Life cycle assessment of amorphous and micromorphous PV modules

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Introduction and goal of the study

Up to date life cycle inventories of emerging PV technologies manufactured in Switzerland, Europe and China have been established. Two studies on life cycle assessment of different producers of amorphous thin film plastic and micromorphous PV modules have been accomplished in fall 2012.

The first producer, which provided information on the production of the modules, is Flexcell, a Swiss producer of amorphous thin film plastic PV modules. Flexcell's technology makes it possible to use a thin, flexible plastic substrate instead of glass for the PV modules.

The second producer is tel.solar formerly known as Oerlikon Solar, a producer of production facilities for the production of amorphous PV modules. They provided information on their production facility called ThinFab, which produces micromorphous (µC-Si) solar modules. In addition, the non-renewable energy payback time was analysed for µC-Si solar modules made by the ThinFab.

Micromorphous solar modules (ThinFab, tel.solar/Oerlikon Solar)

Fig. 1 shows the Carbon Footprint of electricity from photovoltaic slanted roof installations using modules produces in the ThinFab in China and from photovoltaic slanted roof installations using various different technologies in Switzerland, assessed with IPCC GWP 2007. The thin-film modules produced in China and Europe are coloured in dark and light green. The other module technologies manufactured in Europe are coloured in yellow.

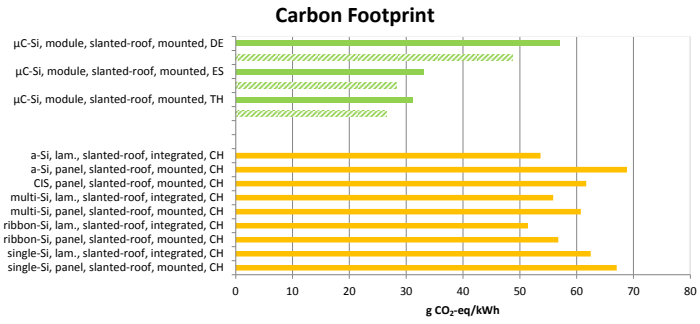

Fig. 1: Carbon Footprint of electricity from photovoltaic slanted-roof installations using modules produced in the "ThinFab" in China and from photovoltaic slanted roof installations using various different technologies in Switzerland, assessed with IPCC GWP 2007 Green: thin-film modules produced in China; Light green: thin-film modules produced in Europe; Yellow: other module technologies manufactured in Europe, operated in Switzerland;
Electricity yield: Germany: 809 kWh/kWp; Spain: 1394 kWh/kWp; Thailand: 1481 kWh/kWp; plants with other module technologies: 922 kWh/kWp (Swiss average).

Amorphous thin film plastic PV modules (Flexcell)

Fig. 2 shows the carbon footprint of photovoltaic flat roof installations using Flexcell modules compared to slanted roof installations of various other technologies in Switzerland.

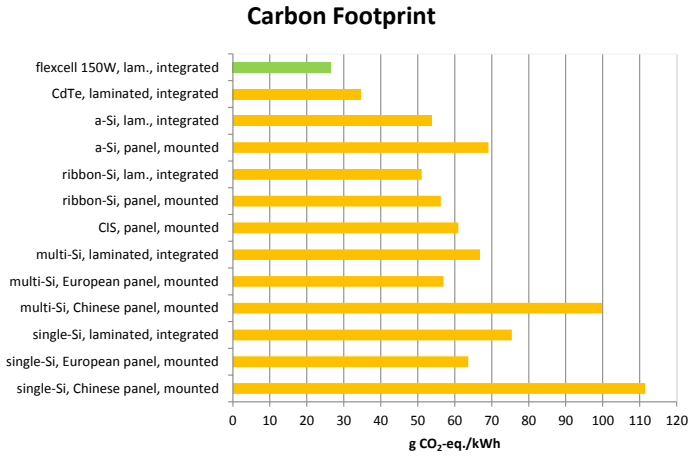

Fig. 2: Carbon Footprint of electricity from photovoltaic flat roof installations using Flexcell modules and slanted roof installations with various other technologies in Switzerland. Flexcell modules are in green; other module technologies in yellow. Electricity yield: 1'050 kWh/kWp of Flexcell PV plants; 922 kWh/kWp of plants with other module technology.

Energy payback time

$$Energy\ Payback\ Time = \frac{E_{mat} + E_{manuf} + E_{trans} + E_{inst} + E_{EOL}}{\frac{E_{agen}}{\eta_G} + E_{O\&M}}$$

E_{mat}:	Primary energy demand to produce materials comprising PV system
E_{manuf}:	Primary energy demand to manufacture PV system
E_{trans}:	Primary energy demand to transport materials used during the life cycle
E_{inst}:	Primary energy demand to install the system
E_{EOL}:	Primary energy demand for end-of-life management
E_{agen}:	Annual electricity generation
$E_{O\&M}$:	Annual energy demand for operation and maintenance
η_G:	Grid efficiency, average primary energy to electricity conversion efficiency at the demand side

The latest technology developments in silicon based photovoltaics are analysed in view of their effect on the energy payback time and the environmental performance of PV electricity. The **energy payback times** of amorphous flexible and micromorphous PV electricity are close to or below **1 year**.

Conclusions

- Amorphous **thin film plastic modules** are among the **most favourable** photovoltaic technologies due to their low weight, the small amount of materials required, the production with hydropower and the avoidance of additional mounting structure
- The most important factors influencing the carbon footprint and the environmental impacts of the µC-Si solar modules are the electricity consumption during the production, the glass input, the transport services as well as the natural gas consumption
- Installations under **optimal conditions** and in regions with comparatively higher solar irradiation lead to higher electricity yields and consequently to the **reduction of the environmental impacts** per kWh electricity produced.
- Environmental impacts of photovoltaic electricity differ significantly between **different PV technologies**.
- Environmental impacts of photovoltaic electricity differ between production chains in **China versus Europe.**
- **Electricity mix** (quality) and the **amount of electricity** (quantity) consumed in the photovoltaic production chain are environmental **key factors.**
- PV manufacturers may further improve the environmental performance of PV electricity by **reducing** their **energy consumption** and using **electricity from renewables**.

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