THREE HEATING SEASONS MONITORING OF USAGE OF LOW ENTHALPY GEOTHERMAL RESOURCES: EXERGETIC PERFORMANCE ANALYSIS OF AN EAHE ASSISTED AGRICULTURAL BUILDING

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ABSTRACT

The study experimentally investigated the exergetic performance (efficiency) of a closed loop Earth (geothermal) to Air Heat Exchanger (EAHE) in the heating mode. EAHE systems are used as a technique from ancient times for heating and cooling purposes, and they make it possible to evaluate low enthalpy geothermal resources. The experimental system was commissioned in June 2009 and experimental data collection has been conducted since then. The data, consisting of hourly thermodynamic records for heating over a three year period from 2009-2012, were measured by the Solar Energy Institute of the Bornova Campus at Ege University. At the present time, the database contains more than 30000 records of measurements. Exergetic efficiencies based on the performance of the system components have been analyzed. Furthermore, the long term exergetic performance of a closed loop EAHE agricultural building heating system was monitored to develop a performance assessment model. Exergetic efficiency of the overall system and its components at various reference states are also determined.

INTRODUCTION

The variation of air temperature inside the ducts, to an annual cycle, was investigated via an experimental and numerical study of earth–air heat exchangers in southern Brasil by Vaza and Sattlerb (2011). The energy performances achievable using an earth-to-air heat exchanger for an air-conditioned building have been evaluated for both winter and summer by Ascione et al. (2011). By means of dynamic building energy performance simulation codes, the energy requirements of the systems have been analysed for different Italian climates, as a function of the main boundary conditions (such as the typology of soil, tube material, tube length and depth, velocity of the air crossing the tube, ventilation airflow rates, control modes) by Ascione et al. (2011). The implementation of thermal design method and a simple pneumatic was made for the EAHE of a large passive house (PH) built near Bucharest in Romania by Badescu and Isvoranu (2011). Year round hourly performance analysis of integrated EAHE- evaporative cooling system using multiphase CFD modeling for investigating performance enhancement was carried out using a simplified EAHE system developed by Bansal et al. (2012). Their model used the FLUENT simulation program and validated using the experimental results on a set-up installed in Ajmer (Western India) by Bansal et al. (2012) have been carried out to find the performance of integrated EAHE- evaporative system for every hour of a year. Misra et al. (2012) experimentally investigated the thermal performance of a hybrid EAHE system in four different modes by integrating active and passive cooling systems, i.e. a combination of window air conditioners and EAHE. Trząski and Zawada (2011) validated a developed method of air-ground heat exchanger performance evaluation using research results from a conducted simulation. The air-ground heat exchanger model (based on a quasi 3D finite

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elements method) allows analysis of energy performance dependence on a wide range of parameters including air-ground heat exchanger geometrical configuration, mode of operation and environmental factors (Trzaski and Zawada, 2011). The earth-to-air heat exchanger has shown the highest efficiency for cold climates both in winter and summer (Ascione et al., 2011). Nayak and Tiwari (2010) carried out to evaluate the annual thermal and exergy performance of a photo-voltaic/thermal (PV/T) and earth air heat exchanger (EAHE) system, integrated with a greenhouse, located at IIT Delhi, India, for different climatic conditions of Srinagar, Mumbai, Jodhpur, New Delhi and Bangalore. Fintikakis et al. (2011) studied the urban micro-climatic conditions in the historic centre of Tirana in order to integrate the information in the rehabilitation of specific open space. A new numerical model of earth-to-air heat exchanger is discretized into “n” sections perpendicular to the exchanger pipe by Tittelein et al (2009).

In this paper, authors extend these studies by conducting an exergetic heating performance analysis of the system, using thermal data collected at the site. The objectives of this work are to assess the entire system and its essential components for performance evaluations and comparisons, as well as possible efficiency improvements.

The passive heating system was tested only in experimental studies often without windows, and were actually applied in occupied a agricultural building. The tests were without any internal heat source. Still, the paper demonstrates the potential of the system under the climatic conditions prevailing during the experiments, but without any of the effects of interior heat generation and with solar energy penetration through windows.

In this work, results from monitoring exergy efficiency from the last three heating seasons of operation of the closed loop EAHE system are presented. The case study covers the actual system data taken from the system in Izmir, Turkey.

