Powering the future: Solar power applications on the ground (Part 3)

by C M Meyer, technical journalist

"By early 1973, the scientists at Solar Power Corporation were making single-crystal silicon modules for $10/W and selling large quantities for around $20/W, bringing to earth what had hitherto been principally a space-based enterprise" (Ref.1;54-55).

Limited space does not permit a better description of the how solar power reached space. Even less, of how various applications of solar panels developed as their costs began to decrease. For the many fascinating stories in this, readers are again referred to John Perlin's superb book.

All that can be done here is to briefly list the applications of solar technology in something like the order in which they developed.

First came navigation aids on gas and oil platforms for the American oil industry in the Gulf of Mexico. By 1980, seven years after their introduction, some twenty to twenty-five thousand lights used to warn shipping of the platform's presence were powered by solar panels.

Although not cheap, the photoelectric panels were still vastly cheaper than the previous source of power: huge non-rechargeable batteries, which were much like large flashlight batteries weighing five hundred pounds [ca 227 kg]…which lasted less that a year.

The next application also involved isolated equipment of the oil and gas industry in remote locations that needed small but regular amounts of current. Oil and gas wellheads, well casings and pipelines could be protected against corrosion of their steel with these small but regular currents. Again, this proved an ideal application for solar panels, as in many of the areas where the oil and gas industry is involved, such as North Africa and the Middle East, sunlight is abundant and access to utility-generated electricity is limited.

Next came the US Coastguard, where, by the 1980s, all floating buoys and lighthouses operated by the Coastguard had been converted to solar power. This was largely though the pioneering efforts of one man, Captain Lloyd Lomer who saw the potential for solar power and, after a persistent struggle against his commanding officers, had the primary batteries replaced with photovoltaic cells.

Traffic signals for railways, microwave repeater stations, and water pumps were other applications that soon became powered by photovoltaic cells in countries around the world. But, in each case, they were, and still are, basically limited to areas where sunlight was available, and electricity from a grid was not.

Current costs

"Even within the world of renewable energy, solar is dwarfed by wind power and hydroelectricity, simply because the technology is much more expensive. And expert opinion does not expect growth in the field to change the picture very much: a 25% annual growth in installed capacity for the next 15 years would still see photovoltaics producing just 1% of the world's energy"(Ref.9;2).

Even though the price of solar cells has dropped hugely since 1956 to roughly $6/W, solar power still remains the most expensive of all the renewable energies.

In his Scientific American article published in 2006, Daniel Kammen, a Professor of Energy at the University of California, Berkeley, makes the point very clearly. "Photovoltaic electricity produced by crystalline cells costs 20 to 25 [American] cents per kWh. The next most expensive source, depending on how you look at it, is still solar, with solar thermal costs between 5 and 13 cents per kWh." At the upper end of the range are Stirling engines driven by arrays of dish-shaped mirrors. And, at the bottom end, are the better known SEGS plants and power towers."

Nuclear power, because experts disagree on which expenses to put in the analysis, ranges between 2 to 12 cents per kWh. This compares with four to six cents for coal-fired electricity, five to seven cents for power produce by burning natural gas, and six to nine cents for biomass plants.

He rates wind power as the cheapest form of new electricity, with costs ranging from four to seven cents per kWh. This is presumably before one deducts the tax credit for wind of 1,9 cents per kWh, enabling wind turbines to compete with coal-fired plants. That is, if the American Congress has not carried out its repeated threat to eliminate the tax credit, which is extended year-to-year, and is the closest the United States has come to a long-term subsidy scheme for wind power.

Kammen does not give a statistic for hydropower. And, strangely enough, hydropower is not mentioned once in any of the articles in Scientific American's September 2006 special issue "Energy's future: beyond carbon".

One could argue that many of the statistics given by Kammen are limited to the USA, that different authorities give other costs, etc, etc, etc. But there is one key point Kammen raises that nobody can really argue with. And that is that the biggest challenge will be lowering the price of the photovoltaics, which are now relatively expensive to manufacture. Lowering the price of photovoltaics is not easy when there is a shortage of silicon. So that is why alternatives other than silicon are being investigated.

High hopes for thin films

"The fastest growing energy technology in the world is grid-connected solar photovoltaic (PV), which grew in existing capacity by 60% per year from 2000-2004, to cover more than 400 000 rooftops in Japan, Germany, and the United States (Ref.16;5)."

