WASTE PREVENTION IN THE PHOTOVOLTAIC SECTOR BY INDUSTRIAL SYMBIOSIS

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ABSTRACT

The FP7-project ZeroWIN wants to find innovative approaches and effective strategies for the prevention of waste in industrial networks based on industrial symbiosis. The paper presents the results for a photovoltaic case study and describes the implemented measures as well as their environmental impacts. Measures related to industrial symbiosis cover e.g. the use of second hand or off-spec PV modules or the replacement of the steel structure by wooden components which also could be by-products from other industries. Beside other measures the focus was laid on the design for easier dismantling and therefore replacement of components which fail in the total life time of a PV system.

INTRODUCTION

One well-known and promising possibility to reduce environmental effects within industry is industrial symbiosis. Different approaches are more or less applied and especially the sharing of services or utility like the usage of the waste steam from a waste incinerator in neighboring plants where the heat is used as an input. Within the framework of the EU-FP7 program, the project ‘ZeroWIN’ wants to concentrate on the usage of by-products. New and innovative approaches and strategies for the prevention of waste in industries based on industrial symbiosis have been examined and developed.

Network activities between traditionally separated sectors shall be established to enable an exchange of by-products and materials in such way, that they are not disposed as waste, but continued to be used as quality assured material in other industrial branches. Case studies concerning construction, electronic devices and photovoltaic systems play an important role within the project, as the feasibility and sustainable performance can be proved or improved, respectively.

Within this paper the results for a photovoltaic case study will be presented. Study objects was an off-grid photovoltaic system

The photovoltaic sector shows an important development during the last years not least because of his growing very fast growing. The world-wide photovoltaic market doubled in 2010. This is due to a major increase in Europe with a total of over 29 GW cumulative installed capacity in 2010. It is leading with 70% of the total world-wide capacity (Jäger-Waldau et al., 2011).

Compared to other renewable energy technologies photovoltaic plants show though environmental burdens in the production phase. Pehnt (2006) compared PV with electricity systems of wind, hydropower, geothermal and bioenergy in an LCA. The results of the LCA showed that the cumulative energy demand (CED) and the global warming potential (GWP) revealed the most burdens in the photovoltaic system. It is mainly due to the very energy intensive process of the PV panel manufacturing as mentioned in various publications (Alsema and Wild-Scholten, 2004) and (Raugei et al., 2007). The metals which are used in the Balance of the System (BOS) are also influencing the LCA significantly. Jungbluth et al. (2008) showed for the BOS a share of 30 to 50% of the burdens depending on the environmental indicator.

Improvement options proposed in the literature therefore also focus mainly on design recommendations in the production technology of PV panels (c.f. Alsema and Wild-Scholten, 2004, Raugei and Frankl, 2009). Also for the BOS proposals for optimization can be found.

The goal of the study was to show improvement potentials of a pilot scenarios compared to the baseline through waste prevention strategies. Therefore the focus the study was not technical improvement but to find out possibilities for e.g. design improvements or optimization of the installation and decommissioning phase options. How the life time can be increased and which other options for material reduction or reuse strategies for a better environmental performance exist, were focuses of this study.

In literature the use of secondary materials is mentioned by Alsema and Wild-Scholten (2004). In the EOL phase the reuse of silicium or the reuse of aluminium from the BOS (Sander et al., 2007) were found. In the use phase life prolongations through increased life time of moudles and inverters was furthermore mentioned (Alsema and Wild-Scholten, 2004).

Additionally an outstanding invention to increase the improvement potential was the development of a power conditioning equipment with special conditions. The development of this prototype was carried out within the ZeroWIN project. The pilot scenarios have been implemented in practice in Barcelona (Spain) in the year 2013 within the same project.

MATERIALS AND METHOD

The environmental assessment was carried out in three steps. Firstly a so called baseline assessment was elaborated to analyse the hotspots of a PV system. Along with the identification of hotspots waste prevention strategies were developed in a consortium to improve the environmental performance. In a second step the improvement strategies were assessed to show the effects in fictial pilot scenarios (mid-term assessment). Finally pilot scenarios were set up and the implemented strategies were analysed in a final assessment. The steps were accompanied with unpublished reports (available only for the project's consortium) and several discussions in partner meetings.

For the assessment LCA methodology was used based on ISO 14040 (International Standard Organisation (ISO), 2006) and 14044 ((ISO), 2006). It is based on a consequential approach on a fictional baseline. The baseline is based on standard technology without improvements on waste prevention strategies which were developed in the course of the project ZeroWIN. The modelling was carried out with GaBi 5 (AG, 2012). In addition to databases of GaBi 5, databases from Ecoinvent (Frischknecht and Jungbluth, 2007) were consulted.

