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REPORT TITLE: Case study 1: Implementation of the Solimpeks PVT Hybrid collector for hot water / pool heating / photovoltaic power generation

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Executive Summary

A simulation study has been carried out in this work to investigate the energy output from two solar energy systems:

1) A system which comprises of a combination of glazed and unglazed solar thermal collectors to meet the thermal demands of domestic hot water and pool heating. Additionally a 5kWp photovoltaic array for grid feed was included.
2) An equivalent system using the Solimpeks PowerVolt hybrid collector sized at 5kWp.

Systems 1 and 2 above were applied to meet the energy demands of a four person home with a 36m^3 swimming pool heated to 25^{o}C located in Brisbane, QLD. All work was carried out using Polysun software.

It was found in this work that both systems were able to meet the thermal demands of the proposed system with equivalent solar fractions (percentage of solar contribution to thermal load), however, the PVT system was able to do so with 46% less roofing area. Interestingly, it was also found that the photovoltaic output from the PVT system only differed by 1.5% over the traditional PV array. Examining the hourly data produced by Polysun over the year, the average module temperatures were found to be 29 and 26.7 degrees C. These results demonstrate that an appropriately sized PVT system will provide an equivalent output to a traditional photovoltaic panel despite being used for a domestic hot water application.

Finally, as the PVT collector energy yield per unit area of collector is greater than conventional solar technologies (PV and solar thermal), the carbon emissions reduction is also greatest.

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.

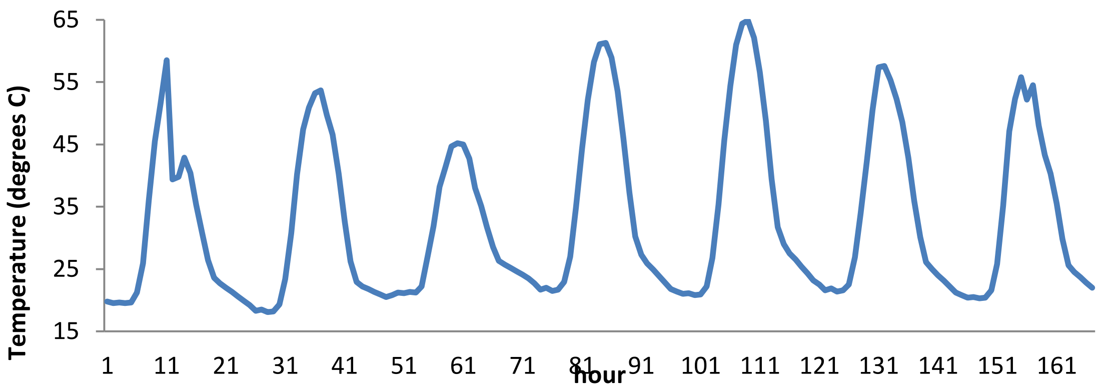

Figure 1 Module temperature for the Suntech STP200S mono-crystalline module for the first week of January in Brisbane, QLD. Data obtained from a simulation study using Polysun software.

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.

