Life cycle assessment of photovoltaic systems

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Solar energy is one of several energy sources related to renewable energy generation and is thus beneficial for the environment in comparison to fossil fueled energy generating plants. There is unfortunately a drawback to every product, service and process, namely their environmental footprint during the production, operation and disposal phases. Even renewable energy sources require energy and resources which in turn leave an impact on the environment.

The study "*Life cycle assessment of photovoltaic systems- Analysis of environmental impact from the production of photovoltaic systems including solar panels produced by Gaia Solar*", in which life cycle assessment was used, identified the solar cells as having the highest environmental impact of the whole photovoltaic system (solar energy generating system).

The study shows that using thinner solar cells reduced the greenhouse gas emissions by 17% and the remaining environmental impact categories from 0,11 to 21,11% as seen in table 1. This is an astonishing result since the solar cells are the second lowest part, by weight, of all other parts included in the photovoltaic system such as glass, aluminum structure, cables etc., and yet contributes to a significant reduction of almost all environmental impact categories. The study includes several environmental impact categories besides the greenhouse gas category (also referred to as global warming potential), in order to widen the environmental footprint spectra.

Table 1: Results from the environmental impact categories including the reductions in percent (%).

Environmental Impact Categories	Results	Reduction in % due to thinner solar cells	Reduction in % due to extended lifetime
Global Warming Potential	5,30E-02 kg-CO_2/kWh	16,45	23
Acidification Potential	2,40E-04 Kg-SO_2/kWh	11,78	23
Eutrophication Potential	1,36E-04 Kg-NO_x/kWh	13,87	23
Ozone depletion potential	2,25E-08 Kg - CFC11/ kWh	7,46	23
Human Toxicity Potential	8,60E-02 Kg-1,4DCB/ kWh	1,18	23
Ionizing Radiation Potantial	1,50E-10 DALY/ kWh	2,45	23
Water	1,06E-03 m^3/kWh	0,11	23
Land	2,30E-03 m^2a/ kWh	9,23	23
Resources	9,51E-03 kg/kWh	14,34	23
Cumulative Energy Demand	3,10E-01 kWh/ kWh	15,98	23
Renewable Energy	4,10E-02 kWh/ kWh	21,11	23
Non-renewable Energy	2,70E-01 kWh/ kWh	15,17	23

The study also shows a case for extended life expectancy of the photovoltaic system from 30 to 40 years in order to determine the reduction in results and encourage producers to strive for manufacturing of longer lasting photovoltaic systems. All environmental impact categories are reduced by 23% when the lifetime was extended with 10 years.

Another parameter of importance for the producers of photovoltaic systems is the energy payback time (EPBT), which is shown in the study to be 2,5 years. Energy payback time is the time it takes for the photovoltaic system to generate the same amount of energy that it required for its production, use and deposition phases.

When renewable energy sources are installed, they replace the energy sources that should otherwise produce electricity at that location. Since the study is conducted for Danish conditions, the replaced electricity corresponds to the electricity mix of Denmark. Most of the Danish electricity is generated by fossil fueled plants, contributing to increased greenhouse emissions and thus global warming. The amount of carbon dioxide (CO_2) that is spared due to the installation of a photovoltaic system, for the Danish electricity mix, is 44 700 kg CO_2. This reduction is achieved by a 3 kWp photovoltaic system during 30 years operation lifetime for Danish conditions.

Life Cycle Assessment (LCA), which is the basis for the study, is a popular and useful method to determine and describe the environmental footprint of a product, service or/and process. It identifies the environmental impacts from the very beginning to the end. This method is called “from cradle to grave” and includes all inflows and outflows of energy, resources and emissions during the whole lifetime of the photovoltaic system.

Data was obtained from Ecoinvent, which is an online database for LCA for a wide variety of products and services. Ecoinvent as an open source LCA database has high data quality due to transparency and professional data gathering. The only downside with the data is that it is quite old, originating mainly from 2005 to 2006. The technological improvement in the photovoltaic industry from that time period until present (2014) is thus unaccounted for. There is a need for new data in order to reflect an “up to date” case for the photovoltaic system which in turn would make studies more accurate.

Nevertheless, the obtained results, based on Ecoinvent data, are still representative to a large extent but can be seen as a worst case scenario. With highest certainty the technological evolution within the solar power field has improved since that time, leading to lower emissions, better production processes and thus overall lowering the environmental footprint from the production of a photovoltaic system. An ideal case would be if all the suppliers to Gaia Solar established internal LCA’s in order to ensure the highest representation for this study, instead of gathering data from databases, based on other production facilities.

This study provides insight for the company of how the lifecycle of their product looks like. Based on the results, the company can prioritize correct aspects of the system if potential improvement strategies are implemented. This study should be combined with other studies on other aspects such as financial, social, etc. when it comes to strategic decision making. Otherwise the reduction of the environmental impact can be costly and thus not beneficial for the company.

There is on the other hand possibility to identify “win-win” solutions where reduction of a material can lead to lower environmental impact and also lower cost for the company.

If the suggestions presented in the study are implemented by reducing the thickness of solar cells further and by extending the lifetime of the photovoltaic systems, it will lead to an overall lowering of the environmental footprint from the photovoltaic systems and a faster energy payback time.