With support from:

Madi Eco-Village: Self-sustainable, clean, community-based eco-tourism development in Chitwan District, Nepal

Preliminary Results of LCA Study on Solar Micro Grids

myclimate, Zurich, April 5, 2019

1. Carbon Footprint and Total Environmental Impact of Planned Micro Solar Grid System

The homestays in the four villages of the Madi valley are planned to have a self-sustaining energy supply system. The required power supply will be produced by so-called Solar Micro Grids, which will run the homestay as well as the drinking water distribution and irrigation system. As shown in Figure 1, these systems consist of various components like solar panels, inverters, batteries and charge controllers. The Nepal partners of this REPIC project in the Chitwan District, Sustainable Mountain Architecture and Elite Enterprise Nepal, have designed, calculated and planned the features of what the homestays and the combined Solar Micro Grids should look like. myclimate as a further partner of this project has assessed the CO2-emissions (after the IPCC 2013 method) and total environmental impact (ILCD method) of the Solar Micro Grids in order to show where the large burdens stem from and to elaborate on possible optimization measures.

This study discusses the environmental side of the whole project, which will be combined with the economic and social aspects of sustainable development. The results are of preliminary nature.

The models used here to assess the landfill impact in the end-of-life phase are based on a number of assumptions, due to the fact that the long-term impacts of e.g. batteries and solar panels being dumped in nature have not yet been studied in depth by the world-wide research community.

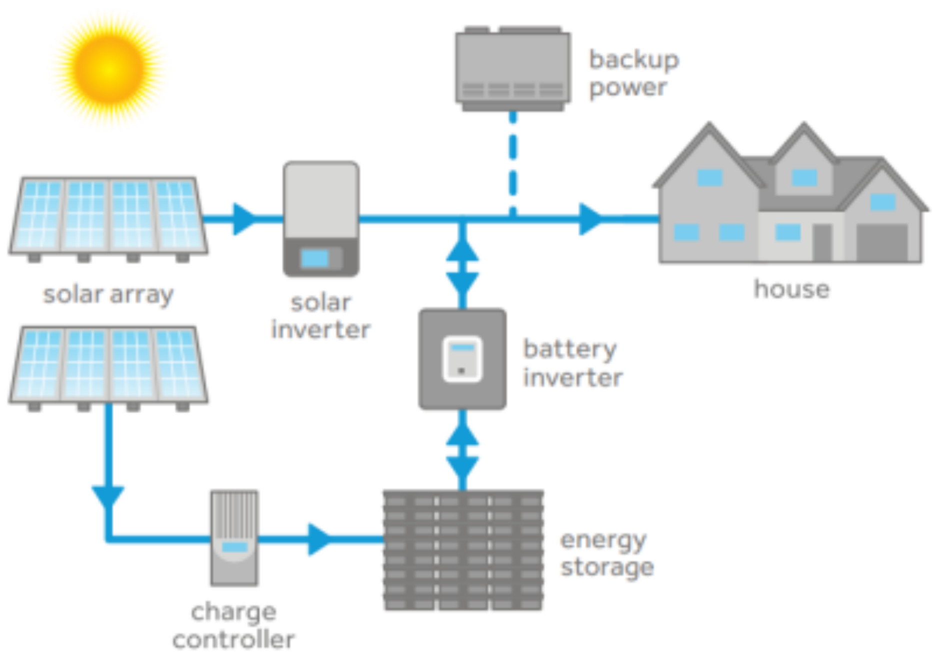


Figure 1: Description of a Solar Micro Grid System in Madi (Source: http://microgridprojects.com)

myclimate has calculated the carbon footprint and total environmental impact of one specific type of planned Solar Micro Grid to be used in all four villages in the Madi valley. The total environmental impact encompasses impacts on acidification, eutrophication, global warming potential, ozone depletion or primary energy use. Elite Enterprises Nepal provided the primary product data for the solar panel, the inverter, the charge controller and the battery. Figure 1 describes the concept of a Solar Micro Grid System schematically; Table 1 lists the features of the Solar Micro Grid looked at.