**SYSTEM DESCRIPTION**

A schematic diagram of the experimental system is given in Figure 1. This system mainly consists of six separate circuits: (i) the converter, (ii) the 0.9 kW PV cells, (iii) the inverter, (iv) the fan (air blower) circuit for greenhouse heating, (vi) the ground heat exchanger (underground air tunnel or EAHE), (vii) greenhouse. The PV assisted EAHE system was installed at the Solar Energy Institute of Ege University (latitude 38° 24’ N, longitude 27° 50’ E), Izmir, Turkey. The solar greenhouse was positioned towards the south along south-north axis. The greenhouse will be conditioned during the summer and winter seasons according to the needs of the agricultural products to be grown in it. The system utilizes an underground galvanized pipe in combination with a blower to keep the greenhouse temperature at the set condition. A positive displacement type of air blower (twin lobe compressor) of 736 Watt capacity and volumetric flow rate of 5300 m³/h was fitted with the suction head positioned in the southwest corner of the greenhouse (Ozgener and Ozgener, 2010a-d; Ozgener et al, 2011; Yildiz et al, 2011, 2012; Ozgener and Ozgener, 2013a,b).

**ANALYSIS**

Exergy analysis, as described in this paper and in more detail in a series of recent studies by Ozgener and Ozgener (2009), (2010a-d), (2013a,b), Ozgener (2011), (2012), Ozgener et al (2011), has been applied to evaluate the performance of the system. The balance equations (mass, energy and exergy flows in the system and its components) are written for steady-state steady-flow control volume systems, and the appropriate energy and exergy equations are derived for this system and its components (Ozgener and Ozgener, 2009; Ozgener and Ozgener, 2010a-d; Ozgener, 2013a,b; Ozgener, 2011; Ozgener et al., 2011; Ozgener and Ozgener 2011). All the formulas used represent the experimental data and conditions of the study and are intended for general prediction of the performance of the tested passive EAHE heating system.

**Performing exergy analysis of the system studied**

Physical exergy is the majority of the process. Therefore, chemical exergy, potential exergy, nuclear exergy, magnetic exergy, and kinetic exergy (kinetic energy) were neglected in this study.

The general exergy balance can be expressed in the rate form as

\[ \dot{E}_{x,heating} - \dot{E}_{x,work} + \dot{E}_{x,thermal} - \dot{E}_{x,ambient} = \dot{E}_{x,dest} \]  \hspace{1cm} (1)

Using Eq. (1), the rate form of the general exergy balance can also be written as

\[ \sum \left(1 - \frac{T_k}{T_0}\right) \dot{Q}_k - \dot{W} + \sum \dot{m}_s \psi_s - \sum \dot{m}_s \psi_s = \dot{E}_{x,dest} \]  \hspace{1cm} (2)

where \( \dot{Q}_k \) is the heat transfer rate through the boundary at temperature \( T_k \) at location \( k \), \( \dot{W} \) is the work rate, \( \psi \) is the flow (specific) exergy, \( h \) is enthalpy, \( s \) is entropy, and the subscript zero indicates properties at the restricted dead or ambient state of \( P_0 \) and \( T_0 \).

The total flow exergy of air is calculated from Eqs. (3)–(5) (Wepef and Gaggioli, 1979)
\[
\psi_a = \left[ (C_{p,a} + \alpha C_{p,v}) \left( T - T_0 \right) - T_0 \left[ (C_{p,a} + \alpha C_{p,v}) \ln(T/T_0) - (R_a + \alpha R_v) \ln(P/P_0) \right] + T_0 \left[ (R_a + \alpha R_v) \ln \left[ \left( 1 + 1.6078 \alpha_b \right) / \left( 1 + 1.6078 \alpha_b \right) \right] + 1.6078 \alpha R_v \ln(\alpha/\alpha_b) \right]
\]

where the specific humidity ratio is
\[
\omega = \frac{m_{a}}{\dot{m}} \quad (4)
\]
and, \( T_0, P_0 \) are reference temperature and atmospheric pressure.

