# THE COMPARSION OF THE ELECTRICAL AND THERMAL PERFORMANCE OF GLAZED AND UNGLAZED PVT COLLECTORS

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**Abstract**

Photovoltaic-thermal(PVT) collectors are a combination of photovoltaic modules with solar thermal collectors, forming one device that receives solar radiation and produces electricity and heat simultaneously. The PVT collectors can produce more energy per unit surface area than side by side PV modules and solar thermal collectors. There are two types of liquid type PVT collectors, depending on the existence of glass cover over PV module; glass-covered(glazed) PVT collector, which produces relatively more thermal energy but has lower electrical yield, and uncovered(unglazed) PVT collector, which has relatively lower thermal energy with somewhat higher electrical performance. In this paper, the experimental performance of two types of the liquid type PVT collectors, glazed and unglazed, was analyzed. The electrical and thermal performances of the PVT collectors were measured in outdoor conditions, and the results were compared.

## 1. Introduction

A photovoltaic/thermal(PVT) collector, which is also known as a photovoltaic-thermal system, generates both thermal and electrical energy simultaneously. A photovoltaic/thermal(PVT) collector is a combination of photovoltaic module with a solar thermal collector, forming one device that converts solar energy into electricity and heat simultaneously. The excess heat that is generated from PV modules can be removed and converted into useful thermal energy. As a result, PVT collectors can generate more solar energy per unit surface are than side by side photovoltaic modules and solar thermal collectors.

In general, two types of the PVT collector can be distinguished: Glazed PVT collector with covered glass, which produces more heat but has a slightly lower electrical yield, and Unglazed PVT collector with no covered glass, which produces relatively less thermal energy, but has a somewhat higher electrical performance. Glazed PVT collectors are very similar in appearance to a flat plate solar thermal collector, consisting of a PV-covered absorber in an insulated collector box with a glass cover. This glass covered insulation form leads to high thermal efficiencies, at the reduction of some electrical efficiency due to the solar irradiance reflection and PV module temperature rise introduced by the glass cover. On the other hand, Unglazed PVT collectors are more similar to regular PV panels, and consist of a PV-covered absorber with no additional glass cover. No glass covered form results in lower thermal efficiencies: hence Unglazed PVT collectors deliver relatively lower thermal energy with higher electrical efficiency due to PV module cooling effect. The electrical efficiency of Unglazed PVT collector is higher than Glazed PVT collector, and even higher than that of regular PV panels due to the PV cooling effect. But the thermal efficiency of the Unglazed is lower than Glazed PVT collector due to higher heat loss from the collector surfaces.

The aim of this study is to compare the electrical and thermal performance of the Glazed(Fig. 1) and the Unglazed collectors(Fig. 2). For this paper, two different types of liquid type PVT collector were made, and both the thermal and electrical performance of these prototypes were measured in outdoor, and the results were compared.

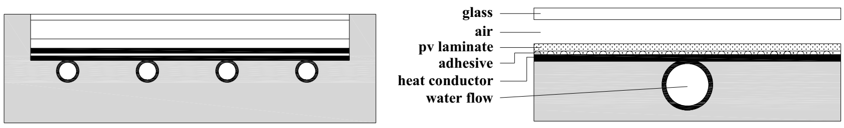


Fig. 1 Sectional view of Glazed PVT Collector

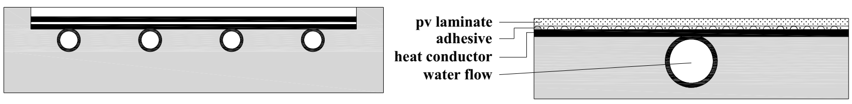


Fig. 2 Sectional view of Unglazed PVT Collector

## 2. PVT Collector Design and Manufacture

The liquid-type flat plate PVT collectors used for this study appear in Figure 3. The PVT collectors consist of PV modules in combination with water heat extraction units made from copper sheet-and-tube. Glazed PVT collector had a low-iron glazing cover of 4mm thickness with air space of 20mm, and thermally protected with 70mm glass-wool thermal insulation. A copper sheet-and-tube absorber was attached at the PV module back side by thermal conduction adhesives. The PV modules used for the collectors were 200Wp pc-si PV modules and had the electrical efficiency of 14% in the standard test conditions(STC). The specifications are shown in Table 1. The configuration of Unglazed PVT collector was the same as the Glazed PVT collector except the glass cover.

Table 1 PV module Specifications

| | |
|---|---|
| cell type | poly crystalline silicon |
| maximum power | 200W |
| maximum voltage | 25.8V |
| maximum current | 7.75A |
| shot current | 8.65A |
| open voltage | 33.21V |
| Size | 1454*974*38mm |

Fig. 3 Tested Glazed and Unglazed PVT collector

## 3. Experiments

### 3.1 Experimental Methods

Two different types of PVT collector were tested at an irradiance above 790W/㎡, flow rate 0.02kg/s ㎡, based on ASHRAE standard 93-77 and PVT performance measurement guidelines of ECN(Energy Research Centre of the Netherlands). The electricity and thermal performance measurements were carried out under quasi-stationary condition in outdoor at the same time. For the electrical performance measurement(DC current-voltage and power) of the PVT collectors, electrical loading resistors and a power meter were installed.