Table 1: Features of the Solar Micro Grid assessed in this study

Name	**AE Solar / Uni Solar / Easy Solar**
Exact Description	A system with 200 Ah lead acid battery and 320 Wp solar panel polycrystalline
Manufacturing Companies	Solar Panel: AE Solar GmbH, China Battery: Uni Solar, India Inverter: Easy Solar, Netherlands Mounting structure: India Cables: Nepal Cable ties and clips: India
Country of Origin	Germany, Netherlands, India, China, Nepal
Weight	1’120 kg (total installation)
Power Output	Solar Panel 320Wp , Inverter and Charge controller 5000VA/100A, Battery 200Ah
Number of Separate Units	12 batteries, 9 solar panels, 1 solar inverter, 1 mounting structure, cables
Reference	Information by Elite Enterprise Nepal, real data

2. Impact of SHS in Different Life-cycle Phases

The study results shown in this report are of preliminary nature and will be refined during the course of the project based on workshop findings, real-life data from the building sites and expert opinions. However, it can be stated that the highest environmental impact occurs during the production and use-phase, mainly due to the fact that over a system life-time of 25 years, a number of components of the Solar Micro Grid have to be replaced or maintained. Still, this does not mean that the other two phases (transport and end-of-life treatment) can be ignored. One of the main targets of this project is to extend the life-time of the products through improved maintenance and repair services, and to avoid any environmental impact of obsolete products after their first system life during the end-of-life phase. The Solar Micro Grids vary in size and power output depending on the size and location of the individual homestay. This study shows the assessment of the Bankatta Solar Micro Grid.

2.1. Results over Entire Life-Cycle

The following Figure 2 describes the carbon footprint of the planned Solar Micro Grid over the entire life-cycle. The share of the PV panels (production phase) and the battery (spare parts during use-phase) are by far the highest. One Solar Micro Grid (25 y) produces approximately 16.6 tons of CO2e in 25 years.

