48 degrees Celsius at point of use. Furthermore, facilities such as laundries, kitchens, and communal bathrooms will result in an approximate total daily load of 5000L of hot water. This is equivalent to approximately 165 kWh of energy per day or 60 000 kWh per year to meet the hot water requirements of the home.

In addition to meeting the thermal loads of the facility, a photovoltaic array may be installed to offset the consumption of electricity. This option is becoming more appealing considering the rising cost of utility prices, and the downward trend in photovoltaic system costs.

To meet the thermal energy demands and photovoltaic power generation requirements, a number of solar solutions are available:

1) System 1: Flat plate solar thermal collectors and photovoltaic module array.
2) System 2: Evacuated tube solar thermal collectors and photovoltaic array.
3) System 3: Hybrid PVT Collector system.

In this study we examine the feasibility of each system with respect to energy yield and roofing area. Annual simulations were carried out on an hourly basis using the commercial software package Polysun in order to quantify the thermal and electric outputs from each of the three systems mentioned above. The following section will provide details of the analysis procedure.

3.0 Analysis method

The thermal performance of the flat plate, evacuated tube, and hybrid PVT collectors will differ due their design differences. The optimal collector technology is dependent on a number of parameters related to its intended application and the installed climate, such as:

1) Required water temperature
2) Hot water consumption
3) Available roofing area
4) Climate (irradiance, wind, ambient temperature)

As the conditions and system state will vary throughout the day, simulations are performed to approximate the energy output from a solar energy system. For this, we used Polysun software, a popular software package used for the analysis of solar thermal, photovoltaic, and heat pump systems.

In total, three systems were created and simulated in Polysun. The Polysun schematics for each of the systems are shown in Figures 3, 4, and 5 of Appendix A. The simulation parameters provided in Table 1 were universally applied.

Table 1 Universal parameters for each of the three simulations performed in Polysun.

	Parameter	**Setting**
1	Daily hot water consumption	5000L
2	Desired hot water temperature	48^{o}C
3	Auxiliary energy source	100kW continuous flow gas
4	Hot water storage tank	8000L, stainless steel
5	Photovoltaic power rating	20kW$_p$
6	Collector azimuth	165^{o}
7	Collector tilt	12^{o}
8	Hot water consumption profile	Aged care facility

For System 1, the Solimpeks Wunder ALS1809 flat plate collector and Winaico WSI-200M6 photovoltaic modules were used. The Wunder ALS1809 is a high performance collector made using a laser welded aluminium absorber coated with a Tinox selective surface. The performance parameters for this collector were taken from a report published by the Institute of Thermodynamics and Thermal Engineering (ITW) in 2012. Using Polysun, it was found that 38 Wunder flat plate collectors were needed to obtain a solar fraction of 90%.

For System 2, the Solimpeks PowerTube collector consisting of 30 tubes was used. Performance data for this collector was taken from a Fraunhofer test report published in 2012. In total, 20 x 30 tube collectors were used in order to obtain a solar fraction of approximately 90%.

Finally, the Solimpeks PowerVolt collector was used for the hybrid collector. Collector performance data was taken from a Eurofins test report published in 2011. A total of 100 PVT modules were used to provide 20 KWp of electricity.

Results of the simulations are presented in the proceeding section.

4.0 Results and discussion

Annual results produced from Polysun are presented in Table 2. All three systems were able to meet the thermal loads of the system using the proposed 100kW auxiliary gas booster. Based on the annual simulation results, it was determined that the total annual energy demand was approximately 65,000 kWh for hot water use. If electricity at the rate of $0.25 per kWh is used to heat the water, this equates to an approximate annual utility cost of $16,250. Examining Table 2, we can see that using flat plate or evacuated tube solar thermal collectors we can provide up to 90% of this energy. Similarly using the hybrid PVT collector, we can supply almost 75% of this energy. The implementation of solar thermal collectors can therefore make a significant reduction to the running costs of the facility.

Table 2 Annual simulation results for Systems 1, 2, and 3. For schematics of each system see Appendix A.