Specific exergy of ideal gas (air)
\[
\psi_{p,a} = C_{p,a}(T - T_0 ln \frac{T}{T_0}) + R_a T_0 ln \frac{P}{P_0} \quad (5)
\]

Multiplying flow or specific exergy given in Eqs. (3)-(5) by the mass flow rate of the fluid gives the exergy rate
\[
\dot{E}_X = \dot{m}_a \psi_a \quad (6)
\]
The exergy content of the solar radiation absorbed by the solar collecting area of PV is
\[
\dot{E}_{solar} = (1 - \frac{T_o}{T_{sun}}) S \cdot A \quad (7)
\]

It is usually more convenient to estimate entropy generation \( \dot{S}_{gen} \) first, and then to evaluate the exergy destroyed or the irreversibility \( \dot{i} \) directly from the following equation:
\[
\dot{i} = \dot{E}_{dest} - T_0 \dot{S}_{gen} \quad (8)
\]

Exergy destruction rates of the EAHE, PV, and blower are estimated using Eqs. (9)-(11).

The exergy destroyed in the EAHE is evaluated as
\[
\dot{E}_{dest\ EAHE} = \dot{m}_a (\psi_{a,in} - \psi_{a,out}) + \dot{Q} a \left( 1 - \frac{T_o}{T_k} \right) \quad (9)
\]
The exergy destroyed in the PV is evaluated as
\[
\dot{E}_{dest\ PV} = \dot{E}_{solar} - \dot{E}_{electric} = \left( 1 - \frac{T_o}{T_{sun}} \right) S \cdot A - \left( V_m \cdot a \right) \quad (10)
\]
The exergy destroyed in the blower (fan) is evaluated as
\[
\dot{E}_{dest\ b} = \dot{W}_b - \dot{m}_a (\psi_{a,out} - \psi_{a,in}) \quad (11)
\]

**Exergy efficiency**

The exergetic analysis allows to evaluate for each component of the system the exergy destroyed and to determine which component weights more on the overall system inefficiency. In this context, different ways of formulating the exergetic (or exergy) efficiency (second law efficiency, effectiveness, or rational efficiency) proposed in the literature have been given in detail elsewhere (Kotas, 1985, Szargut, 1998). Taking Eqs. (2) and (6) the general exergy efficiency of the system can be written as follows:
\[
\eta_{sys} = 1 - \frac{\sum E_{dest}}{\sum E_{xin}} \quad (12)
\]
The exergy efficiency of earth to air heat exchanger may be written as follow:
\[
\eta_{EAHE} = \frac{\dot{E}_{dest\ EAHE}}{\dot{E}_{xin}} \quad (13)
\]

\[
\dot{m}_a (\psi_{a,in} - \psi_{a,out}) + \dot{Q} a \left( 1 - \frac{T_o}{T_k} \right)
\]

The exergy efficiency of the PV is calculated as follows
\[
\eta_{PV} = 1 - \frac{\dot{E}_{dest\ PV}}{\dot{E}_{solar}} \quad (14)
\]

The exergy efficiency of the blower (fan) can be defined as follows
\[
\eta_{b} = \frac{\dot{E}_{dest\ b}}{\dot{W}_b} \quad (15)
\]

**Measurements and uncertainties**

In the present study, the temperatures, air flow rates, voltages and currents were measured with appropriate instruments described previously. The data collection was made at an interval of every second and the hourly average values are also recorded. As known, errors and uncertainties in data recording and experiments may arise from inherent instrument uncertainties, operating conditions, and/or calibration errors, environmental, observation, and reading and test planning (Ozgener, 2011, Ozgener and Ozgener, 2009). An uncertainty analysis was needed to quantify the accuracy and reliability of the experimental data taken. As a result; the total uncertainties of the measurements are given (Ozgener and Ozgener, 2010a-d; Ozgener et al, 2011, Yildiz et al, 2011, 2012). In experiments, IR effects on air temperature measurements and the errors in the thermal properties because of non-uniform conditions in the soil were neglected. The data was recorded by using Elimko E-680 data logger. E-680
series universal data loggers are new generation microcontroller based instruments compatible with IEC (International Electrotechnical Commission) 668 standards. E-680 series indicate measurements from 32 different points on instrument display and determine the alarm conditions by comparison of two set points for each channel. The instruments can be connected to an RS-485 communication line and the data can be collected and stored in a centrally located PC. It has a resolution of 0.1 °C, 1 W/m² for temperature and its accuracy of 0.5% (Ozgener and Ozgener, 2011). TESTO 6621 temperature and relative humidity (RH) transmitters have ±0.5 °C, and ±2.5 % RH, respectively. Air flow velocities were measured by Lutron AM-4206M anemometer and its accuracy and resolutions are ±2% 0.2 m/s, 0.01 m/s, respectively.