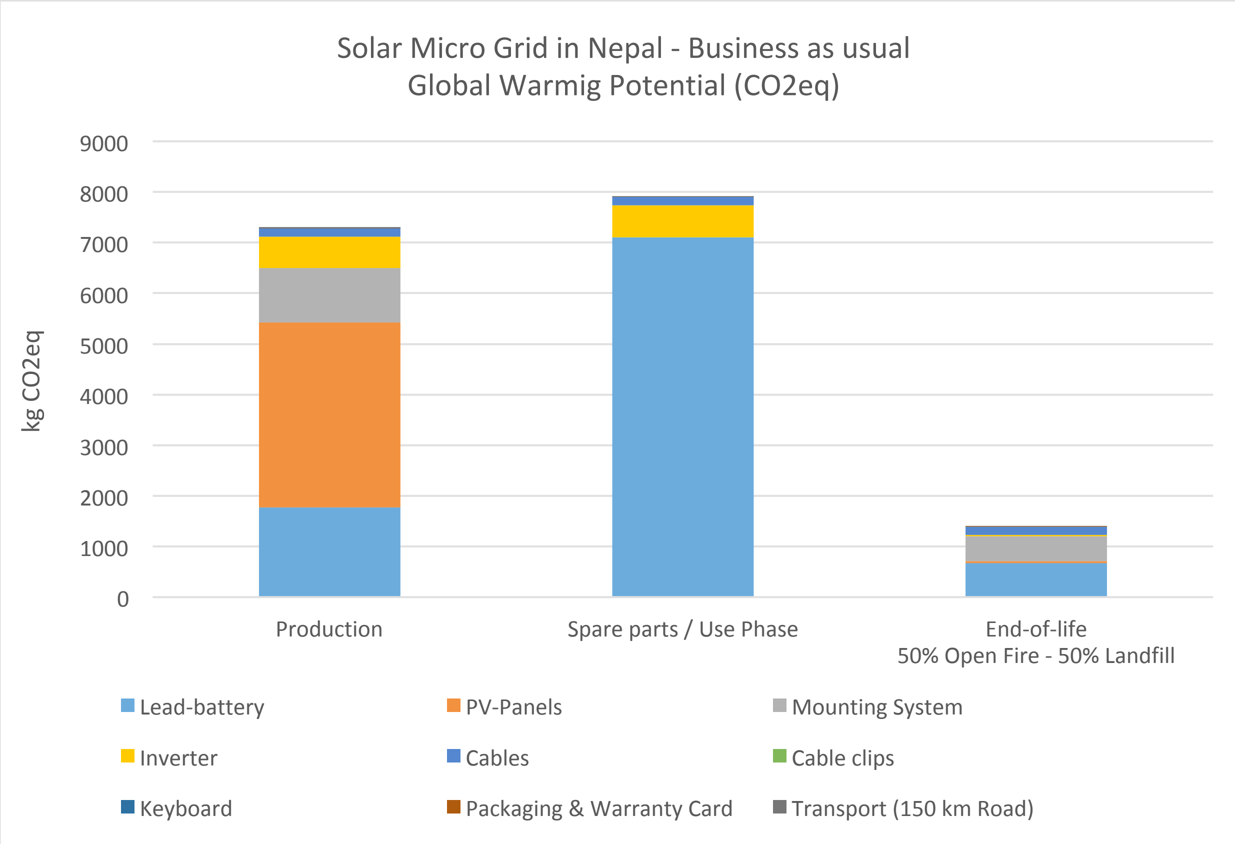


*Figure 2: Entire life-cycle **Carbon Footprint** of a Solar Micro Grid System according to IPCC 2013 method.*

The production phase includes the first set of components for the system, whereas the impact of the use-phase comprises all the spare parts that are needed to replace components or fix the system. The number of spare parts in 25 years are calculated based on information by the manufacturers, on real-life data from Elite Enterprise or estimations by the research team.

The chart clearly shows that a large part of the CO2-emissions is due to the replacement of the battery, which is only to last 5 years on average. The production phase makes up 44% of the total emissions over the entire life-cycle, the use-phase 48% and the end-of-life phase 8%. It has to be stressed that CO2e is only one indicator of the whole spectrum of environmental impacts.

The end-of-life phase is calculated with a 50/50 scenario, namely 50% open fire burning and 50% open dump or landfill. This describes the existing situation in Madi, which is likely to change after the implementation of this project, which emphasizes also the importance of THE smart waste-management component of the project. Chapter 2.5 "End-of-life" discusses the different waste management options and their possible impact.