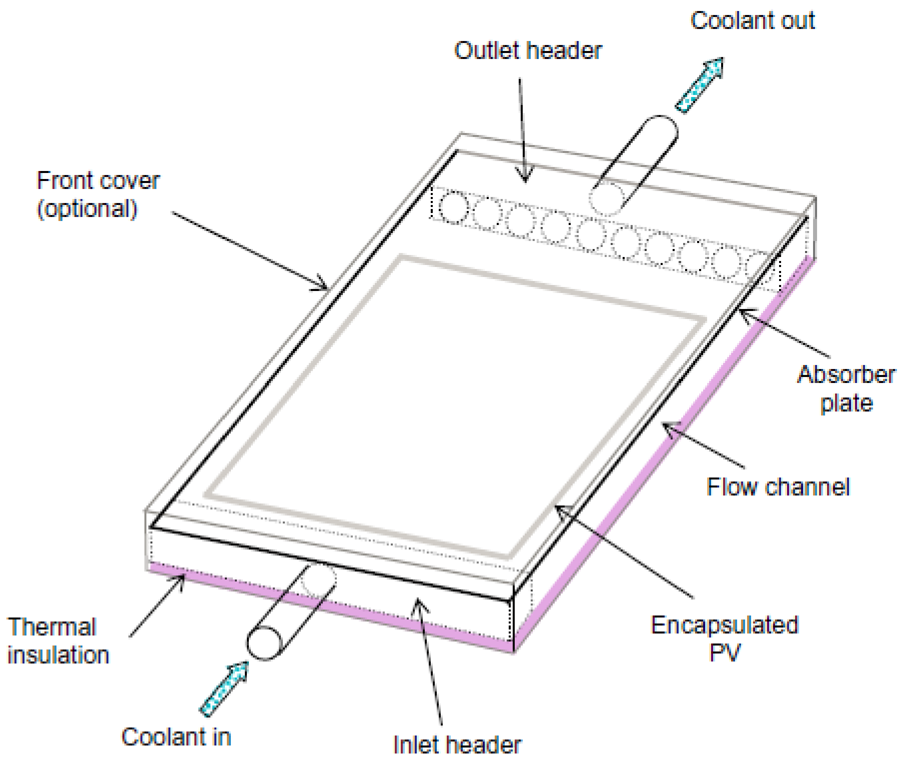

Figure 2 Diagram of the PVT collector with main components and fluid flow directions identified [1].

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.

In order to highlight the advantage of the PVT collector, Solimpeks Australia has carried out a simulation study for a residential system consisting of:

1) A photovoltaic array;
2) A domestic hot water system;
3) A pool heating ;

All powered using the Solimpeks PowerVolt hybrid collector. The next section will discuss the system design and the parameters of the simulation.

2.0 Analysis procedure

Using the commercially available software package Polysun, a simulation was carried out to quantify the output of two systems:

1) System 1: A system using traditional solar technologies (photovoltaic, solar thermal, and black matting) for domestic hot water, pool heating, and electricity production.
2) System 2: A system equivalent to system 1 using the Solimpeks PowerVolt collector as opposed to traditional solar collector types.

Schematic diagrams of Systems 1 and 2 investigated in this case study are shown in Figure 8 and Figure 9 respectively in Appendix A. Both systems were modelled in Brisbane, QLD based on the domestic hot water requirements of four people. We determined this value to be 200L of water per day at 50 degrees C at point of use. Based on this thermal load, a 400L thermal storage tank with a twin coil heat exchanger was used for both systems. One heat exchanger coil was dedicated to the solar thermal collector loop, and the second was used for auxiliary boosting using a 10kW gas heater. Both tanks and gas heaters were identical for each system. Details for both systems are shown in Table 1. The photovoltaic output for both systems was rated at 5kWp under standard test conditions (STC).

Table 1 Details of the various components used for this simulation study specified in Polysun software.

	System 1	**System 2**
Description	Traditional collector technology	Solimpeks PowerVolt collector
Storage tank	400L, twin coil	400L, twin coil
Swimming pool (outdoor)	6 x 4 x 1.5m	6 x 4 x 1.5m
Plate heat exchanger rating	10 000 W/K	10 000 W/K
Collector 1	Glazed flat plate, Rheem Vulcan	Solimpeks PowerVolt PVT
Collector 1 Area (m^2)	4.02	34.25
Collector 2	Solar Black Matting	N/A
Collector 2 Area (m^2)	23.04	N/A
Collector 3	PV module, Suntech STP200S	N/A
Collector 3 Area (m^2)	36.75	N/A
Total collector area (m^2)	63.81	34.25

Key simulation parameters are provided in Table 2.

Table 2 Parameters of the simulation study.

