The full cycle
How sustainable is solar PV?

Engineer Alex Bruce became a convert to life cycle assessment (LCA) after failing to answer a question on PV sustainability. He describes how LCA is used by the company he co-founded, eTool.

MY experience with solar PV began seven years ago working on a remote power system for a wildlife sanctuary in the Kimberley. As a mechanical engineer with a passion for the environment I couldn't have been happier. Delivering renewable energy solutions to a group who were working to protect the local environment—what more could I ask for?

But when I returned to Broome I was challenged by a friend at the local pub who stated that "solar ain't sustainable. There's more energy and carbon that goes into making the panels than they'll ever produce in their life." A statement which left me looking pretty silly.

Although I didn't have a comprehensive response, my gut feeling told me that this wasn't the case. After a couple of hours on Google the next morning, I was happy to discover that yes, while 1970s solar panels weren't very sustainable, the technology produced today is much more efficient, in both product performance and manufacturing materials and energy use, and will offset its embodied impacts within just a few years of operation.

For the next couple of years, I was content to rely on those Google references, but the concept of 'embodied impacts' kept nagging at the back of my mind. How did they come to these figures, how accurate were they really and was there more to this question than just looking at the embodied energy?

I found answers to these questions in the science of life cycle assessment (LCA) and it inspired me to start eTool, an LCA software company. For those of you who haven't heard of it, LCA is a method that assesses every impact associated with all stages of a product or process over its entire life span. The LCA approach is sometimes referred to as 'cradle to cradle', if it accounts for full recycling of a product, or 'cradle to grave', if it ends in disposal into landfill.

When you apply LCA to a product like solar PV, you're looking at all the impacts associated with it: from mineral sand extraction to make the silicon, to making the panel, through to taking the finished product and installing it on a roof. The scale of the analysis is phenomenal and it takes a dogmatic approach, some pretty clever software and the ability to wade through masses of data to produce a quality LCA.

The good news is that there's a whole bunch of LCA practitioners dedicated to giving us answers to those tricky questions we get hit with down at the pub. With scores of intelligent people conducting LCAs on thousands of products and processes, we're generating a really useful life cycle inventory (LCI) of everything from solar PV panels to clay bricks and even bottled water.

LCA is a fast growing field of study and, as a result, the accuracy of the data being produced is constantly being improved. Just like any scientific area, there is ongoing debate on which method works best and who has the most accurate data—something that's vital to keep driving the research and improving the accuracy and accessibility of LCA.

But back to solar PV…

There are a bunch of things you have to consider when conducting an LCA of an entire solar array:

- embodied impacts of components (solar panels, inverters, aluminium frames, cables and all sundries)
- transport of these components from the factory gate to site
- assembly
- maintenance and replacement (replacing inverters and the odd broken panel)
- disposal and recycling
- design life (how long the system lasts before it's ready for recycling)
- how much energy it will produce in the specified installation.

The data used to generate the embodied impacts of the components, especially the solar panels, is under constant scrutiny and the subject of a bit of controversy. At eTool, we've taken a fairly middle ground and conservative approach in the way we include this in our LCA methodology.

If we were only interested in the carbon impacts of the system, the first few elements above would help us determine the total

↑ The built environment life cycle considered by LCA.

Photos Shutterstock: Prince;Kalinovsky;Lagerek;Ramirez Lee;Pavel;Pi-Lens;Dawes;Khuruzero carbon impact and the last two would help generate what is called the 'functional unit'. The functional unit is probably one of the most important elements when conducting an LCA; as the name implies, it's used to weigh up the impact against the function of the product. So in the case of solar PV, the function is to produce energy (or kilowatt-hours) so the functional unit becomes kgCO_2e/kWh. The functional unit allows us to compare two different products that are used for the same function to work out which one has the most positive outcome. It's also really useful in conducting a consequential analysis: as in, "what is the consequence of installing or not installing a new solar array?"

Case study: Solar Gain 138 kWp solar array

We recently conducted an LCA as part of Solar Gain's winning tender for a 138kWp solar array on the Goldfields Oasis Recreation Centre in Kalgoorlie, WA.

The analysis was conducted using a 50-year project life, so pretty much all of the equipment used would require replacing, including the panels and inverters, some a number of times. There was a massive amount of embodied carbon associated with the system over this project life, totalling 581 tonnes. To put this into perspective, an average residential solar PV system of 3kWp would be responsible for less than 13 tonnes of embodied carbon over the same 50-year period.

Disposal and recycling weren't included in this assessment as the data isn't quite reliable enough yet and the net impact isn't large as a proportion of the total; however, the world of LCA is working on it.

The biggest carbon impact came from the solar panels, sitting at around 90% of the total, given a complete replacement of all the panels at least once. Interestingly, even though the installation is just shy of 600km by road from Perth and a long way from the panel manufacturer by boat, transport and assembly amounted to less than 2% of the total carbon impact.