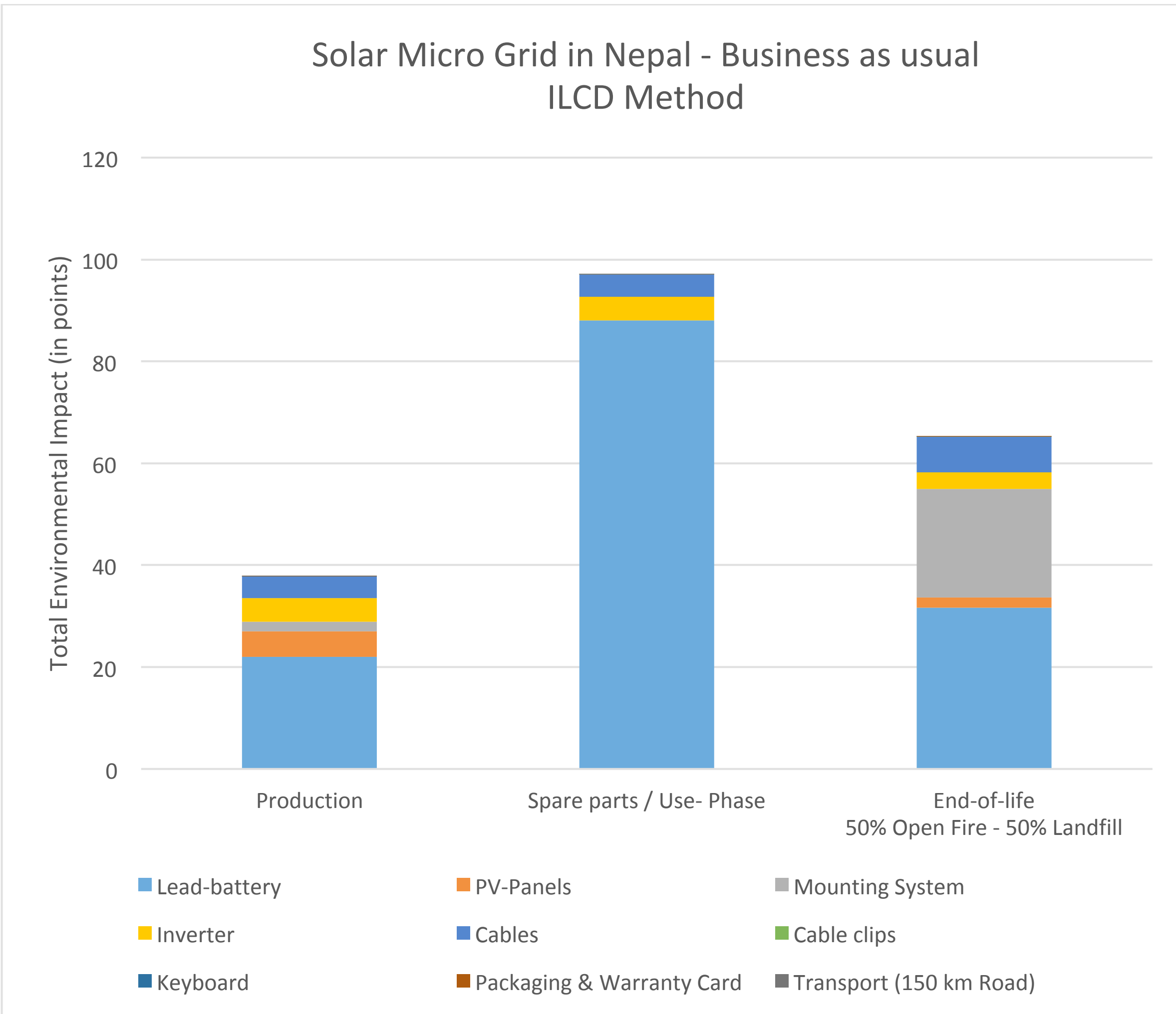


*Figure 3: **Total Environmental Impact** over the entire life-cycle of a Solar Micro Grid System according to ILCD method.*

The calculations for the Total Environmental Impact (Figure 3) indicate slightly different proportions for the Business-as-usual case of the Solar Micro Grid. The production phase is responsible for roughly 19 % of the Total Environmental Impact while the use-phase with all the required spare-parts over a life-time of 25 years has a higher share on the overall emissions (48 % ILCD), and the end-of-life phase results in 33% of the total.

Figure 3 illustrates that the end-of-life phase can have a major impact on the environment. Batteries, solar panels, inverters and cables should not be dumped in a landfill and especially not burnt in an open fire. The transport activities are, compared to the other life-cycle phases of the Solar Micro Grid System, of minor importance.

2.2. Production Phase

The production of the Solar Micro Grid System has been divided into the 6 components battery, PV-panels, mounting system, inverter, cables and the rest. Many of the components are produced in China or India, which means the power-mix consists of a relatively high share of coal power. For that reason, the production phase has a higher contribution to the overall carbon footprint (44%) than to the total environmental impact (19%). The impact of the production phase could therefore be reduced, if a producer with a renewable energy mix could be chosen. The components were assessed on the basis of the processed materials, combined with a production process (injection moulding etc.) where needed.