This statement certainly explains one thing: a worldwide shortage of the silicon used to produce solar photovoltaic cells. According to Karl Hesse, development director of the German firm Wacker Polysilicon, only 30 000 tons of silicon will be available for the world's entire solar industry in 2010. In other words, he is saying that there will only be enough silicon for 3000 MW of silicon modules when the potential market will be 4000 to 6000 MW, and only those manufacturers using less material will stay the course.

Hesse could be wrong. After all, just about all predictions about solar power have turned out to be wrong, and new factories producing silicon could come on stream suddenly, perhaps even producing a silicon surplus. But Hesse could just as well be right. And enough photovoltaic manufacturers are already seriously under-supplied with silicon to start looking at possible alternatives, even if they have risks attached to them, like all new technologies.

CIS, CIGS or CIGSSe?

"The trend is clear: with silicon panels hard to get and very expensive, demand is growing for the more readily available, cheaper modules of amorphous silicon (a-Si) or semiconductor. No wonder, then, that the makers of conventional

technology want to catch the thin-film train as soon as possible" (Ref.17;48).

While a traditional silicon photoelectric cell needs chunks of silicon 200 micrometres thick or more to work, far thinner cells (less than 1 micron) can be made from other semiconductors, because these particular semiconductors absorb a particular color or wavelength of light far more strongly than silicon does. And, if different layers of semiconductors are placed on top of each other, then the light can be absorbed by the different layers as it moves deeper into the cell.

CIGSSe is the newest and most sophisticated of these substances. Its advantage is that its five different elements [copper, indium, gallium, sulfur, and selenium] can better use the light spectrum from the ultraviolet to the red range-than only three or four elements. Its disadvantage is that the production process is more difficult because of the many layers.

And that, hugely oversimplified, are the advantages and disadvantages of thin films. It is simpler to make films with fewer elements in them, but they are less efficient.

The very first thin film, using two elements, cadmium sulfide, was extremely easy to make in 1966, but failed to work properly, for reasons that are still not understood. While some cells worked well outdoors for seven or eight years, most stopped producing all power when exposed to the elements.

Cadmium telluride, another photovoltaic material, worked far better and eventually achieved considerable commercial success, especially after technical improvements in 1992. CIS originally used cadmium indium diselenide, but later replaced cadmium with the less toxic and cheaper metal copper, resulting in CIS coming to mean copper indium diselenide.

With the addition of one more element, gallium, the acronym for the cells became CIGS. These can convert about 15% of incoming solar radiation into outgoing electrical current, and are also durable, some having been run since 1988 without any significant degradation by the American National Renewable Energy Laboratory.

But, like CIGSSe, CIGS is far from simple to manufacture. Making very thin layers of these films has often been a complicated and expensive business, typically involving carefully controlled vapours being laid on to surfaces kept in vacuums.

There you have it. The thin-film train is approaching the station, and many manufacturers are keen to board it. While there may be risks involved, those who want to remain in the photoelectric business will have to master those risks, and make the new technology succeed. Otherwise, the train will leave without them.

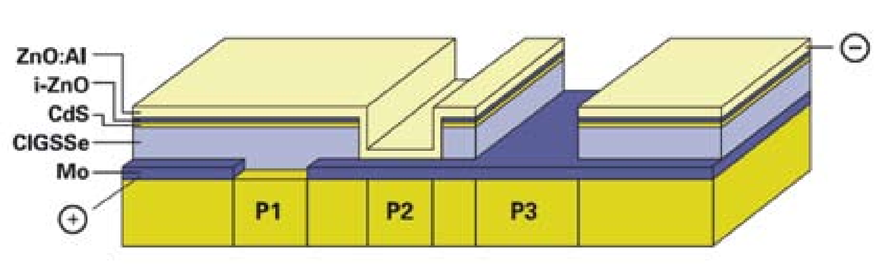

Fig. 1: CIGS thin film technology.

Grid parity vs plants

"But because solar panels are inherently easily decentralised, they do not have to compete with the cost of generating electricity; they just have to compete with the price consumers pay for it. This is four or five times more than the cost of generation, because the power companies need to pay for transmission networks, build new plants and please shareholders (Ref.9;6).

Building big photovoltaic power stations is a very expensive business. As one authority puts it: "You've got to buy land, do the site work on it, dig lots of holes, pour lots of concrete, dig trenches, bury conduits, build foundations and support structures, buy a huge inverter to change the photovoltaic-generated DC current into AC, construct a building in which the inverter is placed, purchase switch gear, and a switch yard and transformers, and because your station is usually far away from where people live, you have to spend money on transmission lines to get the electricity where the need is. You have spent a great deal of money and you have yet to buy a single solar cell."