RESULTS AND DISCUSSION

The results of long-term observations in the Bornova area of Izmir on exergetic efficiency fluctuations of the system are presented in the form of tables, bar charts and graphs. The experimental system was commissioned in June 2009 and experimental data collection has been conducted since then. The data, consisting of hourly thermodynamics records a yearly heating periods for 2009-2012, were measured at the Solar Energy Institute of the Bornova Campus at Ege University. At the present time, the database contains more than 30000 records of measurements. The thermodynamic properties of the air used in the present study are based on the actual data taken from the system measured and recorded average values for 2009, 2010, 2011, and partly 2012 heating seasons, respectively. The thermodynamic properties of air are obtained from the general thermodynamic tables and software. Fan operation during the experiment varied depending on the heating days and operating strategy. The temperature of sun was assumed to be 6000 K for exergetic evaluations of the PV component.

The reference state was considered as the state of environment at which the atmospheric pressure is 101.32 kPa. Table 1-3 shows the variation of energetic and exergetic efficiencies of system and its components. Total uncertainties of the calculated parameters are illustrated in the Tables and are representative of what has been reported in other papers (Ozgener and Ozgener, 2010a-d; Ozgener et al, 2011, Yildiz et al, 2011, 2012). During the winter experimental study, the EAHE air inlet temperatures varied between 4.1 and 20 °C, the EAHE outlet air temperatures varied between 8 and 26 °C, and the solar radiation incident on the greenhouse varied between 0 and 950 W/m². The average value of the temperature for the sink was obtained to be 15.7 °C. Over three successive heating seasons, the mean temperature difference between the inlet and outlet was approximately 6.2 °C. In addition, the mass flow rate of air was measured to be 0.56 kg/s. During the heating period, the rate of extracted heat from air to the ground was found to be 10.74 kW on average. Using the the database, which contains more than 30000 records of measurements taken during experimental study, the mean exergy efficiency of the EAHE, as given in Table 1-3, was determined to be 54 %, the mean exergy efficiency of fan was 72% and overall exergy efficiency was 69% for 2009-2012 heating period. Table 1-3 also shows that 46% of the total exergy flow entering the EAHE is lost, while remaining 54% is utilized. The highest exergy loss is found to be 96% from the PV component by using Eqs. (5)-(7). Exergetic efficiencies of PV arrays were found to be 4%, respectively. This result was consistent with the exergy destruction associated with the air blower and amounts to some 0.20 kW. About 9% of the required electric energy was obtained from solar photovoltaic cells with the remaining 91% coming from conventional resources. As expected that maximum supplement provided by the solar photovoltaic cells was measured to be greater than 55% between the hours 13:30 and 13:40.

In the present study, the results obtained from the experiments were evaluated to determine the overall performance of the system. During periods of no sunlight the north-facing wall was insulated to reduce the potentially large heat losses through that wall.

The design of passive greenhouse systems requires the strategic placement of windows, storage masses, occupied spaces. Results of the study can be used in conjunction with fundamental principles of solar radiation geometry and tilt factors, as described by Kreith and Kreider (1978), and Kreith and Goswami (2007), to achieve improved designs. The maximum ambient air temperature varied between 1.7 and 18°C during the experimental studies. When the system is operated, the maximum greenhouse temperatures changes are between 10.8 and 21°C. When the system is not operated, maximum greenhouse temperature and minimum humidity could reach 54.9°C, 8%, respectively [20]. The total heating demand ranged from 0 kW to 10 kW for different reference state values to provide better coverage and presentation of how the varying reference state temperature affects the performance of the system in terms of energy demands. Gross mean electricity energy consumption (TEEC) was found to be 69.14 kWh/month by assuming the COP value was 15.40.

CONCLUSIONS

Additional observations and conclusions drawn from the present study may be summarized as follows:

- The maximum heating capacity of the system was determined to be 10 kW. The required
Pipe lengths in meters per kW of heating capacity were found to be 4.7.

