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# SYSTEM STUDIES ON COMBINED PV/THERMAL PANELS

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# SYSTEM STUDIES ON COMBINED PV/THERMAL PANELS

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## Introduction

PV/Thermal Panels transform sunlight into electricity and heat. Combining PV panels and thermal panels into one panel results in lower direct electric as well as thermal efficiencies, but the advantages are a potential cost saving in production and installation and a saving of roof area. To examine the best way to use these kind of panels, 3 different systems with PV/Thermal panels are studied numerically. These systems use the PV/Thermal panels for electricity and a hot water system for a house, for preheating ventilation air for a boarding school and for a low temperature heating system for a house.

The aim of the study is to find an optimum for the panel area in relation to the size and isolation of the storage tank and to compare the three systems with each other in terms of annual electric an thermal efficiencies. All systems are simulated with TRNSYS, a transient systems simulation program with a modular structure.

## System 1: Hot water system

Normally, natural gas or electricity is used for making hot water in houses. To make hot water with renewable energy, a PV/T panel is an option. In this system, the PV/Thermal panel is south located, on the roof of a house (tilt 37 °). The hot water system is provided with a storage tank, located in the attic of the house. In the case of enough sunshine, the water from the storage tank will be pumped to the panel, with the result that the water will be heated. If there is a hot water demand in the house, the water will be tapped from the top of the storage tank. After the storage tank, there is an after heater for the case of the temperature of the water in is too low (below 60 °C). At the tap, the hot water will be mixed with cold water to get the right temperature. At the moment there will be a water tap, the storage tank will be filled with cold water.

The simulations are executed with Dutch climate data (TRY De Bilt), a PV/T area of 6 $m^2$ and a volume of the storage tank of 200 liter with 10 cm insulation. The daily hot water demand is 175 liter.

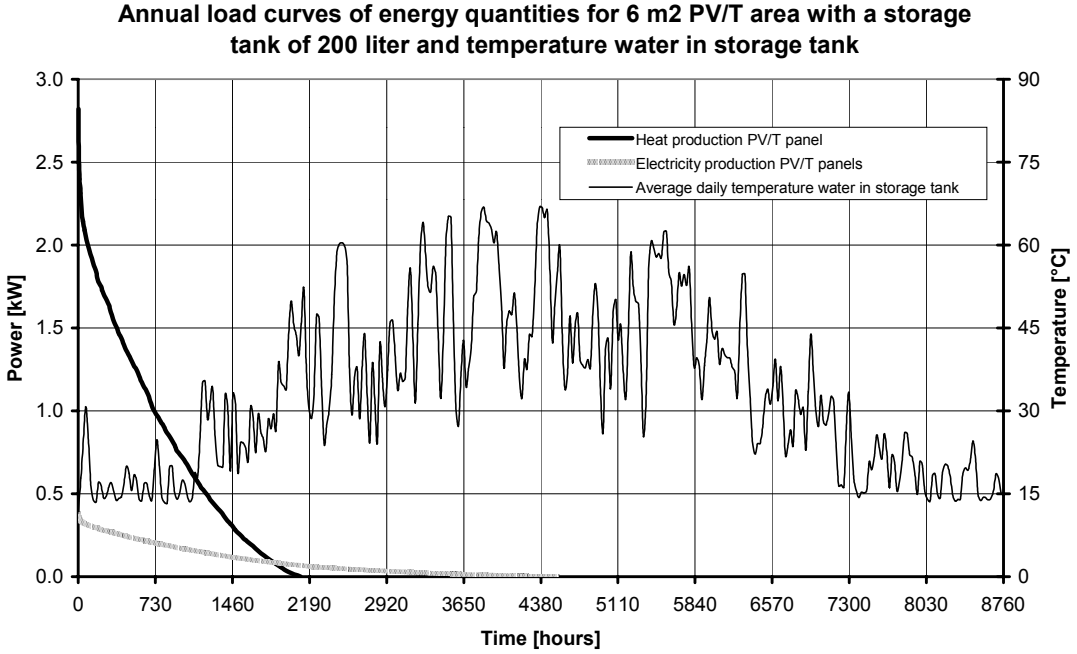
The simulations are executed for a period of a year. The results concern to the heat and electricity production of the PV/T panels and the temperature of the water in the storage tank.

