Executive Summary

Life Cycle Assessment (LCA) screening of the Maltha recycling process for Si-PV modules

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Introduction

Several studies have proven that PV power generation is an environmentally friendly alternative to conventional energy production technologies using fossil fuels. However, due to lacking data recent LCA studies are mainly focused on the production and utilization of PV power systems. The end-of-life phase has not been evaluated in detail. Since the further treatment and recycling of PV modules could significantly influence the environmental profile of PV modules, and for avoiding a shift of burdens throughout the life cycle phases, the potential environmental impacts during the whole PV module life cycle have to be assessed. Based on life cycle thinking, the method of life cycle assessment (LCA) is a proven and in science and industry accepted tool for evaluating the environmental performance of products and systems. In addition, to ensure a sustainable supply of required materials in PV module production, the recycling of PV modules, and hence closing the loop of valuable materials could be from major importance for future developments. To answer these questions, an environmental assessment of the PV module recycling process applied at Maltha Recycling (Lommel) has been carried out by using a screening life cycle assessment. Goal of the study is the environmental assessment of the current recycling process of silicon based PV modules applied at Maltha Glass recycling in Belgium. The study is conducted in cooperation with PV CYCLE and Maltha Glass Recycling, Lommel, Belgium. The environmental assessment is conducted by a Life Cycle Assessment (LCA) screening using LCA software GaBi 5[1].

Based on the results of the study the environmental impacts due to the processing of spent Si PV modules as well as the relative share of the recycling to the whole life cycle of mono and multi crystalline PV modules are evaluated. In addition, the potential benefits from the recycling of recovered valuable materials from spent Si-PV modules are identified.

Goal, scope and system boundaries

The functional unit of the LCA screening is the processing of one metric ton of Si-PV module waste processed in the glass line. The system boundary includes all relevant processes on the recycling site, e. g. the provision of required energies, transports as well as the further treatments of outgoing valuable materials and wastes. Direct emissions (e.g. dust emissions on the recycling site) are not accounted for in the recycling processes. The location of the recycling plant is Belgium. All datasets concerning energy production and end-of-life processes like material recycling or disposal on landfill are chosen to match country representative boundary conditions. To identify the potential environmental benefits of the module recycling, environmental credits have been accounted for the recycling of valuable materials (aluminium frames, copper cables, glass cullet) and thermal recovery from plastic wastes. To this, all caused expenses and emissions related to the whole recycling process of materials, e.g. for the re-melting, as these are applied to produce the recycled materials are accounted for. In terms of waste incineration processes the recovered energy from materials (e.g. plastics) is considered as credit by substituting energy production from conventional energy production. Since the laminate from broken cells and polymer foil are currently stored and not further processed, the recycling of these materials is not accounted for.

Considered recycling processes

The recycling of spent silicon PV modules is based on the processes of a flat glass recycling line. In the first step, aluminium frames and junction boxes are removed in a manual process. The prepared PV module waste is then fed into a shredder by using a wheel loader. The shred PV modules enter the glass recycling line which includes a manual pre-sorting, crushing of the laminates, separation and extraction of materials. The output materials of the glass recycling line are separated according to their material fractions like ferro metals, plastics, PV-cell/polymer foil laminate and glass cullet. The glass recycling line mainly requires electricity for running the processes (shredder, conveyors, hammer mill, compressor). The required electric power is provided by the local power grid and an on-site power PV generation. The PV power plant provides around 50% of the consumed electrical power. Furthermore small amounts of organic foam soap are used to reduce dust generation in the crushing processes.

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1 GaBi 5: Software-system and databases for Life Cycle Engineering, University of Stuttgart, Chair of Building Physics in cooperation with PE International Stuttgart: Echterdingen; 2011