2.3. Transport Phase

For the transport phase, the possible ship transport from China to India has been neglected for these calculations. This would anyway only apply to the PV panel. An average distance of 150 km transport by lorry was modelled. As both Figures 2 and 3 show, the transport of the components for the Solar Micro Grid do not have a high impact on the overall results regarding greenhouse warming potential and total environmental impact. Nevertheless, it has to be stated that the shorter the transport distance, the smaller the emissions. The truck technology can have another positive impact on the results. Included in the total transport activities are the transports of the spare parts required over the system life-time of 25 years.

2.4. Use-Phase

The Use-Phase of the Solar Micro Grid System is described by the “Business-as-usual” scenario. For this matter, the different components of the Solar Micro Grid have been critically assessed to determine how many of them are used per life-time of the entire system (see Table 2). In case of the “Business as usual” scenario, we assumed that 5 lead-acid batteries are in use over a life-time of 25 years, whereas the solar panels do not have to be replaced over the same time span.

The amount of components in use over the life-time has an immediate impact on the resulting emissions. Figure 2 as well as Figure 3 clearly express that the use-phase has a determining role in the sustainability discussion of the Solar Micro Grids, be it in Nepal or anywhere else in the world.

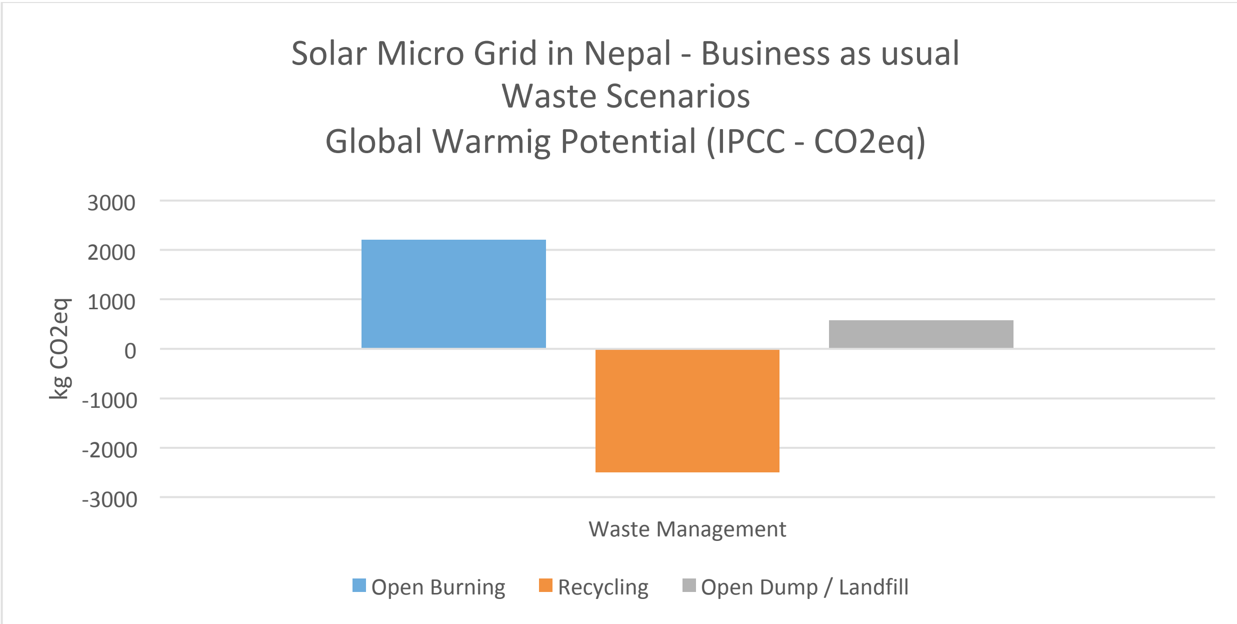
Table 2: Use-phase: Business-as-usual scenario

