Environmental profile of PV mass production: globalization

Mariska de Wild-Scholten

26th European Photovoltaic Solar Energy Conference, Hamburg
8 September 2011
Outline

- Life Cycle Assessment
- Energy payback time & Globalization of the PV industry
- Carbon footprint
- Data request
Life Cycle Assessment

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

ISO14040 series
Market share of cell technologies

Photon International March 2011

other
CIS
CdTe
a-Si/μc-Si
ribbon c-Si
multi c-Si
mono c-Si
Global PV production

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Global PV production

Raspe in Sun & Wind Energy 10/2010
Poly-silicon production partly with local electricity (hydropower or CHP) instead of country mix.
Energy payback time
Energy payback time

- mono: 2008 (14.4%)
- multi: 2009 (14.1%)
- CdTe: 2010 (11.3%)
- µm-Si: 2012e (10.0%)
- CIGS: 2010 (11.0%)

2010 estimate

1700 kWh/m².yr irradiation on optimally-inclined modules

- take back & recycling
- inverter
- mounting + cabling
- framing
- laminate
- cell
- ingot/crystal + wafer
- Si feedstock

poly-Si: hydropower
wafer/cell/module: UCTE electricity
%: total area module efficiencies
ecoinvent 2.2 database

26 August 2011
mariska@smartgreenscans.nl
Energy payback time

PV module installed at 1700 kWh/m².year irradiation on optimally inclined plane

sensitivity to type of electricity for electricity consumption in poly-Si, wafer, cell and module production

poly-Si / wafer-cell-module
ecoinvent 2.2 database
IEA Statistics Electricity 2008
29 August 2011
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Energy payback time

- REC
- LCA by ECN

- Value chain A:
  - poly-Si: FBR, hydro
  - wafers/cells: Norway
  - modules: Singapore

- Value chain B:
  - poly-Si: Siemens/FBR, hydro
  - wafers, cells, modules: Singapore

@ 1700 kWh/m².year

Energy payback time

2-axis tracking CPV system in Catania (Sicily, Italy)
1794 kWh/m².yr direct normal irradiation (DNI) in-plane

Global irradiation in Catania is 1925 kWh/m².year

Soitec (was Concentrix)
CX-M400/S420
25.5%
2011

Amonix
7700
2011

%: total area module efficiencies
Amonix: Fthenakis, Kim
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DNI vs global irradiation

Compare CPV with flat plate PV only for one DNI-GI combination (location)!

30-Year Average of Monthly Solar Radiation, 1961-1990 (U.S.A.)

Global Irradiation south-facing/optimized angle/no tracking kWh/m².year

DNI 2-axis tracker kWh/m².year

Cold Bay (Alaska) mariska@smartgreenscans.nl
Dagget (California)
Catania (Sicily, Italy)

1794 1925

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Carbon footprint

= life-cycle CO$_2$-equivalent emissions

now with module degradation included: 20% / 30 years
Carbon footprint

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

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2012e</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>mono</td>
<td>14.4%</td>
<td>14.1%</td>
<td>11.3%</td>
<td>10.0%</td>
<td>11.0%</td>
</tr>
<tr>
<td>multi</td>
<td></td>
<td></td>
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</table>

30 years 30 years 30 years 30 years 30 years

Estimate

- takeback & recycling
- inverter
- mounting + cabling
- frame
- laminate
- cell
- wafer
- silicon feedstock

poly-Si: hydropower
wafer/cell/module: UCTE electricity
degradation: 20%/30 years
ecoinvent 2.2 database

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Carbon Footprint

- **REC**
- **LCA by ECN**

**Value chain A:**
- poly-Si: FBR, hydro
- wafers/cells: Norway
- modules: Singapore

**Value chain B:**
- poly-Si: Siemens/FBR, hydro
- wafers, cells, modules: Singapore

@ 1700 kWh/m².year

Carbon footprint electricity

Data Sources:
- Viebahn 2008 (hard coal)
- ecoinvent 2.2 (wind, nuclear)
- this study (PV)
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Carbon footprint electricity

**Top production locations**

**High uncertainty**

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Carbon footprint

PV module installed at 1700 kWh/m².year irradiation on optimally inclined plane

sensitivity to type of electricity for electricity consumption in poly-Si, wafer, cell and module production

poly-Si / wafer-cell-module
module degradation: 20%/30 years
ecoinvent 2.2 database
IEA Statistics Electricity 2008

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Installation location

Comparison of yearly global irradiation incident on optimally-inclined photovoltaic modules in 25 European Union member countries and 5 candidate countries

The country averages are connected by the red line. The minima/maxima in each country are shown as dashed lines, while the boxes show the range in which 90% of built-up areas in the country fit.