### 3.2 Analysis of the Experimental Results

With the results of the outdoor testing of the PVT collectors, the thermal and electrical performances were analyzed: The experimental results for the two different types of PVT collector were compared.

(1) Thermal performance

The thermal efficiency is determined as a function of the irradiance($G$), the input fluid temperature($T_i$) and the ambient temperature($T_a$). The steady state efficiency is calculated by :

$$\eta_{th} = \dot{m}\, C_p\, (T_o - T_i) / A_{pvt}\, G \qquad (1)$$

$\eta_{th}$ : thermal efficiency

$A_{pvt}$: collector area (㎡)

$T_o$: collector outlet temperature (℃

$T_i$: collector inlet temperature (℃)

$\dot{m}$: mass flow rate(kg/hr)

$C_p$: specific heat (kJ/kg℃)

$G$: irradiance (W/㎡)

The thermal efficiency $\eta_{th}$ of the PVT collectors was conventionally calculated as a function of the ratio $\Delta T/G$ where $\Delta T = T_i - T_a$

Where $T_i$ and $T_a$ are the PVT collector inlet temperature and the ambient temperature, respectively, and $G$ is the irradiance in the collector plane. Hence, $\Delta T$ is a measurement of the temperature difference between the collector and its surroundings, relative to the irradiance. The thermal efficiency $\eta_{th}$ is then expressed as

$$\eta_{th} = \eta_0 - \alpha_1(\Delta T/G)$$

Where $\eta_0$ is the thermal efficiency at zero reduced temperature, and $\alpha_1$ is the heat loss coefficient.

With the measurement results of the PVT collectors of two different types, the thermal performance can be expressed with Fig. 4. Thermal efficiencies of the Glazed and Unglazed PVT collector can be expressed with relational expression $\eta_{th}$ = 0.51-5.36($\Delta T/G$) and $\eta_{th}$ = 0.45-10.15($\Delta T$/G) respectively. Thus, the thermal efficiencies ($\eta_0$) at zero reduced temperature are 0.51, 0.45 respectively, and Glazed PVT collector efficiency is higher than that of Unglazed PVT collector. Also, the heat loss coefficient ($\alpha_1$) is -5.36W/m$^2$K, -10.15W/m$^2$K, respectively: the Unglazed PVT collector was better performed at approximately two times than the Glazed PVT collector. The average thermal efficiency of the Glazed and Unglazed PVT collector is about 38%, 24% respectively, at the same outdoor condition.

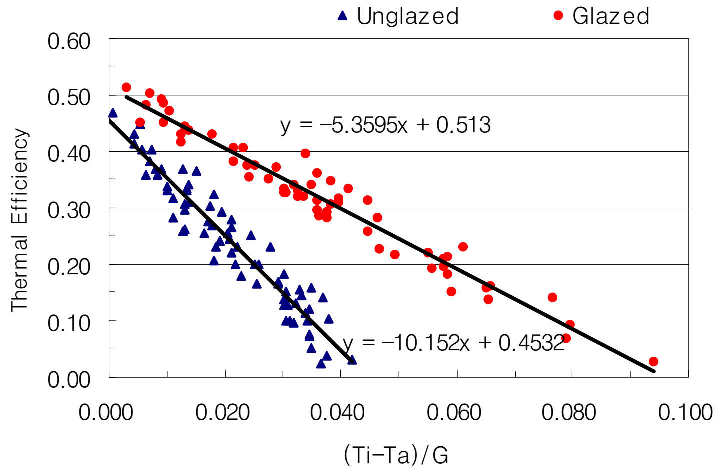


Fig. 4 Glazed and Unglazed PVT Collector Thermal Efficiency

(2) Electrical performance

The electrical efficiency depends mainly on the incoming irradiance and the PV module temperature and is calculated with the following equation:

$$\eta_{el} = I_m V_m / A_{pvt}\, G \qquad (2)$$

$I_m$ and $V_m$ are the current and the voltage of the PV module operating at maximum power.

The electrical efficiencies of the Glazed and Unglazed PVT collector at the outdoor condition are shown in Fig. 5. The performance of the Glazed and Unglazed PVT collector can be expressed with relational expression, $\eta_{el}$ = 0.108-0.15($\Delta T/G$) and $\eta_{el}$ = 0.123-0.22($\Delta T$/G), respectively. Thus, the electricity efficiency ($\eta_0$) at zero reduced temperature is 0.108 and 0.123, respectively, and the electricity loss coefficient is -0.22 and -0.15, respectively. From these results, it can be found that the Unglazed PVT collector presents about 14% higher electrical efficiency, compared to the Glazed PVT collector. This difference seems to be significant as this means about 1.5% difference of the PV module's electrical efficiency. It is obvious that while the Unglazed PVT collector had the poorest thermal performance at zero reduced temperature, it performs better in generating electricity. The average electrical efficiencies of the Glazed and Unglazed PVT collector are about 10.4% and 11.8%, respectively.

