Photovoltaics for Sanitary Hot Water Production

Pedro V. Quiles
Francisco J. Aguilar
Damian Crespí

Heat Pump Water Heaters, a challenging future
Workshop at ICR 2019
Photovoltaics for Sanitary Hot Water Production

P.V. Quiles, F.J. Aguilar, D. Crespí

$\eta = 15\% \times 3.4 = 50\%$

COP = 3.4

HEAT PUMP + SOLAR PV

VS.

$\eta = 50\%$

BOILER + SOLAR THERMAL
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HEAT PUMP + SOLAR PV

$\eta = 15\% \times 3.4 = 50\%$

COP = 3.4

VS.

HEAT PUMP + SOLAR THERMAL

COP = 3.4
PV ALTERNATIVE TO SOLAR THERMAL???

- **EFFICIENCY?**
  - PV Panels
  - ST Collectors
  - Electricity vs. Heat

- **COST?**
- **RELIABILITY?**
- **DURABILITY?**
- **EASY TO INSTALL?**
- **LIFE COST ANALYSIS?**
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Power (W)
100% annual self-consumption = 15% real self-consumption
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100% annual self-consumption = 15% real self-consumption

Water heating: Shower, cleaning, washing machine, dishwasher
DESING CHARACTERISTICS

- ELECTRICITY EXPORT: YES/NO
- BATTERIES: YES/NO
- THERMAL STORAGE: YES/NO
- COMPRESOR: INVERTER, W=CONSTANT
- IMPROVED CONTROL (SOLAR)

DIMENSIONS:

- NUMBER OF PV PANELS
- COMPRESOR POWER
- BATTERIES: Ah
- STORAGE CAPACITY (liters)
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Diagram:
- REFRIGERANT CIRCUIT
- Control
- Inverter DC/AC
- WATER TANK
- DHW
- CW
- PV PANELS
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MIDEA Compak KHP 15 190

<table>
<thead>
<tr>
<th>Component</th>
<th>Symbol</th>
<th>Unit</th>
<th>Value</th>
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<td>Thermal Capacity</td>
<td>Q_{HP}</td>
<td>W</td>
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<tr>
<td>Compressor Power</td>
<td>P_{E-COMP}</td>
<td>W</td>
<td>470</td>
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<tr>
<td>COP</td>
<td>COP</td>
<td>-</td>
<td>3.19</td>
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<tr>
<td>Refrigerant</td>
<td>---</td>
<td>---</td>
<td>R134a</td>
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<tr>
<td>Evaporator Fan Power</td>
<td>P_{E-FAN}</td>
<td>W</td>
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<tr>
<td>Tank Volume</td>
<td>Vol.</td>
<td>L</td>
<td>190</td>
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DIMENSIONS:
- NUMBER OF PV PANELS = 2 x 235W
- COMPRESOR POWER = 470 W
- BATTERIES: Ah
- STORAGE CAPACITY (liters) = 190 L
Localización: Elche  
Clima: Mediterráneo  
$H_o=5,06\ \text{kWh/m}^2\cdot\text{día}$  
$T_o=15,3^\circ\text{C}$
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\[ E_{PV} = 2.39 \text{ kWh} \]
\[ E_{PV,\text{ELEC}} = 1.38 \text{ kWh} \]
\[ E_{PV,\text{HP}} = 1.03 \text{ kWh} \]
\[ E_{\text{GRID,HP}} = 0.68 \text{ kWh} \]
\[ E_{\text{TOT,HP}} = 1.71 \text{ kWh} \]
\[ E_{\text{TOT,SYST}} = 3.07 \text{ kWh} \]
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<table>
<thead>
<tr>
<th>Month</th>
<th>$E_{\text{GRID,HP}}$</th>
<th>$E_{\text{PV,HP}}$</th>
<th>$E_{\text{PV,ELEC}}$</th>
<th>$E_{\text{PV}}$</th>
<th>$Q_{\text{HP}}$</th>
<th>$Q_{\text{ELEC}}$</th>
<th>$Q_{\text{TOT}}$</th>
<th>$Q_{\text{DHW}}$</th>
<th>$Q_{\text{LOSS}}$</th>
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<td>kWh</td>
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<td>January</td>
<td>0.90</td>
<td>1.40</td>
<td>0.61</td>
<td>2.02</td>
<td>6.94</td>
<td>0.61</td>
<td>7.55</td>
<td>5.56</td>
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<td>February</td>
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<td>1.43</td>
<td>0.75</td>
<td>2.18</td>
<td>6.90</td>
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<td>5.67</td>
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<td>7.17</td>
<td>1.10</td>
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<td>June</td>
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<td>1.24</td>
<td>7.72</td>
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<td>July</td>
<td>0.71</td>
<td>0.98</td>
<td>1.41</td>
<td>2.39</td>
<td>6.39</td>
<td>1.41</td>
<td>7.80</td>
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<td>August</td>
<td>0.76</td>
<td>0.88</td>
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<td>2.23</td>
<td>6.43</td>
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<td>Sept.</td>
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<td>2.14</td>
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<td>Oct.</td>
<td>0.76</td>
<td>1.04</td>
<td>1.15</td>
<td>2.19</td>
<td>6.41</td>
<td>1.15</td>
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<td>Nov.</td>
<td>1.13</td>
<td>0.89</td>
<td>0.72</td>
<td>1.62</td>
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<td>Dec.</td>
<td>1.04</td>
<td>1.20</td>
<td>0.72</td>
<td>1.92</td>
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<td>7.50</td>
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<td>Total</td>
<td>317.6</td>
<td>403.7</td>
<td>379.2</td>
<td>782.9</td>
<td>2449.2</td>
<td>379.2</td>
<td>2844.2</td>
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<td>Average</td>
<td>0.87</td>
<td>1.11</td>
<td>1.04</td>
<td>2.15</td>
<td>6.71</td>
<td>1.04</td>
<td>7.75</td>
<td>6.16</td>
<td>1.63</td>
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</tbody>
</table>
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Vol = 190 liters
HP: 450 W