"The" carbon footprint of multi c-Si PV system

Photovoltaic Solar Electricity Potential in European Countries

<table>
<thead>
<tr>
<th>g CO₂-eq/kWh</th>
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<tbody>
<tr>
<td>98</td>
</tr>
<tr>
<td>73</td>
</tr>
<tr>
<td>59</td>
</tr>
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<td>49</td>
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# Data & Assumptions

<table>
<thead>
<tr>
<th>DATA SOURCES</th>
<th>mono</th>
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<th>μm-Si</th>
<th>CdTe</th>
<th>CIS</th>
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<tbody>
<tr>
<td>poly-silicon</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ingot/wafer</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cell</td>
<td>Schottler2009</td>
<td>2 + Schottler2009</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>module</td>
<td>same as multi</td>
<td>2</td>
<td>Oerlikon Solar THINFAB</td>
<td>First Solar DE, US, MY</td>
<td>DE</td>
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<tr>
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<tr>
<td>inverter</td>
<td>ecoinvent 2.2</td>
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<table>
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<th>KEY PARAMETERS</th>
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<th>μm-Si</th>
<th>CdTe</th>
<th>CIS</th>
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<tr>
<td>wafer thickness</td>
<td>180 μm</td>
<td>180 μm</td>
<td></td>
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<tr>
<td>cell size</td>
<td>156 mm x 156 mm</td>
<td>156 mm x 156 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>module size</td>
<td>6 x 10 cells</td>
<td>6 x 10 cells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>glass</td>
<td>single</td>
<td>single</td>
<td>double</td>
<td>double</td>
<td>double</td>
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<tr>
<td>EVA or PVB</td>
<td>EVA</td>
<td>EVA</td>
<td>EVA</td>
<td>EVA</td>
<td>PVB</td>
</tr>
<tr>
<td>frame</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
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<tr>
<td>mounting on -roof</td>
<td>Schletter</td>
<td>Schletter</td>
<td>fiX</td>
<td>Schletter (cSi)</td>
<td>Schletter (cSi)</td>
</tr>
<tr>
<td>inverter</td>
<td>2.5 kW</td>
<td>2.5 kW</td>
<td>2.5 kW</td>
<td>2.5 kW</td>
<td>2.5 kW</td>
</tr>
<tr>
<td>module recycling</td>
<td>via glass recycler</td>
<td>via glass recycler</td>
<td>excl. filtercake recycling</td>
<td>same as CdTe</td>
<td></td>
</tr>
<tr>
<td>average total module eff</td>
<td>14.4%</td>
<td>14.1%</td>
<td>10.0%</td>
<td>11.3%</td>
<td>11.0%</td>
</tr>
<tr>
<td>degradation (%/year)</td>
<td>0.67</td>
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<tr>
<td>performance ratio</td>
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<td>0.75</td>
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Data request

- Update renewable energy data in GEMIS:
  - Project financed by BMU (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
  - draft/final report ready 31 October/November 2011

- Update ecoinvent database:
  - deadline data delivery to ecoinvent 31 December 2011

- Excel data template is available on request (english & chinese)
Conclusions

Energy payback time & environmental impacts / kWh produced depend on production and installation location.

For commercial roof-top PV system with Siemens poly-Si from hydropower and wafer/cell/module from UCTE electricity, installed in Southern Europe (1700 kWh/m².year)

- Energy payback time \( \sim 0.8-1.7 \) years
- Carbon footprint \( \sim 19-34 \) g CO\(_2\)-eq/kWh

More data needed to reduce uncertainty in analysis & make it more representative

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Acknowledgements:
  BMU
  Certisolis
  First Solar

Further info:
  http://smartgreenscans.nl/
  - download this presentation
  - free energy payback time tool thin film PV module

IEA PVPS Task 12
EPIA Sustainability Working Group
Thank you!

Tropical Aquarium Hagenbeck in Hamburg