In the table below, the results of the simulations are shown in numerical values.

| | Energy [GJ/year] | Number of hours [-] | Maximum power [kW] |
|---|---|---|---|
| Heat production PV/T panels | 5.8 | 2106 | 2.8 |
| Total system losses | 0.8 | - | - |
| Heating demand after heater | 4.9 | - | - |
| Electricity production PV/T panels | 1.5 | 4533 | 0.4 |

In the graph below, the annual load curve of the heat and electricity production of the PV/T panels and the average temperature of the water in the storage tank are shown.

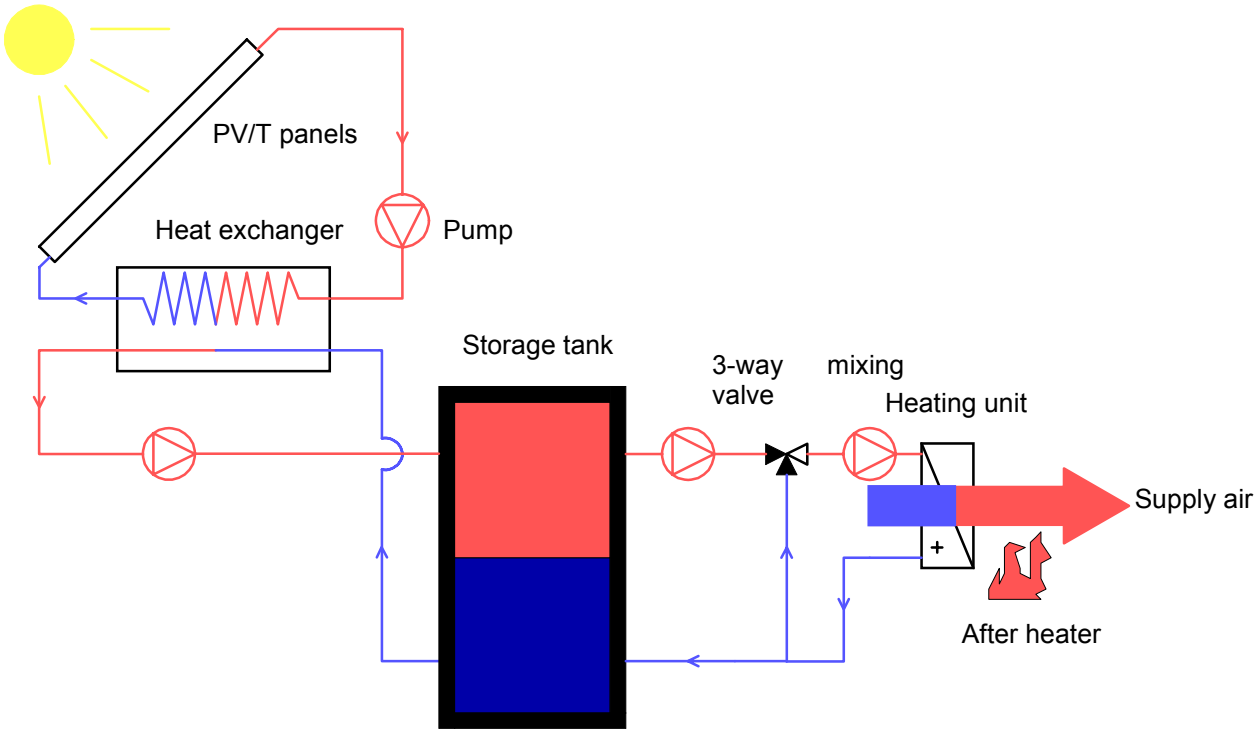
With this system, the thermal and electrical efficiencies are 22.1 and 6.8 %, with a solar fraction of 50.5 % of the total energy demand for hot water.




**System 2: preheating ventilation air for a boarding house**

A boarding school in the United Kingdom, located near London, will expand their boarding houses. The new boarding house will be provided with PV/T panels on the roof. These panels will supply electricity and heat for the boarding house. The generated electricity will be used for own use. The boarding house is connected to the mains, so during periods of little electricity production the boarding house will have enough electrical power.

The supplied heat from the PV/T panels will be stored in a big storage tank. With the help of the stored heat in the tank, the ventilation air of the boarding house will be preheated. In the air handling system, there is also an after heater. This heater will only be used if there is in the tank not enough heat to preheat the ventilation air to the desired temperature. Below, a schedule of the heating system is shown.