	System		
	1	**2**	**3**
Total collector area (m^2) [Solar thermal + PV]	201.10	233.70	137.80
System performance $[(Q_{use}+E_{inv})/(E_{aux}+E_{par})]$	7.52	7.46	3.10
Solar fraction (%)	89.80	89.50	74.00
Solar thermal collector yield (kWh)	63,154.00	62,394.90	49,592.00
Photovoltaic array yield (kWh)	31,306.00	31,306.00	30,776.00
Total annual collector yield (thermal and electric)	94,460.00	93,700.90	80,368.00
Reduction in CO_2 emissions (kg/m^2)	161.82	136.62	231.70
Specific annual yield of PV system (kWh/kWp)	1,565.30	1,565.30	1,538.80
Total Auxiliary fuel consumption (kWh)	-22,299.00	-22,292.00	-9,679.90

Interestingly, System 1 comprising of the Wunder ALS 1809 flat plate collectors, was found to be able to match the thermal output from the evacuated tube solution, while using less roofing area than System 2 made up of evacuated tube collectors. This result can be explained by the fact that the gross area of the flat plate collector has a much higher percentage of absorber area comparatively to the evacuated tube collector. Furthermore, the thermal losses from a flat plate collector made using a selective surface absorber are low minimising the performance disparity between it and the evacuated tube whose primary advantage is reduced thermal loss.

Figure 3 below plots the total energy output (thermal and photovoltaic) per unit area of collector (disregarding plumbing work). From this plot we can see that the hybrid PVT collector yields the maximum energy output per unit area of roofing. This plot highlights the principal advantage of this collector in comparison to existing solar technology.

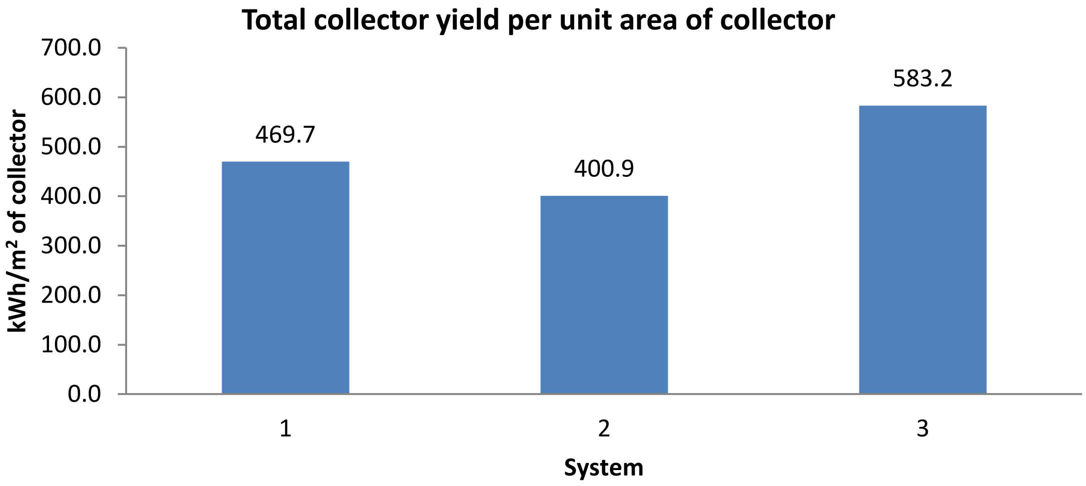

Figure 3 Column plot of energy yield per unit area of collector for each system.

Now looking at the photovoltaic output from each of the three systems, Figure 4 plots the annual output from each system. The photovoltaic output from systems 1 and 2 are identical as both PV systems consist of the same modules installed in the same way. Despite the PVT modules being used to meet the domestic hot water requirements of the facility in System 3, the photovoltaic output was only 1.7% less than the standard PV module systems 1 and 2.

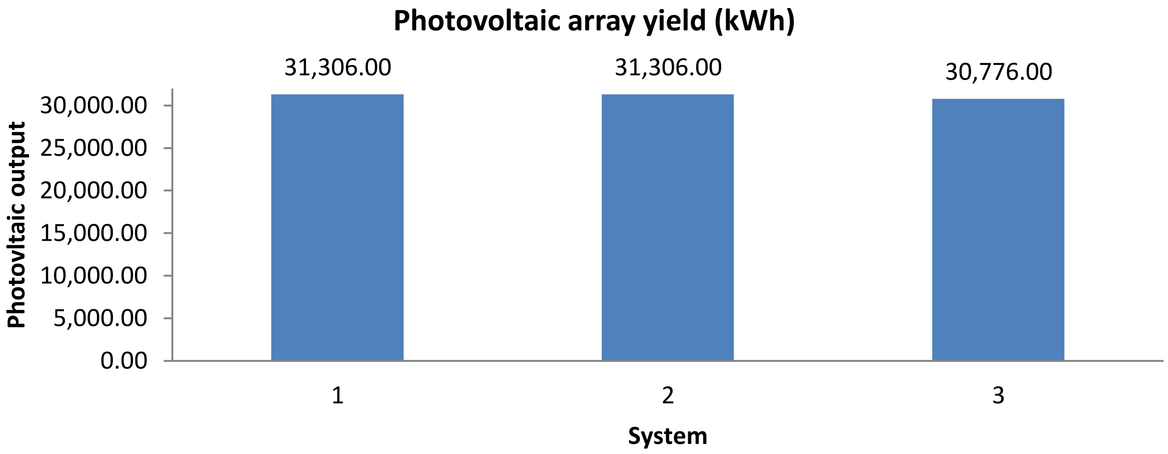

Figure 4 Photovoltaic output from each of three systems investigated.