1	**Location**	Brisbane
2	**Collector azimuth**	180^{o} (North)
3	**Collector tilt**	20 degrees
4	**Thermal load**	200L, 50 degrees C
5	**Desired pool temperature**	25 degrees C
6	**Usage profile**	Family dwelling (morning peak)

Annual simulations were performed based on the components and parameters provided in Tables 1 and 2.

Referring to System 1, three types of collectors were used as specified in Table 1. For domestic hot water production, a glazed flat plate type collector manufactured by Rheem Australia under the brand of Vulcan was taken from the Polysun collector database. This collector was chosen based on the manufacturer's penetration into the Australian solar thermal market. For pool heating, black matting is typically used in Australia. A generic collector was taken from the Polysun collector database for this collector. Similarly, for the photovoltaic array, a 5kWp system was modelled using Suntech Power 200Wp modules.

Using Polysun software, an energy analysis was performed on an hourly basis based on the weather data for Brisbane. This was done in order to quantify the energy obtained from the various solar collectors, whose behaviour will dynamically vary due to changes in environmental conditions (irradiance, wind, ambient temperature) and heat exchanger fluid temperatures. Results of the energy analysis will be provided in Section 3.0.

3.0 Key results and discussion

Key annual results for the analysis of Systems 1 and 2 are presented in Table 3. Overall, both solar system designs were found to meet the thermal energy demands (both hot water and pool heating). From Table 3, we can see that although the PVT collector consumes 46% less area than a system based on conventional solar technologies, it is still able to provide an equivalent solar fraction for the domestic hot water load. Therefore both systems require an equivalent supply of auxiliary energy (i.e. additional energy from either electricity or gas) to meet the thermal domestic hot water demands. Polysun uses the parameter "System Performance" to objectively compare the overall performance of the solar energy system. It is defined by the ratio between the energy required by the system (Q_{use}) and the AC energy supplied to the grid from the inverter (E_{inv}) to the auxiliary energy and parasitic energy losses required. The greater the System Performance value, the better the system is performing. Based on this value, we can see that System 2 is performing with approximately 20% greater performance over System 1.

Table 3 Summary of key annual results for Systems 1 and 2.

		System 1	System 2
1	Total collector area (m^2)	63.9	34.3
2	System performance [$(Q_{use} + E_{inv})/(E_{aux} + E_{par})$]	10.44	12.88
3	Solar fraction (S_f)	94.60%	95.90%
4	CO_2 emissions reduction (kg/m^2)	140.95	194.1
5	Annual PV Energy production (kWh)	8035	7918
6	Specific PV annual yield (kWh/kWp)	1607.1	1583.6

Looking at line 4 of Table 3, the reduction in carbon emissions per unit area of roofing is 37% greater with the PVT collector system over the traditional collector system used in System 1. This further emphasises the principal advantage of the PVT collector which is its ability to deliver the greatest energy output per unit area of collector in comparison to traditional solar technology.

3.1 Photovoltaic output

A typical concern encountered regarding the implementation of the PVT collector is the negative impact temperature may have on the photovoltaic output when used in a domestic hot water application. From Table 3 we can see however, that there is only a 1.5% drop in photovoltaic output from the PVT collector from System 2 in comparison to the standalone PV system used in System 1. Looking at the hourly data produced from Polysun, it was found that the average module temperatures over an entire year were 29 and 26.7 degrees Celsius for the PVT and PV systems respectively. Although the electrical characteristics of the photovoltaic cells for the PVT and PV modules will have some minor differences, as both installations were identical with respect to azimuth and inclination, the small difference in temperature explains the minor difference in photovoltaic output.

