Time for Energy Payback:
How quickly can a solar module amortize its energy debt?

It takes energy to make energy, and for this reason, when considering the advantageous properties of solar modules it is important to consider what happens in the production process, the energy used to power the manufacturing, and how quickly it is paid back in new generation – this is known as the energy amortization time, or Energy Payback Time (EPBT). This paper looks at the major energy usage in the production of an REC solar module and how quickly the same module can generate enough energy to reach a positive energy balance.

Why is an EPBT important to solar module manufacturers?

Renewable energy is considered by the general public to be an environmentally-friendly industry and one of the keys to creating a more sustainable world to live in. Indeed, certain current market developments mean that such ecological aspects of a product are gaining traction to the stage where, in France in particular, tender applications now have to submit approved and verified environmental data in order to participate with 'points' being awarded for better environmental performance.

One of the main advantages of photovoltaic solar cells is the ecological clarity of direct conversion of solar energy to electricity. Often overlooked however, is the energy used to manufacture the generation system in the first place. Indeed, the benefits of using renewable energy would be rendered completely ineffective if the energy used in the making of a solar module for example was more than it produces in its lifetime, leading to an overall energy debt – but this is clearly not the case.

Img. 1: Once installed, the energy generated by an installed solar PV system will quickly reproduced the energy used in its manufacture, dependent on a number of factors.

Energy Usage in Solar Module Production

There are a number of key stages in making a solar panel and all of these need an original source of energy to run all the machines and production equipment. For simplicity's sake, the production process can be broken down into four distinct major stages:

Silicon:
This includes the extraction of the quartz, the handling of the raw material and its purification into solar grade silicon as used for the production of solar wafers and cells.

Wafer:
Where the purified silicon is melted and cut into useable blocks, ingots and wafers.

Cell:
This sees the chemical treatment of the wafers into the familiar dark blue or black solar cells.

Module:
Where the cells are connected and sealed in the encapsulant and frame.

The most energy intensive phase of the production chain is the initial silicon production stage, where roughly 80% of the entire energy used in the process is consumed. This is predominantly due to the various heating processes used by the carbothermic reduction of silicon dioxide in electric furnaces to purify the silicon. In fact, in the most commonly used purification process – a Siemens reactor – the silicon is heated to over 1500°C in an oven over a period of time using more than 200 kWh/kg. As silicon produced in this way is produced in batches, it is clear that the heating of the reactor to the required temperature uses incredible amounts of energy; keeping it at the required temperature, and the subsequent cooling, are also hugely energy intensive processes.

Img. 2: Industrial scale production of silicon in Siemens reactors.

When applied to industrial scale production, the overall energy usage for the purification of silicon is colossal and dwarfs all other energy usage aspects of the production process and is the key phase on which to concentrate in bringing energy consumption down.

REC is proud that its solar modules have a low EPBT, and one of the key factors in this is that the company creates its wafers from silicon produced by advanced low-energy methods compared to Siemens reactor-produced silicon. Although split into two separate companies since 2013, in 2010, the REC Group pioneered the use of the low-energy fluidized bed reactor production process through its Silicon division, which cut energy usage, and therefore EPBT, by around 70% in scale production. Nowadays, the silicon REC uses in its solar wafers is sourced through its Norwegian subsidiary REC Solar Norway (previously known as Elkem Solar), who have developed an alternative process which drives down initial energy usage even further

REC's Use of ESS®

REC Solar Norway has manufactured solar grade silicon under the brand name ESS® based on a proprietary technology since 2009. This has substantially reduced the energy requirements in the production of solar cells to a quarter of that used in the traditional method. The main reason for this is that REC's purification process is performed without the conversion to a gaseous state before cooling it back to silicon, as per the Siemens method.

Furthermore, REC Solar Norway has recently developed a process that reduces energy requirements by another 50% in a true industry revolution. By comparison, the production of ESS® consumes only around 11 kWh/kg compared to the higher usage for standard polysilicon production.

