The bumpy road from renewable to sustainable

Elegance invisible from a distance: electrode design of one of ECN's rear-contact cell architectures. Photo: ECN.

Professor Wim Sinke

ECN Solar Energy, The Netherlands
&
European Photovoltaic Technology Platform

ECN Energy research Centre of the Netherlands

Prepare for impact

Solar energy is inherently renewable, but not automatically (fully) sustainable. Few people will disagree with this general statement, but that is about where consensus ends. Photovoltaic solar energy (PV) has rapidly left behind the megawatt-era and entered the gigawatt-era a few years ago. The PV sector is currently preparing for the 'real thing', i.e. the terawatt-scale manufacturing and installation that is needed for substantial impact on a global level.

For that reason sustainability is now high on the list of development priorities, next to cost reduction and performance enhancement. Clearly terawatt-scale use is impossible, or at least undesirable, if certain sustainability criteria are not met. It would also severely affect the credibility of PV as a solution for sustainability-related problems of society. The challenge is to translate this general concept into concrete actions that are useful for research, manufacturing, installation and other parts of the PV value chain.

An important and famous definition of the concept of 'sustainability', or rather of 'sustainable development' has been given in the Brundtland Report : development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Although this definition catches an essential aspect of 'sustainability', it does not give concrete leads for the difficult choices that have to be made in everyday life in general, and in solar energy technology development and deployment in particular. Many other, more specific definitions and descriptions have also been developed, especially related to the narrower term 'environmental sustainability'.

Unfortunately, but not unexpectedly, these do not give final answers to the questions either. This leads to strong and sometimes emotional debates, but also to confusion and misunderstanding among specialists as well as non-specialists.

Dealing with (or managing) these aspects of PV and using them to define the best development agenda, has become an important challenge for the PV sector. In the following report a few important aspects are discussed in some more detail.

Benefits of diversity

In the public and professional debate the concept of (PV) 'sustainability' is often narrowed down to materials-related issues as availability and toxicity. Clearly these are very important for a technology that is expected to be produced and used in terawatts (1 TW = 10^{12} watt). Note that 1 terawatt roughly corresponds to 10,000 km^2 of PV. Last year, the European Photovoltaic Technology Platform published a public 'statement' as input for this part of the debate under the title: Photovoltaic technologies: the benefits of diversity. Since it summarizes some important considerations in a very clear way, the statement is reproduced hereafter.

"Photovoltaic solar cells and modules convert sunlight into electricity. A range of silicon wafer-based as well as thin-film technologies are already commercially available and many more are under development in laboratories and in pilot production. As a result, progress of PV technology as a whole is robust. For instance, prices have come down continuously for over

Symmetry and colors in PV architecture: family houses in the City of the Sun (Municipality of Heerhugowaard, NL). Photo: Wim Sinke.

30 years and they are expected to show the same trend for decades to come.

Because of this robustness one can safely state that it is not so much a question of whether PV will be a success, but rather in which forms, where, and when exactly. The European Photovoltaic Technology Platform has always actively supported and promoted the further development of a portfolio of PV technologies as opposed to selecting one or just a few. This forms the basis of our Strategic Research Agenda and its Implementation Plan. The portfolio reflects the diversity and creativity found in research and production worldwide and demonstrates that there is not a simple selection criterion to decide which option is most promising or desirable. Moreover, PV applications respond to different needs, vary widely in type and size and are therefore best served by a variety of technologies. A 'silver bullet' cannot be identified or even may not exist.

Clearly, potential for sufficiently low cost is a requirement for all technologies aiming at very large scale application. This potential, however, is what most options have in common. Another important condition for very large scale use is sustainability.

PV may be inherently renewable, it is not automatically sustainable. Sustainability has many aspects, including life-cycle emissions of CO^2 and hazardous substances, materials availability (active and passive parts of cells

and modules), possibilities for recovery and recycling of materials and overall product quality (technical, aesthetical, and more). The PV sector is very well aware of the importance of sustainability.

As it rapidly moves from megawatt-scale through gigawatt-scale to terawatt-scale it has taken the initiative to develop and implement take-back and recycling systems, to gradually replace scarce or hazardous materials in the final product as well as in production, and more. While working on these crucial issues, the sector has to walk the narrow line between maximum performance and minimum cost on the one side and maximum sustainability on the other side. The narrow line between staying in business and working on the ultimate PV technology.