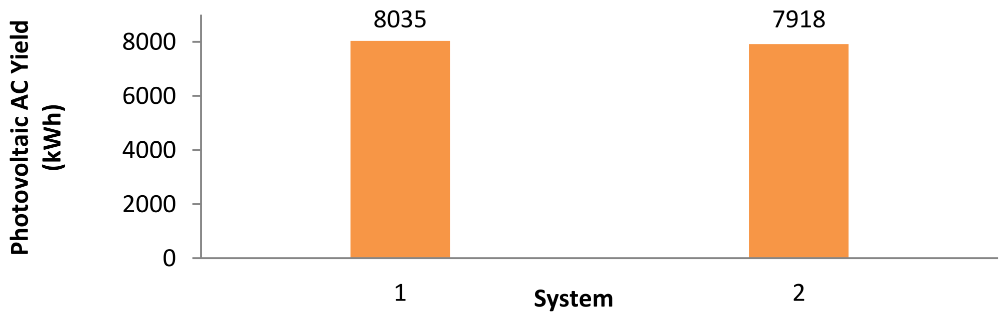

Figure 3 Annual photovoltaic output from System 1 and 2.

Monthly outputs for each system are presented in Figures 6 and 7.

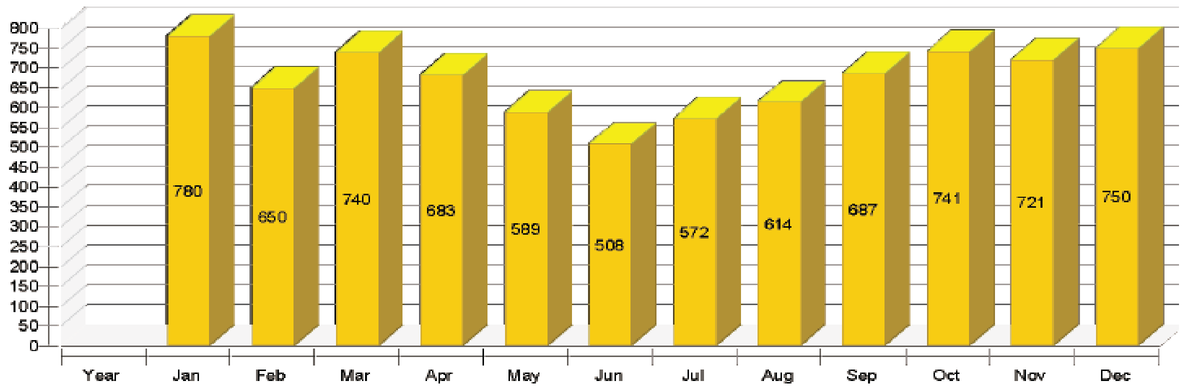

Figure 4 Monthly PV yield 9AC) from System 1.

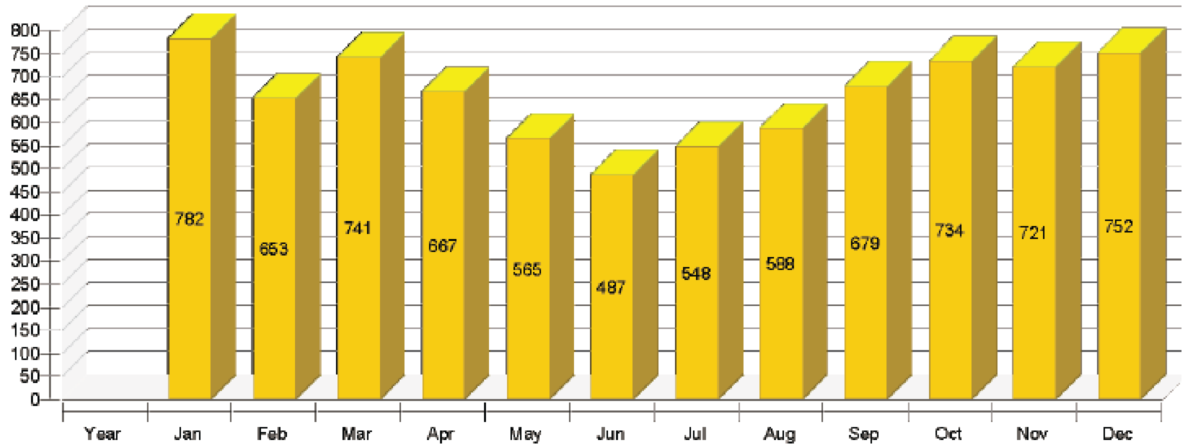

Figure 5 Monthly PV yield (AC) from System2.