$E_{L,GRID} = 0.9$

$E_{PV} = 2.15$

$E_{PV,HP} = 1.11$

$E_{PV,RES} = 1.04$

$E_{HP} = 1.96$

$Q_{DHW} = 6.16$

$Q_{RES} = 1.04$

$Q_{LOS} = 1.63$

$Q_{TOT} = 7.8$ kWh/day

$E_{GRID,HP} = 0.9$

$E_{PV,HP} = 1.11$

$E_{PV,RES} = 1.04$

$E_{HP} = 1.96$

$Q_{DHW} = 6.16$

$Q_{RES} = 1.04$

$Q_{LOS} = 1.63$

$Q_{TOT} = 7.8$ kWh/day

$SPF_{HP} = \frac{Q_{HP}}{E_{TOT,HP}} = \frac{6.71}{1.96} = 3.42$

$SPF_{SYS} = \frac{Q_{SYST}}{E_{GRID,HP}} = \frac{6.71 + 1.04}{0.87} = 8.91$

$SC_{HP} = \frac{E_{PV,HP}}{E_{TOT,HP}} = \frac{1.11}{1.96} = 56.6\%$

$SC_{SYS} = \frac{Q_{RES} + Q_{HP} \cdot SC_{HP}}{Q_{RES} + Q_{HP}}$

$= \frac{1.04 + 6.71 \cdot 0.566}{1.04 + 6.71} = 62.4\%$
Thermo-economic analysis

1. SPF = 8.95, PV = 470 W
2. SPF = 3.40
3. η = 92% [GN]

Referencia

4. η = 92% [GN], CS = 60%
5. η = 100%
6. η = 100%, PV = 940 W
Annual non-renewable primary energy consumption for 90 m² dwelling
317.6 kWhEE/year (45 €/year)
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IMPROVEMENTS (1)

- Grid Energy ($E_{gr}$)
- PV energy consumed by the resistance ($E_{PV,RES}$)
- PV energy consumed by the heat pump ($E_{PV,HP}$)

Power (W)

Time (hours)

- $P_{TOT,HP}$
- $P_{PV}$
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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

RUNNING IN A REAL HOUSE SINCE SEP2017

Vol = 110 liters
HP: 250 W

HPT-Annex 46
Domestic Hot Water Heat Pumps

230V

Vol = 110 liters
HP: 250 W
Vol = 110 liters
HP: 250 W

SC%?
PF?
PE_SAV?

CONFORT?
IMPROVEMENTS (2)

BATTERIES

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Batteries Power (W)

SOLAR: 3 h, GRID: 1 h

Batteries Voltage (V)

HP ON 4h

HP OFF 20h

Time (hours)
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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V

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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V

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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V

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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V

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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V

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EXPERIMENTAL RESULTS ON HEAT PUMP + PV

\[ E_{\text{DHW}} = 6.2 \]

\[ E_{\text{LOS}} = \]

RUNNING IN THE LABORATORY

230V
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IMPROVEMENTS (3)
Photovoltaics for Sanitary Hot Water Production

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IMPROVEMENTS (4)

SMART CONTROL

DHW CONSUMPTION

USER LEARNING

TEMP RADIATION
CONVINCE THE MANUFACTURERS TO JOIN HP AND PV
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