- Seasonal fluctuations of exergetic efficiency have been obtained for the soil depths up to 3 m by measurements over the period of 2009-2012. Results are reported as average monthly monitored values of \( \varepsilon \) of the system for the 2009 - 2012 heating seasons.

- Experimental results also show that mean heating exergetic efficiency value was obtained to be 69% for successive 3 years heating seasons. The maximum yearly mean exergetic efficiency was 71% in 2009 heating season.

- The highest irreversibility on a system basis occurs in the PV unit, followed by the fan, and EAHE, respectively. In addition, the remaining system components have a relatively low influence on the overall efficiency of the system.

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NOMENCLATURE

\[
\begin{align*}
V & \quad \text{Unit of electrical potential difference (volt)} \\
\dot{W} & \quad \text{Work rate (kW)} \\
\varepsilon & \quad \text{Exergy (Second law) efficiency (-)} \\
\psi & \quad \text{Specific exergy (kJ/kg)} \\
\omega & \quad \text{specific humidity (kg_{water vapor/kg_{air}})} \\
\end{align*}
\]

\[
\begin{align*}
\text{} & \quad \text{Greek Letters} \\
\text{} & \quad \text{Subscripts} \\
\text{} & \quad \text{Superscripts} \\
\text{} & \quad \text{Abbreviations} \\
\text{} & \quad \text{REFERENCES}
\end{align*}
\]

( ) a dot per unit time

REFERENCES


Kreith, F., Goswami, D.Y. “Energy Efficiency and


Table 1: Average monthly monitored values for 2009 heating season

<table>
<thead>
<tr>
<th>Months</th>
<th>2009 MAAT</th>
<th>( \dot{E}<em>{x</em>{dest}} )</th>
<th>( \dot{Q} )</th>
<th>( \Delta T )</th>
<th>Extracted Energy</th>
<th>Consumed Energy</th>
<th>First and second law performance evaluation results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kW</td>
<td>kW</td>
<td>°C</td>
<td>kWh</td>
<td>kWh</td>
<td>Blower I (%)</td>
</tr>
<tr>
<td>January</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>February</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>March</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>November</td>
<td>14.6</td>
<td>2.10</td>
<td>10.65</td>
<td>5.90</td>
<td>798.75</td>
<td>54.75</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>13.1</td>
<td>2.21</td>
<td>10.83</td>
<td>6.00</td>
<td>758.1</td>
<td>51.10</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>13.9</td>
<td>2.15</td>
<td>10.74</td>
<td>5.95</td>
<td>778.3</td>
<td>52.93</td>
<td>59.36</td>
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<td>Total uncertainty (%)</td>
<td>±1.5</td>
<td>±5</td>
<td>±4</td>
<td>±0.5</td>
<td>±5</td>
<td>±5</td>
<td>±4</td>
</tr>
</tbody>
</table>

\( \dot{E}_{x_{dest}} \) denotes the extracted energy per unit mass of dest. fluid.
Table 2: Average monthly monitored values for 2010 heating season

<table>
<thead>
<tr>
<th>Months</th>
<th>2010 MAAT</th>
<th>$\dot{E}_{\text{dest}}$</th>
<th>$\dot{Q}_k$</th>
<th>$\Delta T$</th>
<th>Extracted Energy</th>
<th>Consumed Energy</th>
<th>First and second law performance evaluation results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kW</td>
<td>kW</td>
<td>°C</td>
<td>kWh</td>
<td></td>
<td></td>
<td>Blower</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I (%)</td>
</tr>
<tr>
<td>January</td>
<td>10.6</td>
<td>2.22</td>
<td>14.4</td>
<td>8.01</td>
<td>1728</td>
<td>87.6</td>
<td>-</td>
</tr>
<tr>
<td>February</td>
<td>12.6</td>
<td>2.22</td>
<td>10.83</td>
<td>6.00</td>
<td>758.1</td>
<td>51.1</td>
<td>-</td>
</tr>
<tr>
<td>March</td>
<td>13.3</td>
<td>2.83</td>
<td>10.83</td>
<td>6.01</td>
<td>649.8</td>
<td>43.8</td>
<td>-</td>
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<tr>
<td>November</td>
<td>18.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>December</td>
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<td>Average</td>
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<td>9.92</td>
<td>5.5</td>
<td>842.65</td>
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<td>Total uncertainty (%)</td>
<td>±1.5</td>
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<td>±4</td>
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<td>±5</td>
<td>±5</td>
<td>±4</td>
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Table 3: Average monthly monitored values for 2011 heating season

