Payback Periods for Photovoltaic Systems

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Associate Professor
Physics and Optical Sciences
University of Arizona
1 MW_{peak} PV system

Requires \((130 \text{ m})^2 = 4.7\ \text{Acres of land}\)

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*No subsidies, 2009 technology, many variables
Photovoltaic Panels on Cronin’s House

System Cost:
$7.50 / Watt
Financial Cost:

- PV modules $3 / watt
- Mounting + conduit $1 / watt
- Inverter $0.5 / watt
- Labor + engineering $0.5 / watt

(30% Federal Tax benefit)
(8.5 ¢/kwh for RECs)
PV Cost Reductions

Source: Department of Energy ERFC Workshop
Financial Benefit

• Electricity generated annually in Tucson:

\[ 1750 \text{ kwh/yr per kW}_{\text{peak}} \times 11 \, \text{¢/kwh} = 193 \, \$/\text{yr} / \text{KW}_{\text{peak}} \]

(plus 8.5 ¢/kwh in REC money)
85% of my electricity is produced from solar.

13 year payback period at my house after rebates and tax benefits
Solar: In ‘08, family saved over $500

Continued from p.23

panels — which are not needed many months of the year — at wholesale prices.

Cronin's electric bill totaled $686 for 2006, the last full year before the system was installed. In 2008, his bill was $159, amounting while generating the same amount of electricity.

That's tons of carbon dioxide, weighing more than his Toyota Prius, Cronin said. Actually the amount of carbon dioxide produced would have been larger, he added, because some additional electricity would have been lost.
Research on: Reliability, Efficiency, Power forecasting

Contact: Dr. Alex Cronin, cronin@physics.arizona.edu
Annual Energy Yield

1.3 x 10^{10} \text{ J} \text{ in 2008}

from 14 m^2 of c-Si modules.

→ 300 million more systems like this (106 km)^2 could produce 0.4 TW for 50 years.
Finding:

Multiply by 4.8 hrs per day to predict energy yield (year average in Tucson)
4 ½ Years of Daily kWh data

www.physics.arizona.edu/~cronin/Solar/TEPweb
Degradation Rates ~ 0.5% to 2.5% / yr
Table I. Photovoltaic hardware already operating at the TEP solar test yard.

<table>
<thead>
<tr>
<th>SYST. NO.</th>
<th>PV MODULE TYPE</th>
<th>POWER/MOD.</th>
<th>NUMBER OF MOD.S</th>
<th>INVERTER TYPE</th>
<th>TOTAL POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sharp</td>
<td>165 W</td>
<td>16</td>
<td>Aurora</td>
<td>2.64 kW</td>
</tr>
<tr>
<td>2</td>
<td>Kyocera</td>
<td>150 W</td>
<td>9</td>
<td>Xantrex TR</td>
<td>1.35 kW</td>
</tr>
<tr>
<td>3</td>
<td>BP 3150U</td>
<td>150 W</td>
<td>10</td>
<td>Xantrex TR</td>
<td>1.50 kW</td>
</tr>
<tr>
<td>4</td>
<td>Unisolar</td>
<td>64 W</td>
<td>24</td>
<td>Fronius</td>
<td>1.54 kW</td>
</tr>
<tr>
<td>5</td>
<td>Sanyo</td>
<td>167 W</td>
<td>8</td>
<td>Sunnyboy</td>
<td>1.34 kW</td>
</tr>
<tr>
<td>6</td>
<td>BP MST50</td>
<td>150 W</td>
<td>30</td>
<td>Xantrex TR</td>
<td>1.50 kW</td>
</tr>
<tr>
<td>7</td>
<td>ASE DGF17</td>
<td>300 W</td>
<td>6</td>
<td>Xantrex TR</td>
<td>1.80 kW</td>
</tr>
<tr>
<td>8</td>
<td>BP SX140</td>
<td>140 W</td>
<td>10</td>
<td>Xantrex TR</td>
<td>1.12 kW</td>
</tr>
<tr>
<td>9</td>
<td>ASE DGF50</td>
<td>300 W</td>
<td>6</td>
<td>Xantrex TR</td>
<td>1.80 kW</td>
</tr>
<tr>
<td>10</td>
<td>GSE</td>
<td>45 W</td>
<td>32</td>
<td>Xantrex TR</td>
<td>1.44 kW</td>
</tr>
<tr>
<td>11</td>
<td>Shell</td>
<td>40 W</td>
<td>38</td>
<td>Xantrex TR</td>
<td>1.52 kW</td>
</tr>
<tr>
<td>12</td>
<td>Sanyo</td>
<td>180 W</td>
<td>8</td>
<td>Fronius</td>
<td>1.44 kW</td>
</tr>
<tr>
<td>13</td>
<td>BPMST50</td>
<td>50 W</td>
<td>30</td>
<td>Sharp</td>
<td>1.50 kW</td>
</tr>
<tr>
<td>14</td>
<td>Solarex MST50</td>
<td>50 W</td>
<td>150</td>
<td>Beacon</td>
<td>7.50 kW</td>
</tr>
<tr>
<td>15</td>
<td>Shell</td>
<td>150 W</td>
<td>20</td>
<td>Xantrex TR</td>
<td>3.00 kW</td>
</tr>
<tr>
<td>16</td>
<td>Astro</td>
<td>164 W</td>
<td>9</td>
<td>Xantrex TR</td>
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<tr>
<td>17</td>
<td>BP MST43</td>
<td>43 W</td>
<td>60</td>
<td>Solectra</td>
<td>2.58 kW</td>
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<tr>
<td>18</td>
<td>ASE DGF17</td>
<td>300 W</td>
<td>10</td>
<td>Xantrex OH4</td>
<td>3.00 kW</td>
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<tr>
<td>19</td>
<td>ASE DGF50</td>
<td>300 W</td>
<td>10</td>
<td>Xantrex OH3</td>
<td>3.00 kW</td>
</tr>
<tr>
<td>20</td>
<td>GSE</td>
<td>62 W</td>
<td>21</td>
<td>Xantrex TR</td>
<td>1.30 kW</td>
</tr>
<tr>
<td>21</td>
<td>BP 4170</td>
<td>170 W</td>
<td>10</td>
<td>Xantrex GT</td>
<td>1.70 kW</td>
</tr>
<tr>
<td>22</td>
<td>Kyocera</td>
<td>190 W</td>
<td>10</td>
<td>Fronius</td>
<td>1.90 kW</td>
</tr>
<tr>
<td>23</td>
<td>Sharp</td>
<td>300 W</td>
<td>128</td>
<td>3-phase</td>
<td>38.40 kW</td>
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Total 19 Module Types 663 panels 11 Inverter Types 89 kW
TEP PV test yard
4350 E. Irvington Rd.
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To fabricate a c-Si solar panel takes 400 kWh / m²
Source: DOE/GO-102004-1847 report
PV systems can repay their energy investment in about 2 years. During its 28 remaining years of assumed operation, a PV system that meets half of an average household’s electrical use would eliminate half a ton of sulfur dioxide and one-third of a ton of nitrogen-oxides pollution. The carbon-dioxide emissions avoided would offset the operation of two cars for those 28 years.
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Water use:

• For semiconductor Si, 10 gallons of water / sq-inch

• uses HF, HCl, trichlorosilane (SiHCl₃), alcohols, catalysts (Cu), heat, clean rooms ...

Compare to: 1 gallon / kwh evaporated at TEP plus up to 9 gallons / kwh for coal mining and transport ...

Sources:

Scandia National Lab report 1998 “ENVIRONMENTALLY BENIGN SILICON SOLAR CELL MANUFACTURING”

http://www.sciencedaily.com/releases/2008/04/080417173953.htm#
“Water needed to produce various types of energy”
US Annual Energy Flow  (100 Quad BTU = $10^{20}$ J = $3 \times 10^{13}$ kWh)

Figure Source: Energy Information Administration
Official Energy Statistics from the U.S. Government
Net Primary Resource Consumption ~97 Quads

Electrical imports* 0.08
Nuclear 8.1
Hydro 2.6
Biomass/other** 3.2
Natural gas 19.6
Net imports 3.6

Coal 22.6

U.S. petroleum and NGPL 14.9
Imports 24.3

Bal. no. 0.9
Bal. no. 0.3
Export 2.0
Export 1.0
Bal. no. 0.1

Electric power sector 38.2
Electricity 11.9
Electrical system energy losses 26.3

Residential/commercial 19.6
Industrial 19.0
Useful energy 35.2
Lost energy 56.2

Source: Production and end-use data from Energy Information Administration, Annual Energy Review 2002.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004
Lawrence Livermore
National Laboratory
http://eed.llnl.gov/flow
This is a myth that propagates around the internet. There's an acronym that's used called EROEI, energy returned on energy invested.

The myth is that it takes more energy to produce solar panels than the energy they produce from the sunlight.

Crystalline silicon PV systems presently have energy pay-back times of 1.5-2 years for South-European locations and 2.7-3.5 years for Middle-European locations. The U.S. is less than 1.5 years currently.

The accounting life estimate for solar panels is 20 years typically, but they last longer than that, many are guaranteed for at least 20 years, with no definite end due to time.

That's old technology, nothing new here, no inventions, it's been this way for 20 years, I know because I installed solar panels in 1984 and they're still going strong.

There are new panels that will improve that number as well as output per size.
• **One Ton of . . .**
  Steel: 62,000 gallons of water
  Cement: 1,360 gallons

• For an ‘old’ SOLON tracker that holds 40 kw, there are 6 tons of steel and 50 tons of cement.
  ...

• 11,000 gal / kw  compare to:
• 129,000 gal/kw  to fab.