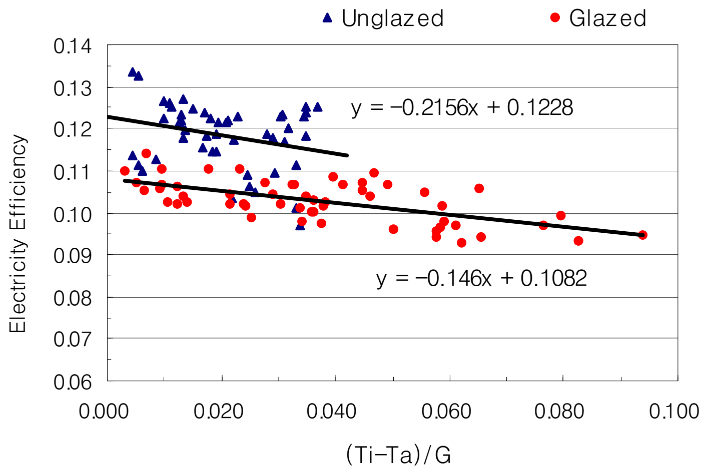


Fig. 5 Glazed and Unglazed PVT Collector Electricity Efficiency

The PV module temperature depends on the cooling effects of PV module by the fluid into the PVT collectors. The electrical performance was analyzed as function of PVT inlet fluid temperature and irradiance. The PV module power generation of the collectors as the function of solar radiation and fluid temperature is shown in Fig. 6, 7.

For the Glazed PVT collector, the electric power increased according to irradiance increase, and PV module's power generation was better with higher the inlet fluid temperature. This result indicates that the inlet fluid temperature of PVT collector had an effect on PV module temperature.

In the case of Unglazed PVT collector, it also found that the lower inlet fluid temperature produced more electricity generation. However the electricity generation of the Unglazed seems to be less influenced by irradiance, compared to Glazed PVT.

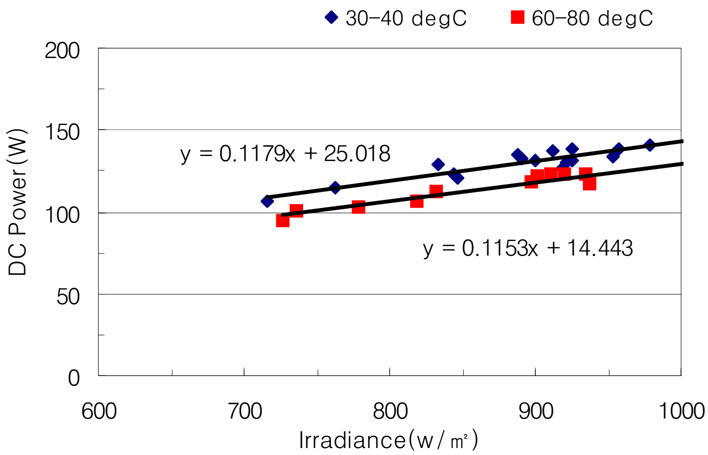


Fig. 6 Electric power of the Glazed PVT Collector as a function of irradiance and temperature

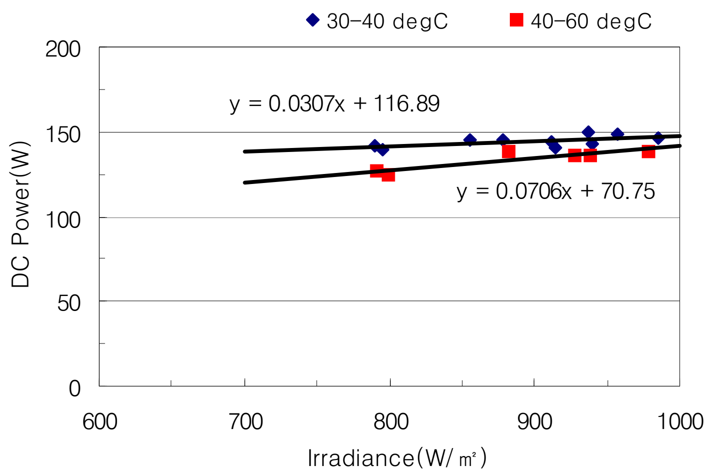


Fig. 7 Electric power of the Unglazed PVT Collector as a function of irradiance and temperature

## 4. Conclusion

This study analyzed the thermal and electrical performance of two types of PVT collector, a liquid Glazed type and an Unglazed type. The results show that the thermal efficiency of the Glazed PVT collector is 14% higher than the Unglazed, and for the electrical efficiency, the Unglazed PVT collector had about average 1.4% higher than the Glazed PVT collector.

The overall energy performance of the collectors can be compared with combining value of the average thermal and electrical efficiency: the Glazed PVT collector, 48.4% and the Unglazed PVT collector, 35.8%. Even though the overall performance of the Glazed is 12.6% higher than that of the Unglazed, it is very difficult to say that the Glazed has a priority against the Unglazed: This is due to that the preference should depend on the overall cost efficiency and energy balance of the systems.

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