The simulated building is a boarding house that consists of a West and East wing. Every wing has bedrooms on the North and South part. Totally, 60 people can sleep in the boarding house. Beside bedrooms, the boarding house is provided with stairwells, relax rooms and sanitary facilities.

The windows in the walls of the boarding house have an insulation value of 1,4 W/m$^2$ K, with a solar gain factor of 43 %. The walls, the roof and the ground floor have an insulation value of respectively 3,1, 3,0 en 3,1 m$^2$ K/W.

The boarding houses will be ventilated with a ventilation rate of 1; the infiltration rate is 0.2. The desired temperatures in the different rooms of the house vary between 16 and 21 °C. Internal heat gains vary between 2 and 20 W/m$^2$.

The PV/T area is 183 m$^2$, the volume of the storage tank is 150 m$^3$ with 50 cm insulation. The supply air quantity is 3600 m$^3$/hr. For weather data, the data of Hoddesdon (United Kingdom) is used.

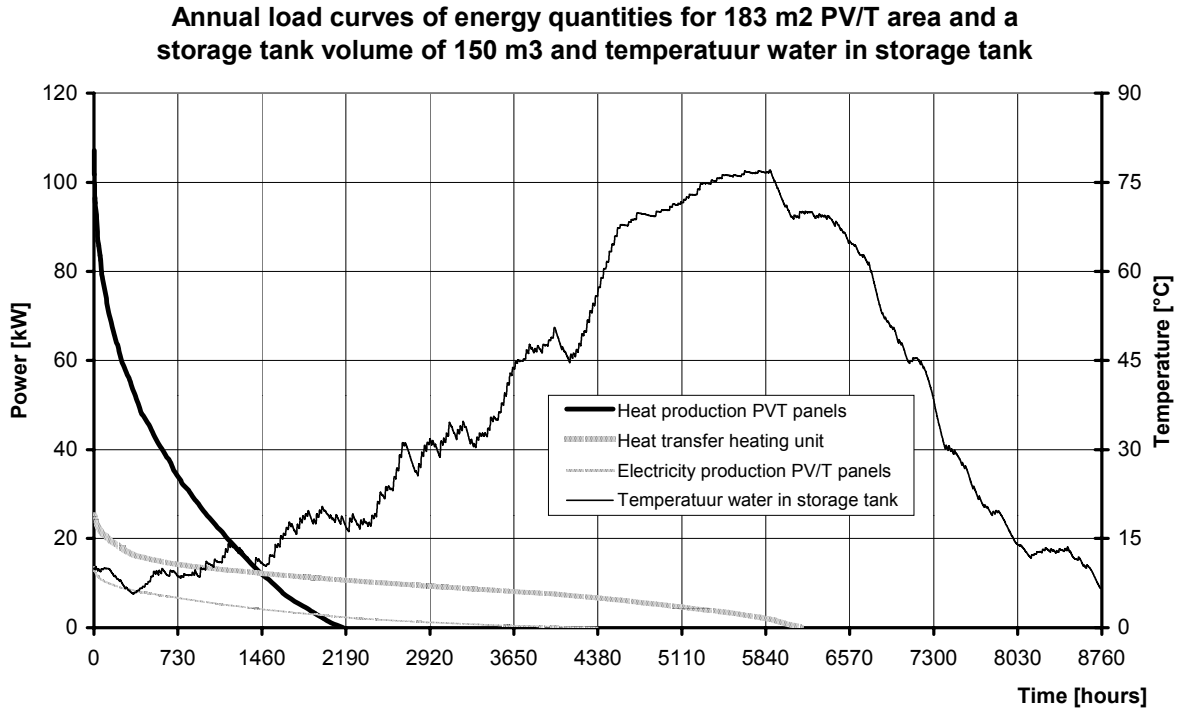
The aim of the simulations is to calculate the total energy production of the PV/T panels, the total energy that will be transferred the heating unit in the air handling unit and the additional power of the after heater.

The simulations are executed for a period of a year. The results concern to the heat and electricity production of the PV/T panels, the heat transfer in the heating unit in the air handling unit, the heating demand of the after heater, the heat loss of the water in the storage tank and the temperature of the water in the storage tank.