With the 2015 combination of the REC Solar Norway silicon and the REC solar module production chains into one company, REC is able to present a fully integrated solar value chain that begins with the extraction of quartz from its own mines and ends in producing clean energy generating solar modules; all done with complete quality control over all processes and the lowest primary energy usage in the industry.

Img. 3: REC Solar Norway's production facility in Kristiansand, Norway

Calculating Energy Payback Times

There is a historical and persistent belief in some areas that during its lifetime, a solar panel does not generate as much energy as is used to actually manufacture it. Recent energy usage studies on REC panels have shown this to clearly be a falsehood. The amortization time, also known as the Energy Payback Time (EPBT), is the duration taken for an object, in this case a solar module to generate the same amount of energy as used in its production and reach a 'zero-energy' consumption versus production balance. Therefore this becomes a relevant figure to take into account when discussing the 'ecological' aspects of solar. Any EPBT value, however, is dependent upon how much irradiation reaches the solar module for electricity generation, i.e., the more energy produced, the lowever the EPBT. As irradiation levels vary greatly dependent upon location, the EPBT also changes dependent upon where the system is installed as well as other local factors, such as orientation, local pollution and rainfall.

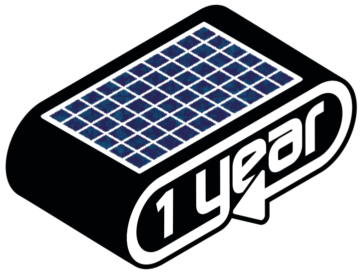
In late 2016, REC engaged the consultancy company Deloitte to perform a new assessment of the energy used in the production of the REC TwinPeak Series panels according to the European PEFCR guidelines (2013/179/EU). The REC TwinPeak solar module uses the Norwegian-produced silicon with wafer, cells and module finishing all performed in Singapore. As shown in the assessment performed and subsequent verification of REC's energy usage data, the energy requirements for the production of REC solar panels is exceptionally low, providing a class-leading value for such applications with an overall result giving an energy payback time of one year based on a location in Phoenix, Arizona.

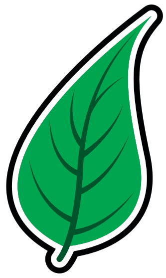
As an EPBT is dependent on the amount of sunlight reaching the panel, a further consideration is therefore also the location of the system and the amount and intensity of sunlight it sees. This has the effect of reducing the EPBT for areas with higher amounts of irradiation and extending it for areas with less sunlight. The table below shows the EPBT calculations for an REC solar module across a series of locations worldwide with differing irradiation levels and their system yields. The table also shows the role local environmental factors, e.g., heat and humidity, play in the energy production of a solar system. Indeed, Singapore and Barcelona have similar global horizontal irradiance (GHI) values, but the EPBT of a system in Singapore is longer due to the effect of the tropical conditions experienced in such a location. What is clear from the table however, is that even in locations where irradiation is less strong, the EPBT of an REC module remains very low and close to the one-year threshold:

Table 1: The calculated Energy Payback Times for various locations worldwide:

Location	Annual GHI (kWh/m²)	Yield/Year (kWh/kWp)	EPBT (years)
Munich, Germany	1183	1182	1.7
Barcelona, Spain	1635	1651	1.2
Phoenix, Arizona	2093	1939	1.0
New Delhi, India	1973	1830	1.1
Tuas, Singapore	1623	1319	1.5
Perth, Australia	1938	1804	1.1

Data based on an REC 290 Wp solar module and calculated using PVsyst simulation software.





Img. 4: REC's 1-year Energy Payback Time and leaf icons are used across company documentation to identify and demonstrate REC's leading environmentally-friendly position in the industry

Conclusion

From the above data and research which has been done into the EPBT of an REC solar module, the notion of an energy debt for solar panels can be easily discredited. Furthermore, REC has been able to demonstrate industry-leading amortization times for comparable technologies.

REC's efforts throughout its value chain to reduce primary energy usage in the production of a solar module are leading the way in sustainable module production and bringing the solar PV industry to a new level of environmental excellence.