<table>
<thead>
<tr>
<th>Months</th>
<th>2011 MAAT</th>
<th>( \dot{E}_{x,\text{dest}} ) EAHE</th>
<th>( \dot{Q}_k )</th>
<th>( \Delta T )</th>
<th>Extracted Energy</th>
<th>Consumed Energy</th>
<th>First and second law performance evaluation results</th>
</tr>
</thead>
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<tr>
<td></td>
<td>kW</td>
<td>kW</td>
<td>°C</td>
<td>kWh</td>
<td>kWh</td>
<td></td>
<td>Blower</td>
</tr>
<tr>
<td></td>
<td>I (%)</td>
<td>II (%)</td>
<td>I (%)</td>
<td>II (%)</td>
<td>I (%)</td>
<td>II (%)</td>
<td>COP (-)</td>
</tr>
<tr>
<td>January</td>
<td>10.5</td>
<td>2.16</td>
<td>17.42</td>
<td>9.65</td>
<td>1620.06</td>
<td>67.89</td>
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<tr>
<td>February</td>
<td>10.0</td>
<td>2.28</td>
<td>12.27</td>
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<td>1374.24</td>
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<tr>
<td>March</td>
<td>11.7</td>
<td>2.20</td>
<td>13.17</td>
<td>7.30</td>
<td>1119.45</td>
<td>62.05</td>
<td>-</td>
</tr>
<tr>
<td>November</td>
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<td>2.20</td>
<td>12.87</td>
<td>7.13</td>
<td>1119.69</td>
<td>63.51</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>10.7</td>
<td>2.71</td>
<td>7.22</td>
<td>4.00</td>
<td>1600.20</td>
<td>70.50</td>
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<tr>
<td>Average</td>
<td>10.9</td>
<td>2.31</td>
<td>10.59</td>
<td>6.98</td>
<td>1376.73</td>
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<tr>
<td>Total</td>
<td>±1.5</td>
<td>±5</td>
<td>±4</td>
<td>±0.5</td>
<td>±5</td>
<td>±5</td>
<td>±4</td>
</tr>
<tr>
<td>uncertainty</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
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</table>
Table 4: Average monthly monitored values for 2012 heating season

<table>
<thead>
<tr>
<th>Months</th>
<th>2012 MAAT</th>
<th>( \dot{E}<em>{x</em>{\text{dest}}} )</th>
<th>( \dot{Q}_\text{d} )</th>
<th>( \Delta T )</th>
<th>Extracted Energy</th>
<th>Consumed Energy</th>
<th>First and second law performance evaluation results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kW</td>
<td>kW</td>
<td>°C</td>
<td>kWh</td>
<td>kWh</td>
<td>Blower (%)</td>
</tr>
<tr>
<td>January</td>
<td>6.9</td>
<td>2.38</td>
<td>12.64</td>
<td>7</td>
<td>1516.8</td>
<td>87.6</td>
<td>-</td>
</tr>
<tr>
<td>February</td>
<td>7.4</td>
<td>2.78</td>
<td>10.83</td>
<td>6</td>
<td>1028.8</td>
<td>69.4</td>
<td>-</td>
</tr>
<tr>
<td>March</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>November</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>7.2</td>
<td>2.59</td>
<td>11.74</td>
<td>6.5</td>
<td>1272.8</td>
<td>78.5</td>
<td>59.36</td>
</tr>
<tr>
<td>Total uncertainty (%)</td>
<td>±1.5</td>
<td>±5</td>
<td>±4</td>
<td>±0.5</td>
<td>±5</td>
<td>±5</td>
<td>±4</td>
</tr>
</tbody>
</table>
Fig. 1: Basic simplified PV assisted EAHE system schema adopted from (Ozgener and Ozgener, 2010a-d; Yildiz et al., 2011)
Fig. 2: A view of PV assisted EAHE system