In the table below, the results of the simulations are shown in numerical values.

| | Energy [GJ/year] | Number of hours [-] | Maximum power [kW] |
|---|---|---|---|
| Heat production PV/T panels | 212.7 | 2168 | 107.1 |
| Heat transfer in heating unit | 203.5 | 6149 | 25.3 |
| Heating demand after heater | 164.3 | 6327 | 24.0 |
| Heat loss water in storage tank | 12.2 | 8760 | 0.9 |
| Electricity production PV/T panels | 52.0 | 4376 | 13.6 |

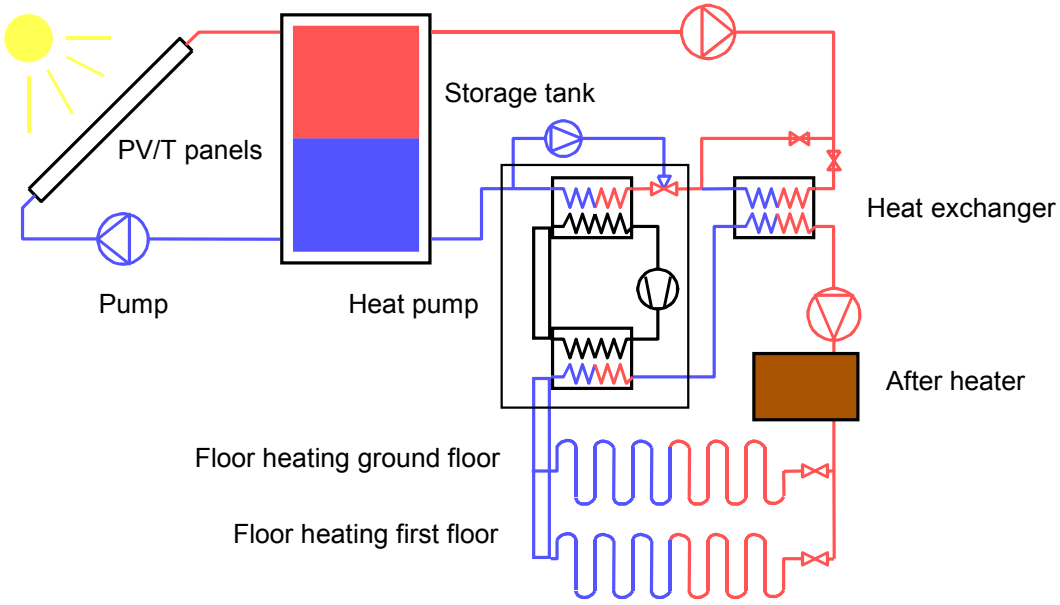
In the graph below, the annual load curves of the heat and electricity production of the PV/T panels, the heat transfer in the heating unit and the average temperature of the water in the storage tank are shown.




With this system, the thermal and electrical efficiencies are 27.0 and 6.9 %, with a solar fraction of 55.3 % of the ventilation air heating demand.

**System 3: Low temperature heating system**

Besides using the PV/T panels for making hot water for a house and preheating the ventilation air, the panels can also be used for a heating system of a house. The problem is that a house has the largest heating demand during wintertime. The winter is the period with the minimum quantity of sunshine. This implies that you have to store the heat in the summertime so that you can use it in wintertime. This will be realised by using a big storage tank filled with water. Because the stored energy is finite, this system will operate the best in low-energy houses provided with a low temperature heating system (floor heating system).
A schedule of the system is shown below.




In days of high temperatures of the water in the storage tank (and heating demand), the heat from the storage tank will be transferred to the floorheating system with the help of the heat exchanger. In the days of low temperatures of the water in the storage tank (and heating demand), a heat pump will be used to transfer the heat of a low temperature from the storage tank to heat of a high temperature so that the heat can be used for the floorheating system of the house.

Sometimes the heat pump will not be able to realise the supply temperature. In that case, the after heater will be used.

The simulations are executed with Dutch climate data (TRY De Bilt), a PV/T area of 5 $m^2$ and a volume of the storage tank of 20 $m^3$ with 50 cm insulation. The total heating demand of the house is 5.5 GJ/year (insulation value of the walls of the house is 6 $m^2$ K/W. The supply temperature floorheating system is 35 °C and the maximum thermal power of the heat pump is 1.3 kW.

The simulations are executed for a period of a year. The results concern to the heat and electricity production of the PV/T panels, the transferred heat in the heat exchanger and in the condenser of the heat pump, heating demand of the after heater, the energy losses from the storage tank to the environment and the temperature of the water in the storage tank.

