Energierücklaufzeiten für PV-Module und Systeme
Energy payback times of PV modules and systems

Mariska de Wild-Scholten
Outline

• Sustainability
• Life Cycle Assessment
• Energy payback time
• Energy yield ratio
• Conclusions
Sustainability: the 3 pillars

People: SLCA
- Social Life Cycle Assessment

Planet: LCA
- Life Cycle Assessment

Profit: LCC
- Life Cycle Costing

health

equency:
- photochemical oxidation
- ozone layer depletion
- global warming
- toxicity
- acidification
- eutrophication

safety

deposition of resources

eexternal costs

Levelized Cost of Electricity

EPIA Sustainability Working Group & IEA PVPS task 12
Life Cycle Assessment (LCA)

ISO14040 series

Determination of the environmental impact of a product from cradle to grave

Simapro software
Ecoinvent database

Life Cycle Assessment framework

Goal and scope definition
Inventory analysis
Impact assessment

Interpretation
Photovoltaics cannot pay back it’s energy investment?
Energy payback time (EPBT)

- **definition**: time in which the energy input during the PV system life-cycle is compensated by electricity generated by the PV system

- \[ EPBT = \frac{E_{\text{input}}}{E_{\text{output}}/\text{year}} \]

- ☹️ Lifetime of PV system not included!
**Energy payback time: calculation example CdTe PV module**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Energy Demand (CED) from LCA</td>
<td>12236 (\text{MJ}_{\text{prim}}/\text{kWp})</td>
</tr>
<tr>
<td>Irradiation</td>
<td>1700 kWh/m(^2).year</td>
</tr>
<tr>
<td>Performance ratio (\text{(IEC 61724)})</td>
<td>0.75</td>
</tr>
<tr>
<td>Generated electricity</td>
<td>1275 kWh/kWp.year</td>
</tr>
<tr>
<td>Efficiency electricity supply</td>
<td>11.4 (\text{MJ}_{\text{prim}}/\text{kWh})</td>
</tr>
<tr>
<td>Avoided energy</td>
<td>14535 (\text{MJ}_{\text{prim}}/\text{kWp}.year)</td>
</tr>
<tr>
<td>Energy payback time</td>
<td>0.84 years</td>
</tr>
</tbody>
</table>
Data & assumptions

- UCTE (European) electricity mix
- Slanted roof-top installation for flat plate, 2-axis tracker for CPV; performance ratio 0.75

- **x-Si**: CrystalClear project
  - Si feedstock = REC Siemens, multi wafers = REC, ribbon “wafers” = Evergreen Solar, frameless modules

- **Si TF**: Performance project
  - a-Si: German producer, µm-Si: best data equipment manufacturers,
  - excluding SF₆/NF₃ consumption/emissions
  - fiX mounting of frameless module
  - a-Si on steel: United Solar
  - a-Si on PEN: Flexcell (Flexcellence project)

- **CdTe**: Performance project
  - First Solar data 2004 ecoinvent 2.0 + updated energy/glass consumption/Cd emission
  - mounting of frameless modules: Schletter roof-top, assumed same as xSi
  - module recycling: no data for filtercake treatment

- **CIGS**: Performance project
  - German producer + ecoinvent 2.0 data for water & some metals
  - mounting of frameless modules: Schletter roof-top, assumed same as xSi
  - module recycling: assumed the same as CdTe

- **CPV**: Apollon project
  - ENE, NaREC, CPower, SolarTech International AG
Cumulative Energy Demand
MJ_{prim} / \text{m}^2 \text{ of module}