Use-Phase Solar Micro Grid System Madi	Business as usual (replacement factor of components in 25 years)
Battery	5.0
Solar Panel	1.0
Mounting system	1.0
Inverter	2.0
Cable	2.0
Keypad	2.0
Packaging	1.5
Small parts	2.0
Transport Lorry	1.5
Total (kg CO_2e)	**7'906**

2.5. End-of-Life Phase

The last life-cycle phase of a product or system, the "End-of-Life" phase, might not signify a huge share of the overall carbon footprint (compare Figure 2), but a remarkable 33% of the total environmental impact compared to the entire life-cycle phase (Figure 3). Although landfill impacts of electronics are still not very specified and a challenge to measure, this life-cycle stage should be looked at in more details, as open burning or landfill can have severe long-term impacts on health and environment. The newest ecoinvent database 3.5 has a number of end-of-life processes that are applicable for these Solar Micro Grid scenarios. As Figure 4a and 4b point out, open burning of Solar Micro Grid components are much worse than landfill regarding both carbon emissions and total environmental impact. Landfill has a relatively smaller impact on the results, because Life Cycle Assessment methods normally calculate environmental impacts for a time-frame of 100 years, in which plastic materials and also metals are relatively stable and compounds are often only dissolved after hundreds of years. But who can tell what will happen to the disposed Waste Electric and Electronic Equipment (WEEE) after a few hundred years? Will open dumps and landfills become new time bombs? Further investigations and research projects have to be launched to better quantify the end-of-life phase of landfilling and open burning activities.

It can be stated that recycling activities, if properly operated, lead to an environmental benefit, as valuable secondary resources are recovered and the use of primary resources in production can be avoided. This is true for various metals (like aluminium, steel, copper), but also for a number of plastics (like PP, PE etc.).