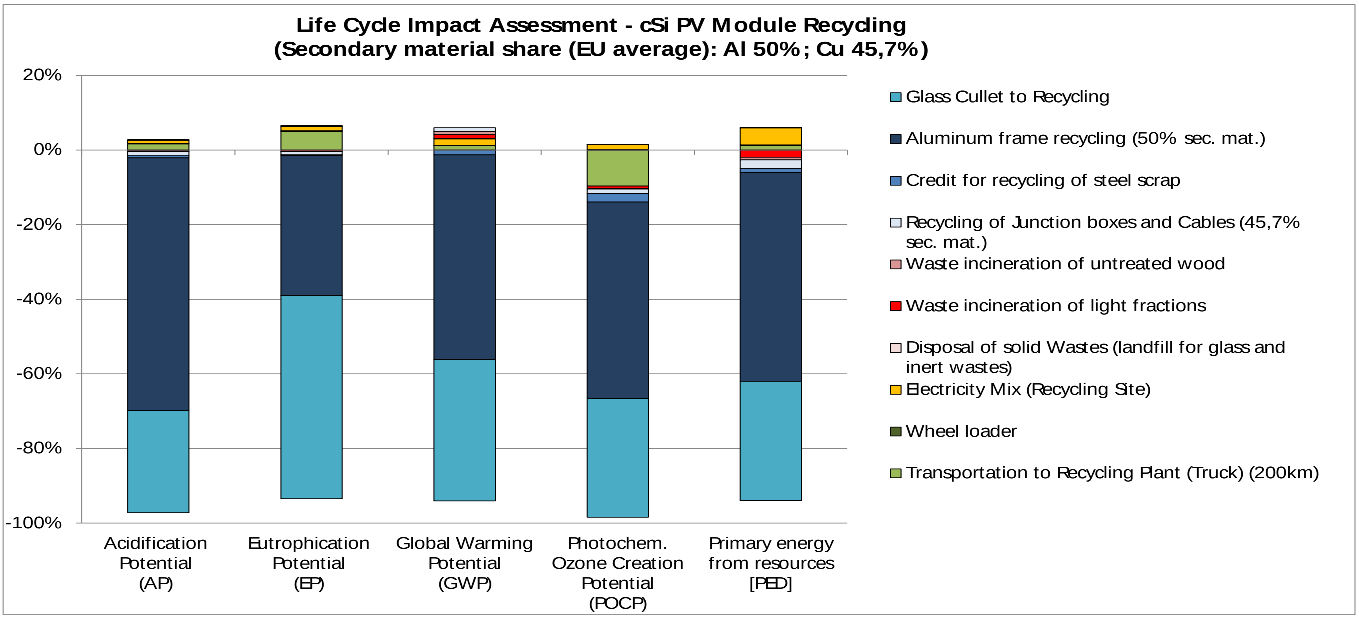

Figure: Life cycle impact assessment (LCIA) results of the recycling process of Si-PV modules (relative shares)

Results

Based on the defined boundary conditions and collected data, the results show that the PV module recycling process as applied at Maltha Recycling has the potential to contribute to a further reduction of the environmental profile of the life cycle of crystalline silicon PV modules (around 4% -11% depending on the module technology and considered impact category).

The main impacts of the recycling processes at Maltha Recycling are related to the transports of spent modules to the recycling site and the electricity demand for running the processes. The Maltha recycling plant is equipped with an on-site PV power plant, which provides around 50% of the electricity demand at Maltha recycling. This leads to a significant reduction of the environmental profile of the used electricity mix.

The recovered valuable materials, like glass cullet, aluminium frames and copper wires are sent to respective recyclers. The recycling credits given for the substitution of primary materials and thermal recovery of plastic wastes account significantly outweigh the caused impacts of the processing of spent modules. Scaled to the mass of a cSi-PV module with a mass from around 22,4 kg/module, the application of the presented recycling process leads to a reduction of the environmental profile of the module life cycle from around 16kg CO_2-equiv. and around 190 MJ of primary energy from non-renewable resources. In other words, recycling 1t of silicon based PV modules saves approx. 800 kg of CO_2-equiv. and up to 1.200 kg of CO_2-equiv. in the case that the module is 100% manufactured from primary materials.

The results show, that especially the recycling of aluminium frames and glass cullet lead to a significant reduction of the environmental profile of the recycling process, whereas the assumed secondary material content of aluminium frames plays a decisive role. Since the bandwidth of recycling credits is calculated according to the primary material content of aluminium frames and copper wires, different cases with varying secondary material shares have been investigated. For the evaluation of the reference case, a secondary material share of 50% for the aluminium frames and 45,7% for the copper wires has been chosen which stated as average for the European material production mix (see ECI[2], EAA[3])

An additional scenario investigated the significance of varying transport distances from the collection points to the recycling site. To this, distances from 50 to 500km (200km for the reference case) were evaluated. The results show, that higher transport distances would mainly influence the environmental profile of the whole PV module recycling in the eutrophication and photochem. ozone creation potential (POCP). For all other considered impact categories only minor changes have been observed.

Need for further research

At the current state, there is no suitable recycling process for separating from broken cells from the lamination foil available. Since the broken cells are valuable for the production of new PV cells, and hence for closing the material loop, the investigation of potential recycling processes as well as their contribution to the environmental profile of the PV module recycling should be addressed in future studies.

2 Deutsches Kupferinstitut, Berufsverband e.V. 22.09.2011; www.eurocopper.org/doc/uploaded/File/ICSG%20Recyclingstudie.pdf

3 European Aluminium Association (EAA): Aluminium Recycling in Europe: The Road to High Quality Products, www.world-aluminium.org/cache/fl0000217.pdf