**PV system Economics and Ecology**

**PV System Economy**

We conclude our discussions on PV systems with looking on several important topics on the economics of PV systems. Note that the economics of PV can be discussed at several levels, such as the consumer level, the manufacturing level, the level of PV installers, and the technology level where PV is compared to other electricity generation technologies on the scale of the electricity grid. We will start this discussion with the definition of the payback time, which in finance is defined as the amount of time required to recover the cost of an investment. It can be calculated with payback time = initial investment annual return.

Translated to the consumer level, the payback time is the time it takes to recover the initial investment of the PV system as the system continuously reduces the electricity bill. Please note that the financial payback time is different from the energy payback time.

Example

Let us assume that family Smith have installed a PV system with a power of 1 kWp on their rooftop. The initial investment was $8000. Family Smith has an annual electricity bill of $2000. The installation of the PV system leads to an average annual reduction of the electricity bill of $800. As a part of their consumed electricity is provided by their PV system, the electricity bill is therefore constantly reduced. Hence, the average annual return on their PV system is e 800. As a consequence, the Smiths have earned the final investment back after 5 years, the payback time hence is 5 years.

The payback time is strongly influenced by the annual solar radiation on the PV system. This is dependent on the orientation of the PV modules and on the location of the PV systems. In general, we can say that the sunnier the location, the greater the PV yield and the shorter the payback time. Another factor that influences the payback time is the grid electricity costs: the higher these costs, the shorter the payback time. Finally, the payback time also is strongly dependent on the initial costs of the PV system. In practice, often more factors must be taken into account than in the simple example above. This will increase the complexity of calculating the payback time. For instance, if we are considering a significant period of time, also the change of the value of money has to be taken into account, which is due to inflation. For example, today $1000 will have a different purchasing power than in ten years’ time. Another factor that should be considered are policies regarding renewable energy. For example, subsidies and feed-in tariffs can affect the

initial investments and savings. Let us briefly discuss the concept of feed-in tariffs. At the consumer level, the feed-in tariff is the price at which a consumer can sell renewable electricity to the electricity provider. We distinguish between two kinds of feeding tariffs, gross and net. Gross feed-in tariffs are paid for all the electricity the panels produce, irrespective of the consumer’s electricity consumption. In contrast, net feed-in tariffs promise a higher rate for the surplus electricity fed into the grid after domestic use of the consumers is subtracted. For implementing feed-in tariff schemes at consumer level, the facility of net metering is pivotal.

Another very important concept is the Levelized Cost of Electricity (LCoE), which is defined as the cost per kWh of electricity produced by a power generation facility. It is usually used to compare the lifetime costs of different electricity generation technologies. To be able to estimate the effective price per kWH, the concept of LCoE allocates the costs of an energy plant across its full lifecycle. It is somehow similar to averaging the upfront costs of production over a long period of time. Depending on the number of variables that are to be taken into account, calculating the LCoE can become very complex.

**PV System Ecology**

Besides discussing the economics of PV systems, it also is very important to consider their ecological and environmental aspects. The main reason for that is that the aim of photovoltaics is to generate electricity without any considerable effect on the environment. It is therefore very important to check the ecological aspects of the different PV technologies. In this section we will

discuss different concepts to quantify the environmental impact of PV systems.

The concept of the carbon footprint estimates the emissions of CO2 caused by manufacturing the PV modules and compares them with the reduction of CO2 emissions due to the electricity generated with PV instead of combusting fossile fuels. A more analytical approach is to look at the total energy required to produce either the PV modules or all the components of a PV system.

As the different PV technologies vary considerably in the required production processes, the energy consumption for producing 1 kWp varies considerably between the different technologies. If a complete life cycle assessment (LCA)is performed, it is tried to trace the energy and carbon footprints of the PV panels throughout their lifetime. Therefore LCA also is known as cradle-to-grave analysis.

We now are going to introduce several indicators that are used to judge the different ecological aspects. The Energy Yield Ratio is defined as the ratio of the total energy yield of a PV module or system throughout its lifetime with all the energy that has to be invested in the PV system in that time. This invested energy not only contains the energy for producing the components, transporting them to the location and installing them but also the energy that is required to recycle the different components at the end of their lifecycle. As the energy required for producing a PV system depends strongly on the PV technology and also on the quality of the panels, the energy yield ratio for the different technologies varies a lot. While the energy yield ratio for PV modules can be as large as 10 to 15, PV systems usually have a lower ratio because of the energy invested in the components other than the modules.

A very important concept is the Energy Payback Time, which is defined as the total required energy investment over the lifetime divided by the average annual energy yield of the system. Note that the energy payback time is different from the economic payback time.

The energy payback time of typical PV systems is between 1 and 7 years and it also depends on location issues such as the orientation of the PV array as well as the solar irradiance throughout the year.

The irradiance strongly influences the energy payback time and varies between two years (high irradiance) and six years (low irradiance). Roof-mounted systems always have a shorter energy payback time than systems mounted on the ground, mainly because of the BOS that is more energy extensive for ground-mounted systems.

No matter which PV technology is chosen, the energy payback time always is far below the expected system lifetime, which usually is between 25 and 30 years. For the PV systems, the energy yield ratio is between 4 and 10. Hence, the energy invested in the PV system is paid back several times throughout the life cycle of the PV system. The urban legend that PV modules require more energy to be produced than they will ever produced thus is not backed by any data. In contrast, the net energy produced is much larger than the energy required for PV production.

However, a lot of work still needs to be done and can be done. Some studies indicate that the energy required for producing PV modules can be reduced by up to 80%. Further, as the amount of installed PV systems becomes larger and larger, recycling of the components at the end of the lifecycle becomes very important. For example, the European Union introduced already several directives that induced recycling schemes for c-Si based PV modules.