Industrial Ecology Open Online Course (IEooc)

Part II Methods

Methods part 4 (Life cycle assessment)

http://www.teaching.industrialecology.uni-freiburg.de/

IEooc_Methods4_Exercise2: Life cycle impacts of a PV module

Goal: *Practice life cycle thinking and quantitative systems analysis; work with system definitions; apply life cycle thinking to solar power by conducting a quick life cycle assessment (LCA) of PV module production*

Photovoltaics is a key strategy to supply low-carbon electricity. The production, use, and recycling of PV modules, however, comes at an ecological cost as materials and energy have to be used during their production, dismantling, and recycling. This exercise shall illustrate the importance of systems thinking when assessing the overall impacts of renewable energy technologies.

Research question: What are the supply chain impacts of state-of-the art PV modules?

The following methods are to be applied: Life cycle assessment (Matthews et al., 2015).

Data and data formatting: The accompanying excel sheet 'IEooc_Methods4_Exercise2_LifeCycle_Data.xlsx' contains process inventory data and life cycle inventories extracted from the life cycle database ecoinvent (Ecoinvent Centre, 2014). For the LCA calculations, the system definition in Figure 1 should be used. For the processes 1, 6, and 7, unit process inventories are given. Unit process inventories are descriptions of economic processes for which the inputs from the economy and from nature as well as emissions to nature and waste generation are given. All flows are normalized for a (usually small) unit of main output, e.g., 1 m^2 of PV modules or 1 m^2 of SI wafer. For all other processes (those with no inflows in Figure 1), the life cycle inventories (LCI) are given. The life cycle inventories are the emissions to nature of the complete supply chain of the different products. We focus on LCIs for material production and energy supply to keep the calculations manageable. The functional unit of our study is 1 kWh of electricity generated by the PV module.

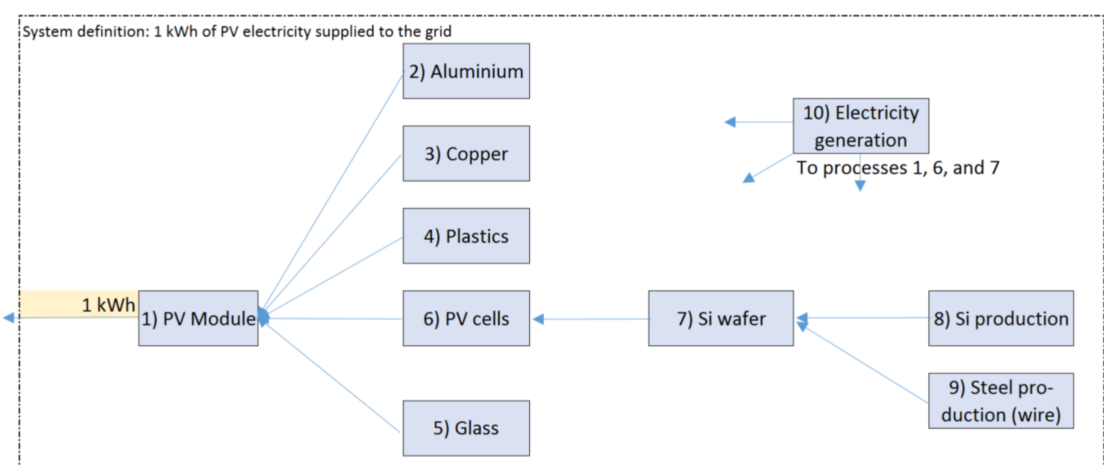

Figure 1: System definition of the simplified supply chain of a PV module.

Each inventory comes with a reference product (the main product to which all other flows are normalized to). Next to the reference product, the process inventories specify the precursor products 'input from techno-sphere', the waste and by-products (we neglect those from our model), the uptake from the environment (natural resources) and the emissions to the different compartments (air, soil, and water).

With the given process and life cycle inventory data the following questions are to be answered:

1) Calculate the reference flow! (how many m^2 of modules are needed to produce 1 kWh?)
2) Construct a model of the supply chain of your reference flow, using the system definition in Figure 1 and the data supplied in the Excel file. Use the generic products 'plastics' and 'glass' as proxies for specialty products such as 'polyethylene terephthalate, granulate, amorphous' and 'solar glass, low-iron'. Calculate the output for each of the ten processes in their reference unit! (e.g., kg for plastics, m^2 for Si wafer). For the baseline case, assume the use of coal-based electricity in processes 1, 6, and 7 (those with direct electricity input).
3) For each of the ten processes in the system, calculate the amount of 'carbon dioxide, fossil' and 'methane, fossil' that is emitted! (Processes 1, 6, and 7 don't have direct emissions of these gases.)
4) Calculate the approximate carbon footprint (in grams of CO_2-equivalents) of 1 kWh of PV electricity, using your results of fossil CO_2 and CH_4. CH_4 emissions can be converted into CO_2 equivalents if a time horizon is specified. For a 100 year time horizon, which is common in impact assessment, the equivalence factor is 25. (https://en.wikipedia.org/wiki/Global_warming_potential)
5) Why is the carbon footprint of PV not zero? What are, according to your calculations, the main contributors to that carbon footprint?
6) How sensitive are your results to a shift from coal-based to solar-based electricity?
7) How well do the results match with the literature values? What could be possible reasons for deviation?

More data and assumptions: Let us assume that the module has an efficiency of 100 Watts (peak) per m^2, that there are 1000 sunshine hours per year, and that the module lifetime is 25 years. Emissions from the use phase and from recycling are not considered.

References:

Ecoinvent Centre, 2014. ecoinvent Version 3 [WWW Document]. URL http://www.ecoinvent.org/database/ecoinvent-version-3/ (accessed 5.10.14).

Matthews, H.S., Hendrickson, C.T., Matthews, D.H., 2015. Life Cycle Assessment: Quantitative Approaches for Decisions that Matter. www.lcatextbook.com/.