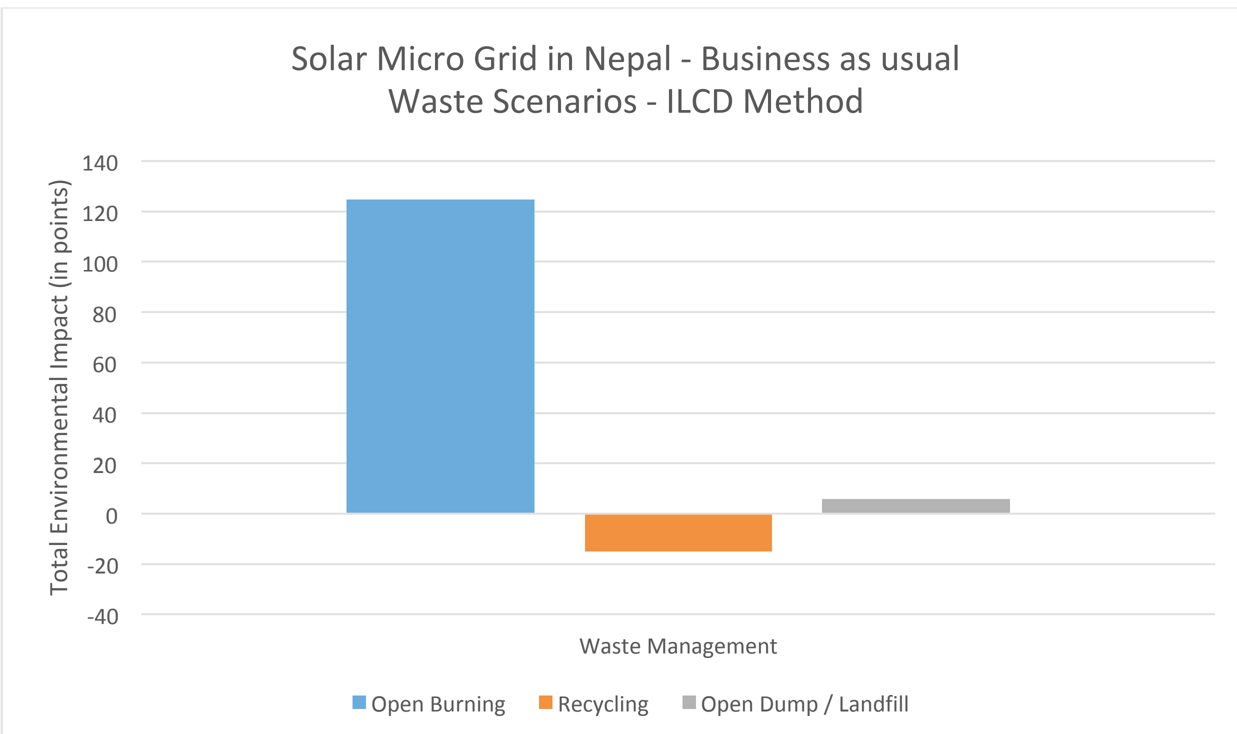


Figure 4a and 4b: Carbon Footprint and Total Environmental Impact of the end-of-life phase of the Solar Micro Grid System according to the three options "Open burning", "Recycling", and "Open dump / landfill". Please notice that accurate end-of-life models especially for landfill options are yet to be established and verified. The assumptions here are based on rough estimates by myclimate.

3. Conclusions

Based on the environmental assessment discussed in Chapter 2, and based on available favorable operation modes, the best practices over the entire life-cycle of Solar Micro Grids can be established. At the same time, worst practices should be avoided as much as possible. This Chapter summarizes the best practices over the life-cycle phases of Solar Micro Grids.

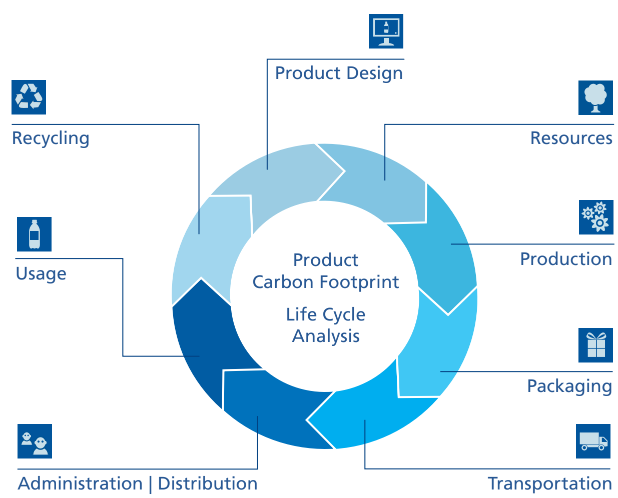
From an environmental point of view, the optimal Solar Micro Grid case in each life-cycle phase can be described as follows:

Production:

- Eco-design: as little material input as possible, as little composite-material as possible
- Raw materials from sustainable extraction methods
- Raw materials from regional suppliers
- Production in a factory with an excellent power-mix (renewable energy)

Transport:

- Regional production with short transport distances
- Light products
- Technically high-standard transportation vehicles



Use-Phase:

- Well working servicing system
- Regular maintenance
- Component-based repair system to avoid waste
- Skilled and motivated users and technicians
- Extended life-span of batteries, panels and other Solar Micro Grid components

End-of-life (see also SRI publication 2017, “From Worst to Good Practices in Secondary Metals Recovery, FACT SHEET”):

- Proper depollution and dismantling of end-of-life products
- Taking care of problem fractions such as batteries and PV panels
- Reuse and/or recycling of Solar Micro Grids through best-practice recycling processes and collection systems (e.g. FRELP “Full Recovery End Life Photovoltaic, compare Bhavesh Uppal et al. 2017, Sustainable recycling technologies for Solar PV off-grid system)
- Avoidance of open dumping of Solar Micro Grid components
- Avoidance of unsound smelting and open burning practices