The total number of collectors required by each of the three systems is listed in Table 3.

Table 3 Number of collectors required by each system, broken down into collector types.

	System		
	1	**2**	**3**
Solar thermal collectors	38	20	NA
PV modules	100	100	NA
Total	138	120	100

5.0 Concluding remarks

Three solar energy systems were designed for a 100 person retirement home located in South East Queensland, QLD. For all systems studied, the thermal loads were met based on the consumption of 5000L at 48 degrees Celsius. A comparison has been between flat plate, evacuated tube, and hybrid PVT collector systems. From this study, the following key findings were found:

1. The Solimpeks hybrid PVT collector was able to yield the greatest energy output per unit area of roofing.
2. The Wunder ALS1809 high performance flat plate collector was able to match the thermal output of the evacuated tube array despite using less roofing area.
3. Only a 1.7% difference was found between the photovoltaic output from the hybrid PVT and the conventional photovoltaic modules despite the PVT collectors being used for domestic hot water supply.

The results of this analysis demonstrate the significant contribution solar energy systems can make to the energy consumed by an aged care facility. The hybrid PVT collector was able to make a significant contribution to the thermal energy requirements of the facility yielding a solar fraction of almost 75%. For installations where there is limited north facing roofing, the PVT collector offers a unique solution that is simpler to install in comparison to traditional solar thermal and photovoltaic collectors and has the added advantage of improved aesthetics.

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Appendix A. System schematics