3.2 Thermal output

Both systems specified a daily draw of 200L of water at 50 degrees Celsius. The hot water demand for domestic hot water usage was met for both systems using the auxiliary energy supply using a 10kW gas boiler. A solar fraction of approximately 95% was obtained for both systems, indicating the solar energy systems could meet the energy loads of the system.

Average monthly pool temperatures for each system are presented in Figure 6 and Figure 7. Comparing these two figures we can qualitatively see that the both systems provide a similar level of pool heating. As expected, a dip in temperature occurs during the winter months, but on average both systems were able to keep the pool temperature greater than the set temperature of 25 degrees Celsius.

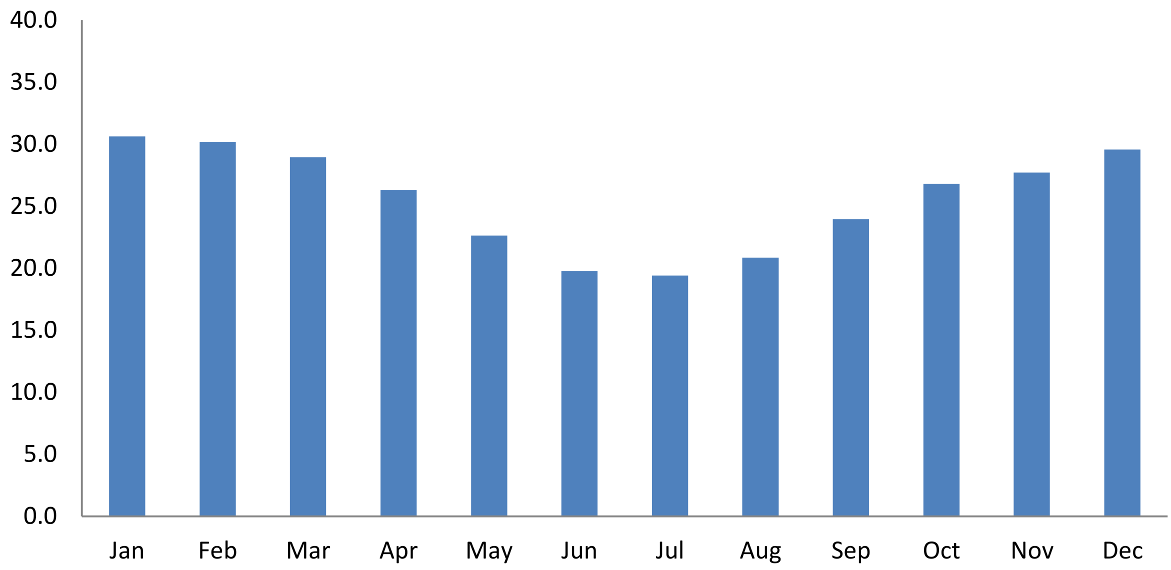

Figure 6 Average monthly pool temperature data for System 2 (PVT collector system).