<table>
<thead>
<tr>
<th>CED of modules (MJ/m²)</th>
<th>mono 2008</th>
<th>multi 2007</th>
<th>ribbon 2009</th>
<th>a-Si 2008</th>
<th>μm-Si 2008</th>
<th>a-Si on steel 2006</th>
<th>a-Si on PEN 2008</th>
<th>CdTe 2009</th>
<th>CIGS (1) 2009</th>
<th>CIGS (2) 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>MJ/m²</td>
<td>2860</td>
<td>2699</td>
<td>1548</td>
<td>989</td>
<td>1173</td>
<td>866</td>
<td>252</td>
<td>811</td>
<td>1684</td>
<td>1936</td>
</tr>
<tr>
<td>%</td>
<td>14.0%</td>
<td>13.2%</td>
<td>13.2%</td>
<td>6.6%</td>
<td>8.5%</td>
<td>5.7%</td>
<td>3.8%</td>
<td>10.9%</td>
<td>10.5%</td>
<td>11.0%</td>
</tr>
</tbody>
</table>
Cumulative Energy Demand
$\text{MJ}_{\text{prim}} / \text{Wp}$ of modules

<table>
<thead>
<tr>
<th>Module Type</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<tbody>
<tr>
<td>mono</td>
<td>13.2%</td>
<td>14.0%</td>
<td></td>
</tr>
<tr>
<td>multi</td>
<td>13.2%</td>
<td>6.6%</td>
<td>8.5%</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CdTe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIGS (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIGS (2)</td>
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<tbody>
<tr>
<td></td>
<td>20</td>
<td>20</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>7</td>
<td>7</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>
Energy payback time

on-roof installation in Southern Europe
1700 kWh/m².yr irradiation on optimally-inclined modules

EPBT in years

mono  multi  ribbon  CIGS  CdTe  a-Si  µm-Si

glass-EVA-  glass-EVA-  glass-EVA-  glass-PVB-  glass-EVA-  glass-EVA-  glass-EVA-
backsheet  backsheet  backsheet  glass  glass  backsheet  glass

14.0%  13.2%  13.2%  10.5%  10.9%  6.6%  ?

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24 November 2009

Ecoinvent 2.0 background

no framing

ECN
Carbon footprint (!) breakdown

- largest contribution from electricity & glass
- similar picture for EPBT

![Carbon footprint chart]

- **Si TF glass-EVA-glass** 2008
- **CdTe glass-EVA-glass** 2008
- **CIGS glass-EVA-glass** 2007

Color codes:
- Green: other
- Red: encapsulation
- Blue: glass
- Yellow: electricity

Communication:
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May 2009
Energy payback time of Concentrator PV systems

- largest contribution from tracking system
What is THE energy payback time of PV?
“The” energy payback time: CdTe PV system

Photovoltaic Solar Electricity Potential in European Countries

2.4 years
1.8 years
1.4 years
1.2 years
1.0 years
0.9 years
0.8 years
0.7 years
“The” energy payback time for CPV system

Direct Normal Irradiation (DNI): kWh/m².year & EPBT

- 4.9 y
- 3.6 y
- 2.9 y
- 2.4 y
- 2.1 y
- 1.8 y
- 1.6 y
- 1.5 y
- 1.3 y
- 1.2 y

Source of DNI map: suri@geomodel.eu

preliminary results Apollon project
Energy yield ratio (EYR)

- **definition**: how many times the energy invested is returned or paid back by the system in its entire life

- \[ \text{EYR} = \frac{E_{\text{output in lifetime}}}{E_{\text{input}}} \]

- \( \text{EYR} < 1 \) : 😞
- \( \text{EYR} > 1 \) : 😊
Energy Yield Ratio of PV systems

• to be calculated when reliable data about system lifetime and module degradation become available [Performance project]
Conclusions

• **Energy payback time**
  ~ 1 year for PV systems in S-Europe
  < lifetime of PV system

• **Major contributions**
  - for flat plate PV from module production (electricity + glass),
  - for CPV from tracking system

• **Energy Yield Ratio** is a better metric for comparisons because based on **lifetime** energy output
Acknowledgements & further info

• EU projects: Flexcellence, CrystalClear, Performance, Apollon

• B.S. Richards, M.E. Watt (2007) Permanently dispelling a myth of photovoltaics via the adoption of a new net energy indicator

• m.dewild@ecn.nl

• papers: http://www.ecn.nl/publicaties/default.aspx?au=44649
Thank you!