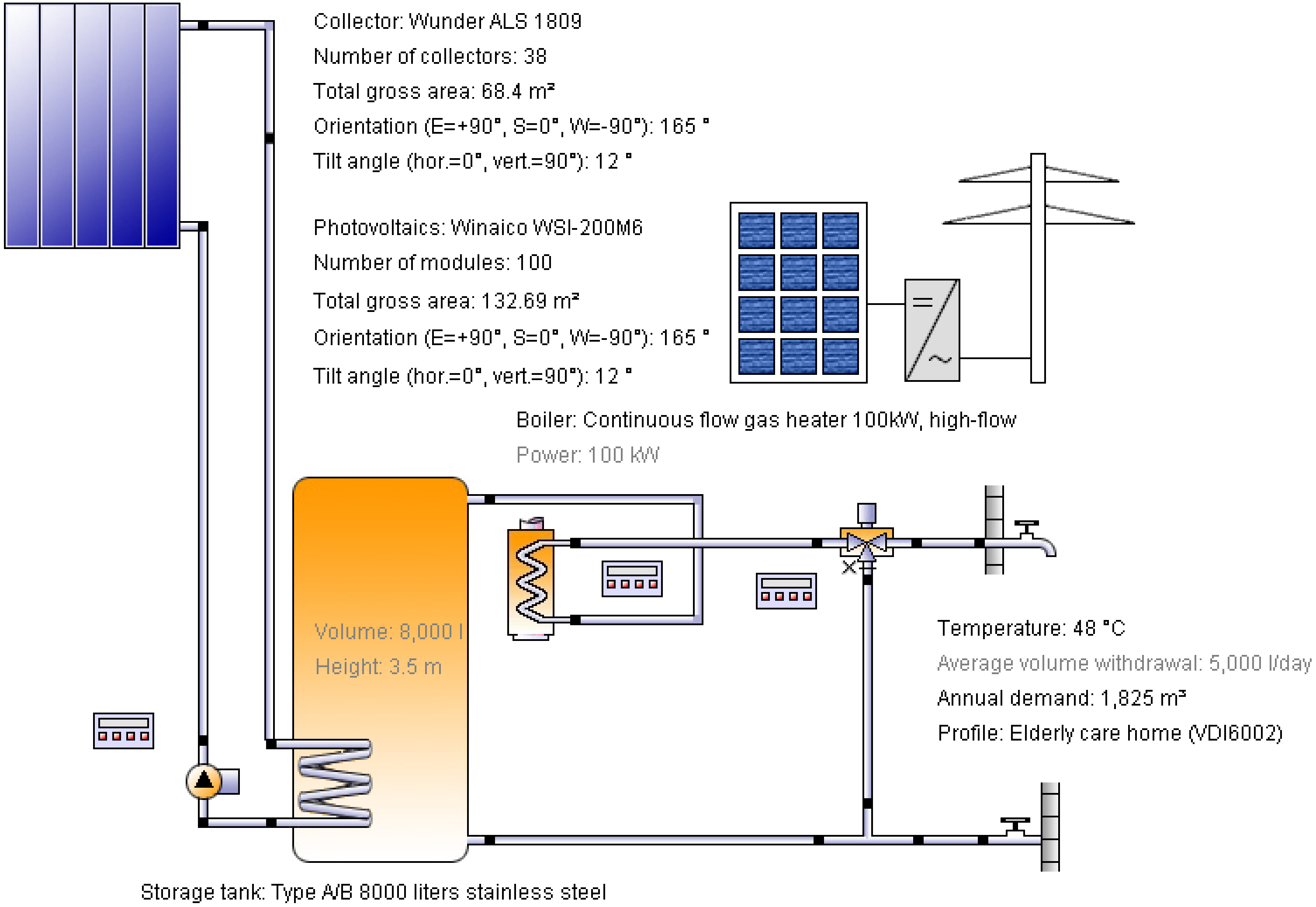

Figure 5 System 1: Flat plate solar thermal collector system with 20kWp PV array.

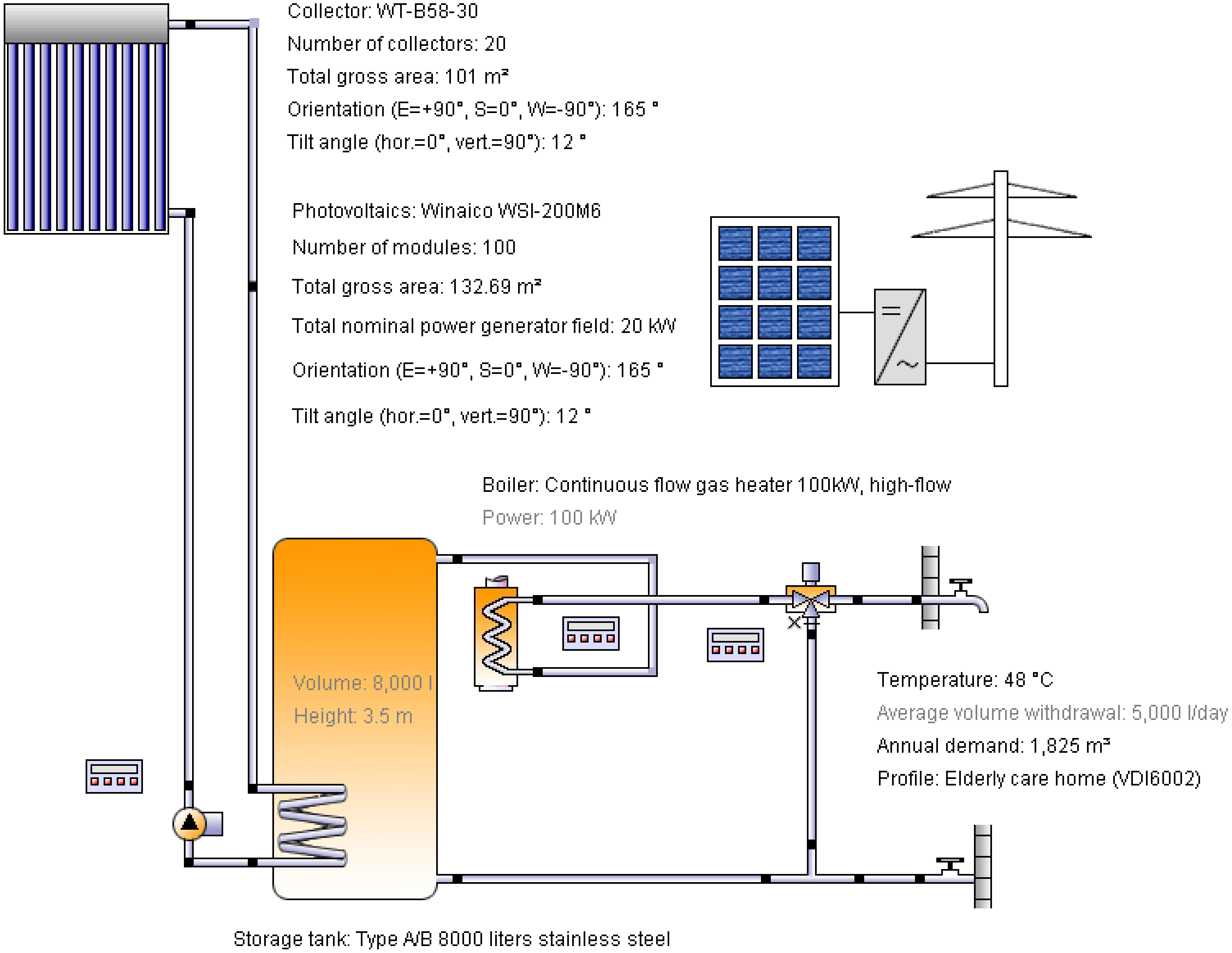

Figure 6 System 2: Evacuated tube solar thermal collector system with 20kWp PV array.