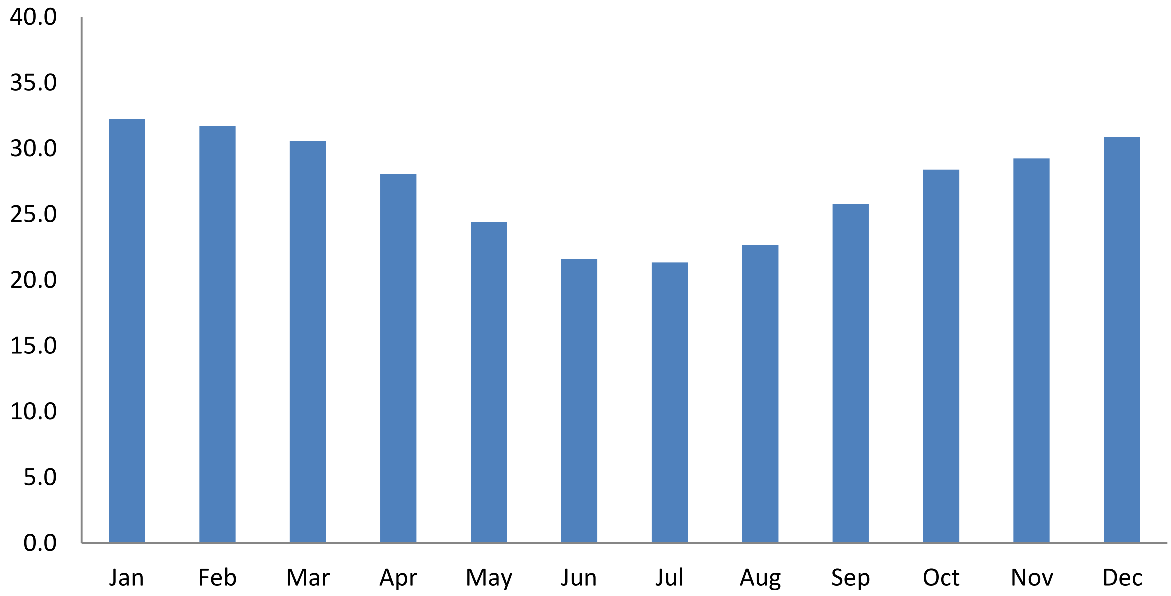

Figure 7 Average monthly pool temperature data for system 1 (conventional solar technology).

4.0 Concluding remarks

In this work, a simulation study was performed to compare the energy yield for a residential system based on; i) conventional solar technology (photovoltaic and solar thermal) and ii) using the hybrid photovoltaic/thermal collector manufactured by Solimpeks. Both systems were based on the loads of a four person home with a 36m^3 swimming pool with 5kWp of photovoltaic power generation. All work was carried out using the commercially available software Polysun developed by Vela Solaris AG in Switzerland.

The following key points were obtained from this work:

1. System 1, based on traditional technology required approximately $64m^2$ of roofing area while System 2 which comprised of only the PVT collector required only $34.3m^2$.
2. Both systems 1 and 2 met the thermal requirements of a four person home and provided sufficient energy to maintain an average pool temperature of 25^oC.
3. Systems 1 and 2 resulted in a solar fraction of approximately 95% and therefore required little auxiliary energy boosting from the gas booster.
4. Despite the PVT collector meeting the thermal demands of the house, only a 1.5% reduction in photovoltaic output was obtained. Examining the hourly data obtained from Polysun, it was found that the average temperature of the PVT module over the year was only 2.3 degrees warmer than the standard PV module.

Overall, the PVT collector solution was able to meet the requirements of the residential system examined in this work while requiring just over half the roofing area needed by using traditional solar thermal and photovoltaic collectors. This highlights the principal advantage of the PVT collector over traditional solar collector technology, the ability to provide the most useful energy per unit area of roofing. Furthermore, the PVT offers reduced installation complexity and improved aesthetics by avoiding the use of multiple collector types to meet the thermal and electrical demands of a residential home.