The environmental assessment is based on the CML 2001 methodology (Guinée et al., 2002) which operates with midpoint indicators. Environmental categories were chosen within a workpackage in the project according to the feasibility and the relevance in the involved sectors. The following categories were determined:

- Acidification Potential (AP) [kg SO_2-Equiv.]
- Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]
- Human Toxicity Potential (HTP) [kg DCB-Equiv.]
- Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]
- Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]

The functional unit has been defined as the service of generating 53,130 kWh of an average PV plant with an installation of 2.76 kWp in a life time of 20 years in a fictional European location. The study covers a whole PV system from production, design, installation and decommissioning of the PV plant and its maintenance.

RESULTS AND DISCUSSION

Figure 1 shows as result for the Baseline Assessment the distribution of environmental indicators through components and life cycle stages of a grid-connected PV system. Benefits occur in the decommissioning phase as recycling is accounted in this life cycle stage. Recycling of certain materials like copper from cables or steel from the steel structure demand benefits to the environment. The operation of the PV module, meaning the production of energy in the system, is not considered as a benefit as the use phase is out of the system boundaries. The total energy output is considered in the functional unit of one kWh.

It can be noticed that, as already shown in literature, throughout all environmental categories the production process of PV modules has the most contributions, followed by the steel structure and the installation of the PV system where further materials are used.

Based on the outcome of the baseline assessment and the possible options for real implementation measures for the optimization of the PV system were defined. Nine measures were implemented in the final pilot PV system. They included an increase of the performance ratio as well as the life time and the change of batteries. The use of off-spec modules, reused structure, reused cabinet for battery system and cabling where measures following as far as possible the idea of industrial symbiosis and industrial networks. Also a smart grid battery system is introduced.

Figure 2 shows the relative results of selected environmental category. The benefits, meaning the decreased emissions from the baseline, are shown for each improvement measure.

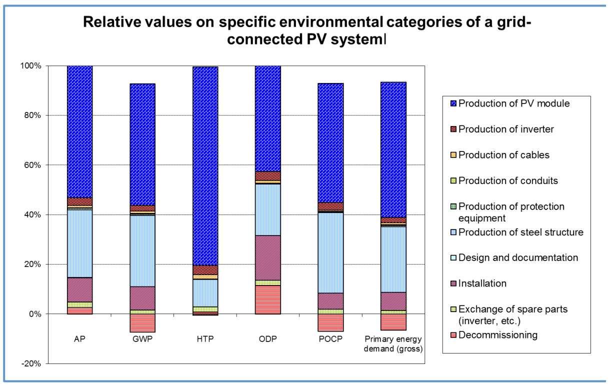

Figure 1. Relative values on selected environmental categories (Baseline)

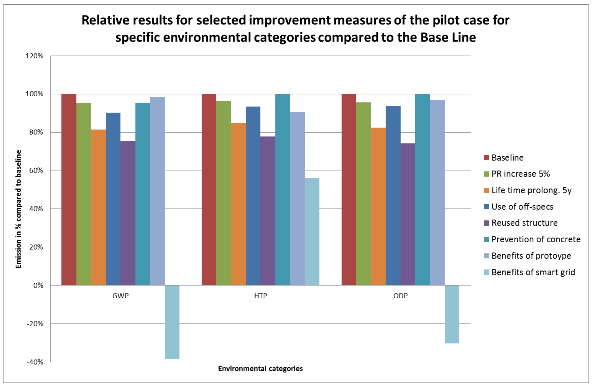

Figure 2. Relative results for improvement measures compared to baseline)

The Reuse of the structure turned out to have a large impact compared to the baseline system (Reduction potential of 24.6%). In the final pilot PV system the complete array structure for supporting the PV modules is reused from construction and demolition sector. Other measures like the life time prolongation and the use of off-specs also turned out to have a relevant reduction potential (18.5 and 9.7 %). The overall result for the reduction potential compared to the baseline under consideration of all implemented measures (except the benefits of saved energy in the smart grid) is about 36 % for the GWP. If the benefits of the smart grid system are considered, the total environmental performance switched to benefits to the environment.

CONCLUSIONS

The paper shows the environmental effects of tested measures concerning an off-grid photovoltaic system. In general it turned out that if a maximum of measures is implemented within the ZeroWIN project set targets for a decrease of 30% greenhouse gas emissions as well as a total of 70% of overall re-use and recycling of waste can be achieved.

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