It is therefore not surprising that most of the growth in photovoltaic generation has been where these huge extra costs are not involved: as part of the building using the electricity. That is a lot closer to grid parity, the point at which the cost of borrowing the money to buy and install a solar-power system is more than covered by savings on your electricity bill.

As the IEC puts it, most PV grid-connected systems are located on residences and public/commercial/industrial applications, whereas installations of large scale centralised PV power stations, typically owned by utilities, continue at a very slow rate.

It therefore looks as if, subsidies notwithstanding, the best place for photoelectric cells, whatever they are made of (single crystal silicon, amorphous silicon or thin films like CIGSSe), is going to be on the rooftops of buildings or as part of buildings. And that this situation will remain unchanged for quite a while to come.

But if the size of these installations continues to increase, the difference between them and large centralised PV power stations may become academic. For example, the world's largest roof-top PV installation is now operating in South Hessen, Germany. and, at 5 MW, it is bigger than many existing or proposed photovoltaic power stations.

A sustainable subsidy?

"Sales of solar PV modules are increasing strongly as their efficiency increases and price falls.But the cost per unit of electricity – at least ten times that of conventional sources, limits its potential to supplementary applications on buildings where its maximum supply coincides with peak demand" (Ref. 19;6).

In "A solar grand plan", the authors predict that roughly 80% of the USA's electricity will eventually come from huge photovoltaic generating plants, and perhaps a fifth from CSP.

With all respect to the authors of that article, I think it should be the other way around. In other words, that most of this will come from CSP (SEGS and power towers) and some from photoelectric panels. Because, as we have just seen, the best and most cost-effective place for photoelectric panels is on the roofs or even walls of buildings. And by the look of things, that is going to stay the best place for them for quite a while.

In other words, yes, there are doubtless some places in the world, like Southern Spain, the Sahara and the Mojave Desert where a company might generate photovoltaic electricity for peak loads at a profit, or, more realistically, at not too much of a loss. But in just about the whole world, even where there is very little sunshine, photovoltaic arrays are already being mounted on top of buildings and used throughout the year to reduce electricity consumption somewhat. Even in northern Germany, which is not nearly as sunny as southern Spain, consumers are enthusiastic about using solar panels on their rooftops.

This is largely because they can sell the electricity back to the utility and, each month, see the benefits of this in terms of a smaller electricity bill. Reducing your electricity bill is something that has universal appeal around the globe.

But how many people would be prepared to pay ten times their current electricity bill to receive electricity generated from a large-scale photovoltaic farm? Not many. They would be prepared to pay no more than what their normal electric power costs are. That is why solar power, especially from photovoltaic panels, is only really feasible during times of peak demand. Then, the higher value of this extra electricity are roughly matched by the higher costs of solar electricity.

So, it is hardly surprising that 95% of Germany's installed PV capacity is on rooftops, and not in large photovoltaic power stations. But all this installed PV capacity comes with a hidden cost to all German electricity consumers, to pay for the high-feed in tariffs for photoelectric energy in that country. These are about ten times higher than that paid for the generation of conventional electricity and five times higher than that for wind energy, and have resulted in the costs of these high solar feed-in tariffs to all consumers increasing quite dramatically as more PV capacity was installed. This went up from a mere €19-million in 1999 to €506-million in 2005, and nearly doubling to €1-billion in 2008.

While these feed-in tariffs are set to decrease slightly until 2011, they are guaranteed to all households with solar panels for 20 years, raising concerns that they may be unsustainable. It was already an awful lot of money to pay for only 0,8 % of the country's total electricity consumption in 2008. Many therefore ask, what will the costs be if, as planned, solar electricity generates 2% of Germany's total electricity by 2010 ?

While costs would be cheaper in areas with more sun, they are still very substantial: and will be even more so if the photovoltaic electricity has to be generated far away from the houses it must reach, and be carried hundreds, if not thousands, of km to them.

So, when you think of it, we have gone full circle, back to Fountains Circle, Pretoria. The problems confronting energy planners wishing to install photovoltaic systems even in Spain and the Nevada desert are not all that different to those facing the city fathers trying to install far smaller photoelectric cells in Fountains Circle, and really reduce to three words: justifying increased costs.

In fact, we will have to think and think again of what Austin Whillier, a South African researcher on solar power said in 1956 when he gave an overview of the prospects for its use: "Yes, solar energy is cheap – it is free – until one tries to use it. Then it becomes expensive" .

Just how expensive solar photovoltaic power will be to implement properly is anyone's guess.

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