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Appendix A: Polysun schematic diagrams

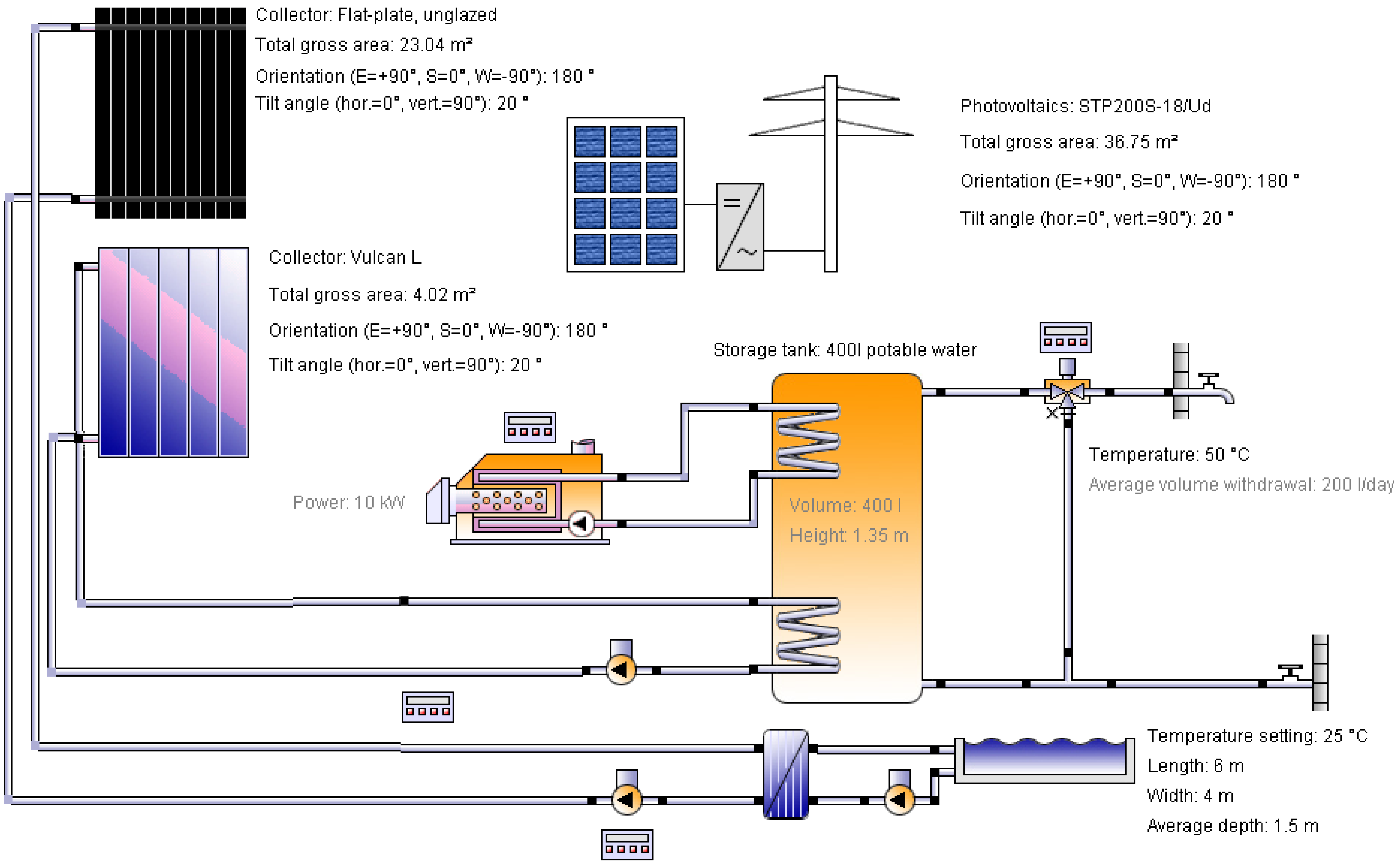

Figure 8 Solar energy system for domestic hot water, pool heating, and photovoltaic power generation using conventional collector technology.