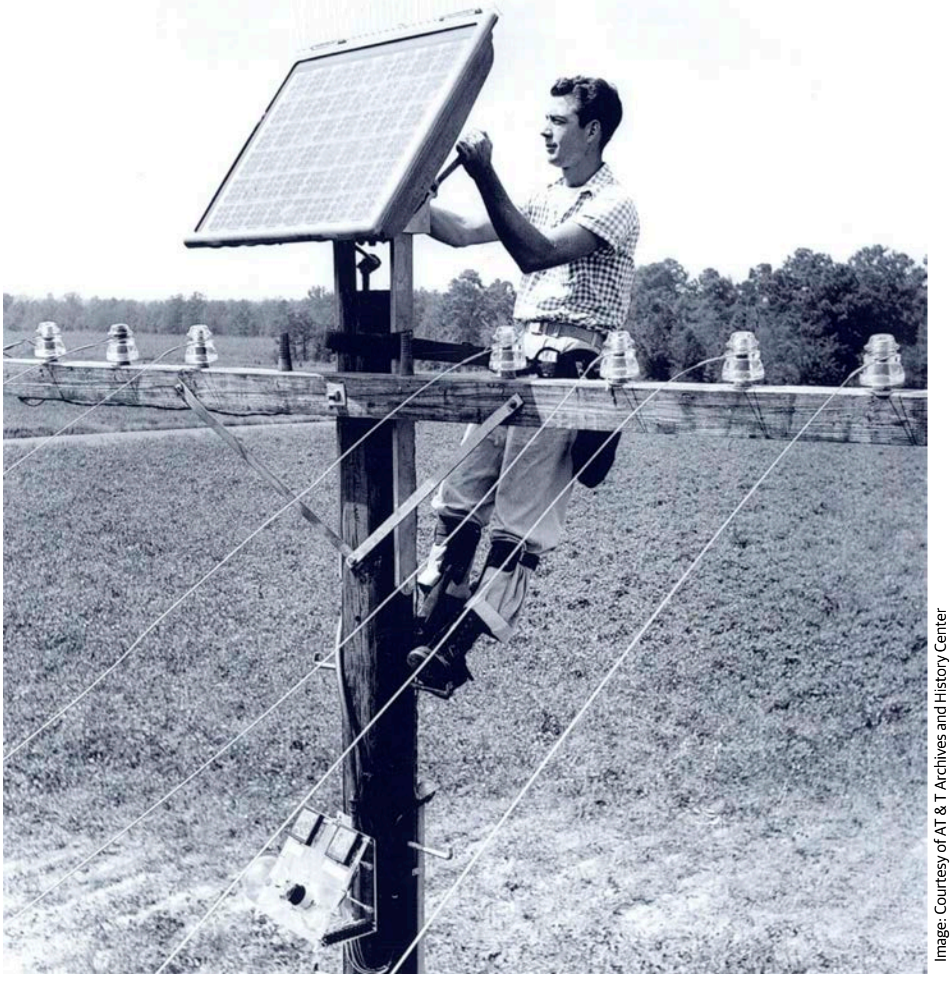

Image: Courtesy of AT & T Archives and History Center

↑ The original Bell Solar Battery (photovoltaic panel) being used in an early test in 1955 in Americus, Georgia. Solar cell efficiency of this new technology was about 6%. Now, efficiencies range from 4 to 20%.

Image: Solar Gain

↑ Part of the Solar Gain PV array on the Goldfields Oasis Recreation Centre in Kalgoorlie, WA.

Using HOMER energy modelling software it was predicted that this system would produce around 210 MWh/year and 12,000 MWh over its 50-year design life. Going back to the functional unit, we are looking at around 0.055 kg CO_2e/kWh. Currently the electricity network that this system will be installed on—the South West Interconnected System (SWIS)—has a carbon intensity of around 0.93 kgCO_2e/kWh (*National Greenhouse Accounts Factors* July 2012 Scope 2&3).

So in this case the system will save about 184 tCO_2e/year (consequential analysis against the SWIS) and pay its embodied impacts off in just over three years. A fantastic result for the planet!

One thing we also need to consider, though, is that the carbon intensity of the electricity network will depreciate as we increase the renewable energy content. As a result, these solar panels won't be offsetting as much carbon in, say, 20 years, as they are today. That said, the embodied impacts associated with manufacturing and installing solar PV continue to drop too. A discussion for another day, perhaps.

So, what if we installed the same system in a less sunny region or on a network that is already dominated by renewables? The consequential analysis would be less favourable as the system wouldn't be offsetting as much carbon. What this highlights is the importance of conducting an LCA to determine the real value of a product and not assuming that one size fits all.

Other impacts

If you've managed to breeze through the techno-babble, you may be thinking "okay, great, solar reduces carbon emissions but what about the local environmental damage from toxic chemicals used in the manufacturing processes or the hole left in the ground from the bauxite mine?"

Well, this is where LCA can get really interesting. A complete LCA will also consider all of these environmental, cost and social impacts and provide the outcomes as well. In some studies, attempts are made to try and weigh one impact against another. For example, trying to determine if carbon emissions are more or less important than toxicity raises even more tricky questions which we'll have to leave for another time. For me, the important thing is that LCA provides a way of quantifying these impacts and at least gives people the ability to make an informed decision.

A good way to look at LCA is not to consider it as the definitive approach to design but as a great tool for informing the decision process; as a very wise person once said, "it is better to be vaguely right than precisely wrong".

It's a rewarding and exciting place to be, watching buildings become quantifiably better. And with more and more LCA tools hitting the market, the science is becoming more accessible to everyone involved in the building industry, from the end occupant right through to the legislators. ❋

Alex Bruce is a renewable energy engineer and co-founder of eTool, a specialist in LCA for the built environment. For more information visit www.etool.net.au