In the table below, the results of the simulations are shown in numerical values.

| | Energy [GJ/year] | Number of hours [-] | Maximum power [kW] |
|---|---|---|---|
| Heating production PV/T panels | 6.6 | 2225 | 2.9 |
| Electricity production PV/T panels | 1.5 | 4197 | 0.4 |
| Transferred heat in heat exchanger | 1.4 | 303 | 3.0 |
| Transferred heat in condenser | 3.8 | 987 | 1.3 |
| Energy demand after heater | 0.2 | 262 | 1.0 |
| Energy losses | 2.4 | - | - |

In the graph below, these energy quantities are shown cumulatively. In the same graph the course of the temperature of the water in the storage tank is shown.

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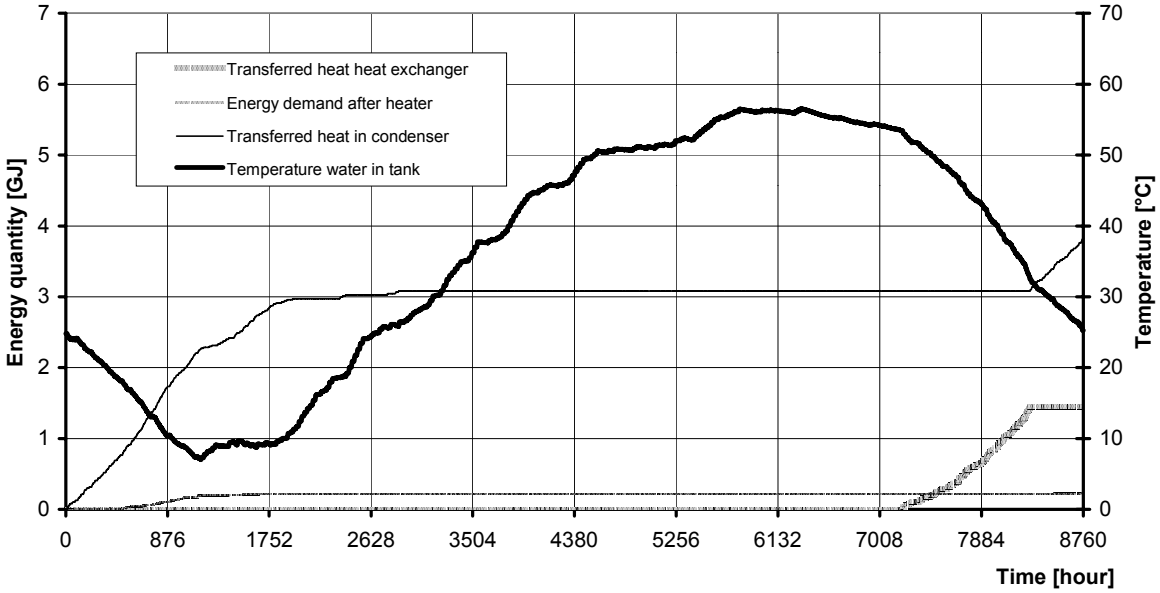
**Cumulative energy quantities and temperature of water in storage tank for a system with PV/T panels for electricity and a low temperature heating system**




With this system, the thermal and electrical efficiencies are 28.2 and 2.5 %. The electrical efficiency is low because a part of the electrical energy will be used for driving the compressor of the heat pump. This part is not counted in the electrical efficiency. This system can supply 95.8 % of the total heating demand of the house.

**Summary**

PV/Thermal Panels transform sunlight into electricity and heat. Combining PV panels and thermal panels into one panel results in lower direct electric as well as thermal efficiencies, but the advantages are a potential cost saving in production and installation and a saving of roof area.

In this study, three different systems with PV/T panels are studied. These systems are:

- PV/T panels for hot water and electricity for a house. With a 6 $m^2$ PV/T area and a storage tank of 200 liter, thermal and electrical efficiencies of 22.1 and 6.8 % are achievable. The solar fraction is 50.5 % of the total energy demand for hot water.
- PV/T panels for electricity and preheating ventilation air for a boarding house. With 183 $m^2$ PV/T area and a storage tank of 150 $m^3$, the thermal and electrical efficiencies of 27.0 and 6.9 % are possible. The solar fraction is 55.3 % of the ventilation air heat demand.
- PV/T panels for electricity and a low temperature heating system for a house. Thermal and electrical efficiencies of 28.2 and 2.5 % are possible with a PV/T area of 5 $m^2$ and a storage tank of 20 $m^3$. The solar fraction is 95.8 % of the total heating demand of the house.