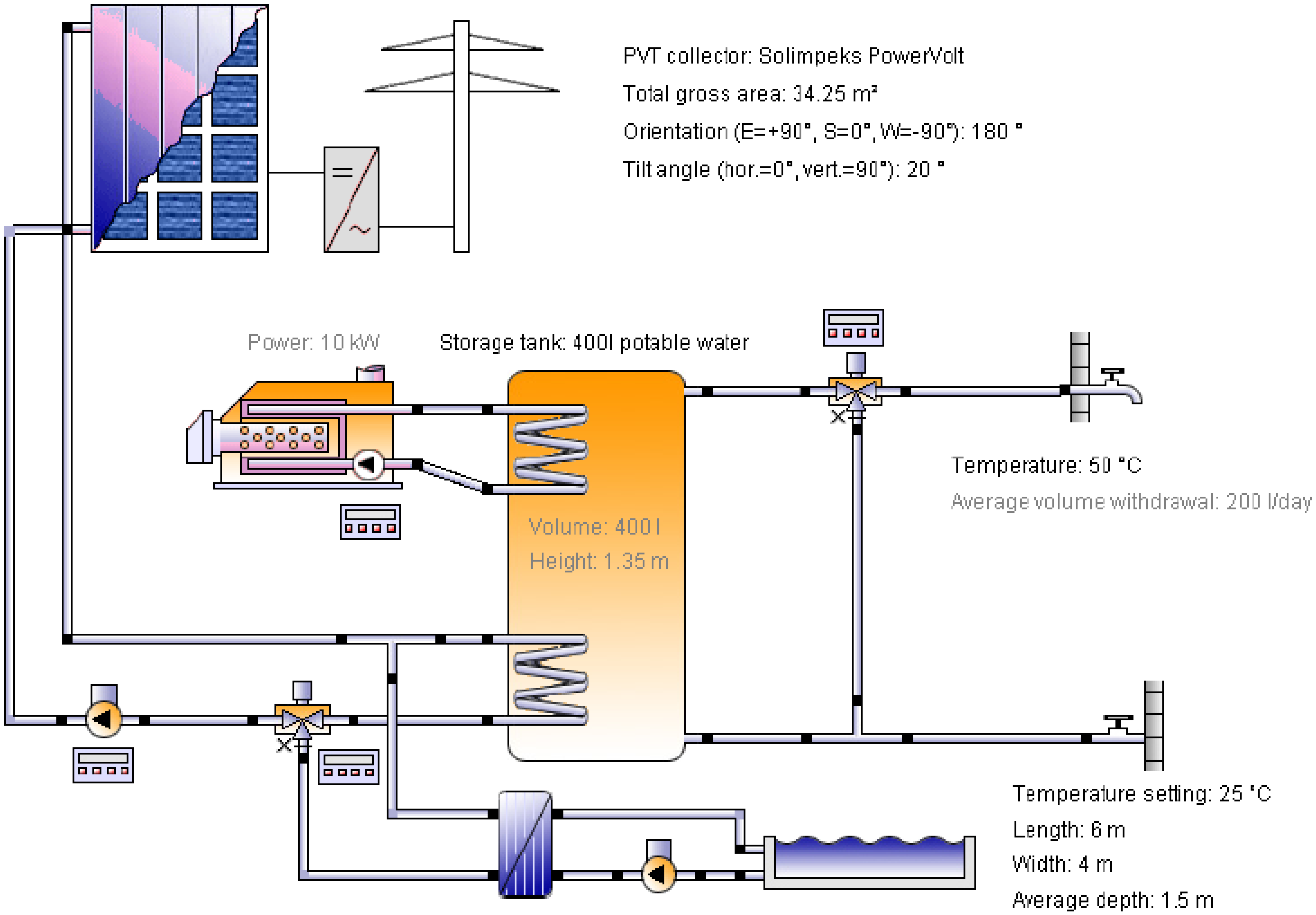

Figure 9 Equivalent domestic hot water, pool heating, and photovoltaic power generation using the Solimpeks hybrid PVT collector.