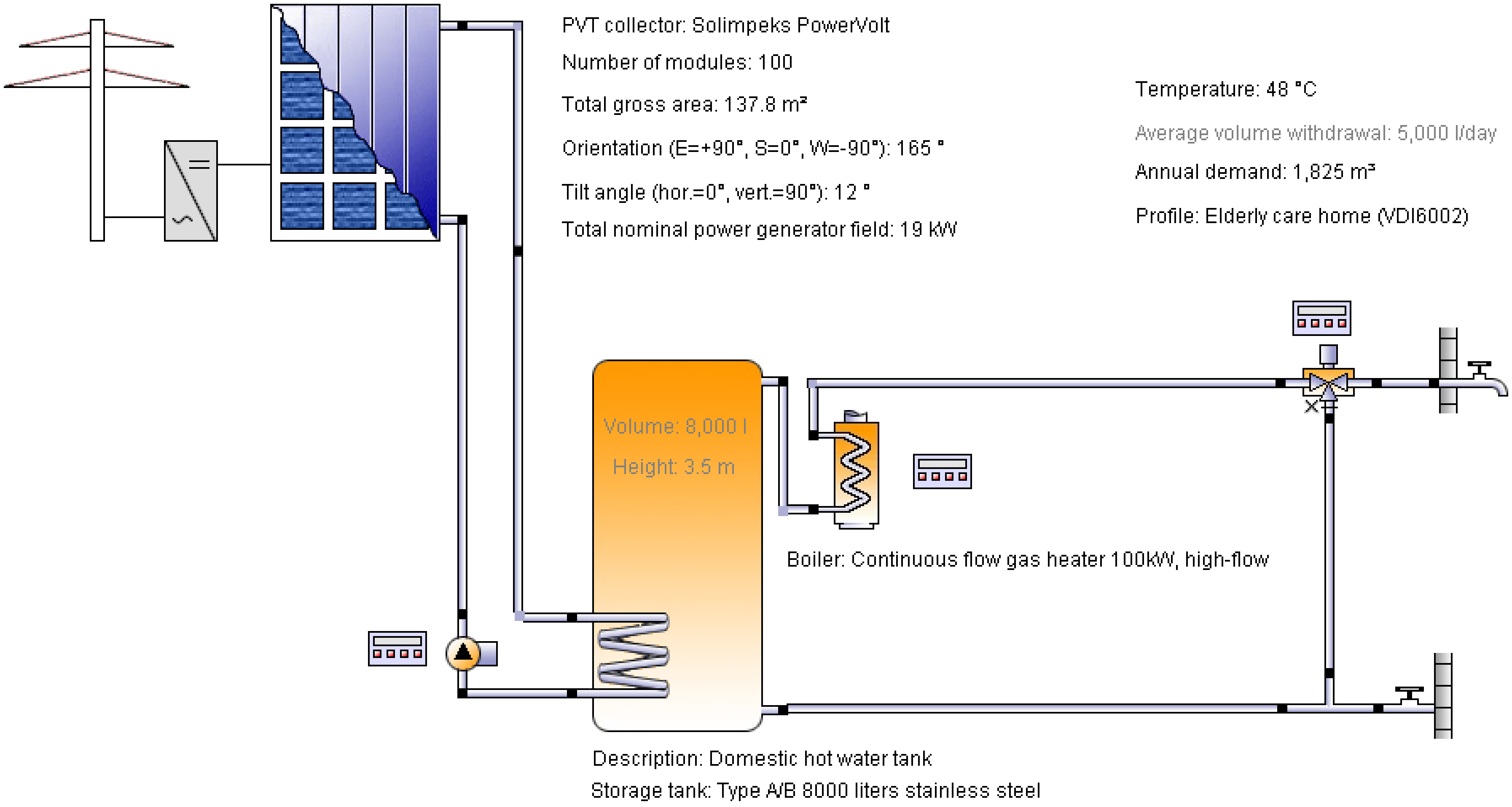

Figure 7 System 3: 20kWp Hybrid PVT System.