PV technology is not yet perfect and full sustainability cannot yet be offered. However, besides cost, energy and materials use have been drastically reduced and they will continue to be so as the industry matures. The PV industry is only at the very beginning of large scale deployment and the sector does not have one simple solution. And yet, the technology is already close to perfect. It is already extremely reliable and will be competitive soon. It has a practically unlimited, very well spread global potential and a wide spectrum of application possibilities: from small systems for rural use, through medium size integrated systems to large power plants. Last but not least, it has broad public support.

Due to these features, PV can already be very effective in fighting several of the big problems this world is facing: climate change, energy security, air quality and lack of rural access to energy.

For PV to become a mainstream energy technology as soon as possible, we should continue to foster what we have and work hard on further improvements and new options in parallel. This way we avoid ending up in the deep gap between what we ultimately want and what we can actually do, for the benefit of mankind."

The statement deliberately does not address well-known specific issues such as availability and price of indium (or silver, or even copper), toxicity of cadmium, and many more. These may be important, but the Platform prefers to point at the features of the overall PV development and to put today's questions in the perspectives of time and volume. Choices are up to individuals, companies, institutes and countries, dependent on their own sustainability agendas and hopefully based on facts where these are available.

(Not) in my backyard / (not) on my roof!

When PV is applied on a very large scale, it will be 'within sight' at many locations. In contrast to common understanding, this is not because PV is an energy source with a very low power density, but because we are used to a large part of our energy being mined and generated at rather remote places.

Actually, PV is one of the most efficient, if not *the* most efficient, (renewable) energy technology in terms of use of physical space and the area that would be needed to supply the world's energy needs is significantly smaller than the total area we need today, for all primary energy sources in use together.

Nevertheless, because we want PV to be used not just in remote areas abroad, but also in our cities, along our infrastructures and in our rural areas (for reasons of security of supply, generation close to consumption, and more), we had better make sure that PV is attractive; aesthetically pleasing, or at least not disturbing. If not, we may as well forget about widespread use.

Public support is a key asset of today's PV and should be cherished as a *conditio sine qua non* for very large scale use. It is a true and crucial part of sustainability. Using cost as the only indicator is not a safe road to terawatts. Which, by the way, does not imply that beauty and design are necessarily expensive. It simply means that these aspects need to be addressed urgently and explicitly by technology developers, manufacturers, system designers and other people involved.

Design of PV products and building elements, solar building architecture and solar landscape architecture will become important disciplines in the PV sector of the future.

Another asset of PV is the proven reliability of properly designed, manufactured and installed systems. PV is a 'long lifetime, low maintenance' technology and should remain as such even when costs come down drastically. The economics of PV electricity generation (levelized costs of electricity, LCoE) is quite sensitive to system lifetime, operation & maintenance costs, and obviously, overall performance. In other words, overall quality is important.

Very low cost technology is only useful for large scale use if the LCoE is low as well. This is a straightforward business consideration, but quality is also related to the image of PV as a technology suitable for large scale professional use, which is again an important asset of PV. There is a saying: 'trust comes by foot and leaves by horse'. This should be kept in mind for PV as well. Unfortunately, in a number of isolated cases during the recent period of explosive market growth, quality has not been a top priority and turned out to be insufficient. Disappointment and bad press followed.

However, as the PV sector rapidly evolves to full maturity, quality assurance at all levels will become a standard aspect of business. Such cases, although already few and far between, are expected to become even rarer in the future.

Where do we go from here?

In the preparation for very large scale use of PV, 'sustainability' has been acknowledged as a top priority for development, in addition to cost reduction and performance enhancement (the three aspects not being independent).

Not because today's PV has bad sustainability scores or because no action is undertaken yet, but because it can and should be improved further as the sector scales up and grows. In spite of the fact that there is no general consensus on what the term 'sustainability' should actually mean, there is now a clear trend in research and technology development as well as in manufacturing to explicitly address sustainability related issues.

Some prominent examples are the development of alternatives for relatively scarce and/or expensive materials, green manufacturing and design-for-recycling. These will guarantee that PV develops from renewable to fully sustainable as it grows from gigawatts to terawatts.