CSP: dish projects inch forward

PART IV: IN THE FOURTH ARTICLE IN A SERIES OF ARTICLES LOOKING AT THE DIFFERENT ASPECTS OF CONCENTRATING SOLAR POWER (CSP) TECHNOLOGY, WE TURN OUR ATTENTION TO SOLAR DISHES, AS WELL AS CONCENTRATING PV (CPV).

Concentrating Solar Power
recent articles:

- Part one – **CSP concentrates the mind**, Jan/Feb 2008, pages 42-47;
- Part two – **Parabolic troughs: CSP's quiet achiever**, Mar/Apr 2008, pages 46-50;
- Part three – **Hot stuff: CSP and the Power Tower**, May/Jun pages 51-54;
- Part four – below, and pages 53 and 54.

Stewart Taggart

Dish/Stirling-engine system at Ft. Huachuca, Arizona, USA.

Solar dishes occupy the middle ground of concentrating solar thermal power, sandwiched between lower-cost, lower-efficiency parabolic troughs and Fresnel reflectors – and higher-cost, higher-efficiency solar towers.

Whether this middle ground ends up as a commercial cul-de-sac or a sweet spot, no one knows.

How do they work?

Solar dish systems consist of a dish-shaped concentrator (like a satellite dish) that reflects solar radiation onto a receiver mounted at the focal point. They consist of clusters of small mirrors set into modular, circular arrays to pinpoint solar energy onto a receiver situated above each dish.The receiver may be a Stirling engine and generator (dish/engine systems) or it may be a type of PV panel that has been designed to withstand high temperatures (CPV systems – *see page 54*). The Stirling engine uses heat to vary the pressure inside a hydrogen-filled sealed chamber. This drives pistons to produce mechanical power.

Dish systems can often achieve higher efficiencies than parabolic trough systems partly because of the higher level of solar concentration at the focal point. Dish systems are sometimes said to be more suitable for stand-alone small power systems due to their modularity but there is no reason why they should not be installed in large numbers in desert regions where they could generate large amounts of electricity.

Compared with ordinary PV panels, CPV has the advantage that smaller areas of PV are needed and, since PV is still relatively expensive, this can mean useful savings in costs.

Unlike thermal CSP systems (parabolic trough, Fresnel mirror, or power tower), dish/engine systems and CPV systems do not lend themselves very well to the storage of solar energy in the form of heat, and they are not well suited to hybridisation with gas firing. This means they are less able to provide dispatchable power – unless or until there are methods for storing electricity that can compete in price with the relative cheapness of storing solar heat.

Are they commercially viable? – and who are the players?

Two major deployments are now underway in solar thermal dishes. One represents the world's biggest financial bet to date on very large scale concentrating solar thermal power. The other is an attempt to become the first concentrating solar power plant to provide 24-hour power through energy storage using ammonia.

In California, Arizona-based **Stirling Energy Systems Inc**. plans to install an initial capacity of 20,000, 11.5-metre solar dishes totalling 500 MW, in the Imperial Valley east of San Diego. In subsequent phases, Stirling could ramp the project up to 1,750 MW. If it does, it would involve up to 70,000, 12-metre diameter, 90m^2 solar dishes.

This would put in train huge economies of scale, potentially causing the price of each dish to fall 80% from its current price of US$225,000 – to as little as US$50,000. Such economies of scale in manufacturing, coupled with larger overall solar project sizes, ongoing research and development and increased experience in deployment and operation, represent the holy grail in solar thermal. Why? Because together, they create a circle of interlocking downward price synergies that could speed the technology's arrival at 'grid parity' – or a price equal to coal – in a few years.

Or so the proponents say.

At present, Stirling Energy Systems' massive California plant project holds bragging rights as the world's largest planned CSP plant. It's also the most expensive, estimated at US$1 billion. The company's credibility is underpinned by a 20-year power purchase agreement (PPA) with regional utility **San Diego Gas & Electric**. However, the company has yet to file official permitting papers with the state of California, even though it has stated it plans to begin construction in 2009.

Nonetheless, the company has also been racking up impressive scientific milestones. In March 2008, Stirling, in conjunction with **Sandia National Laboratories**, achieved a new world record of solar-to-grid system conversion efficiency of 31.25%, significantly beating the previous record set in 1984 – 29.4%. And Neither Stirling, Sandia nor anyone else believes this will be the end of this upward efficiency climb for solar.

Big money has taken notice. In April, Ireland-based renewable energy project developer **NTR plc** sank US$100 million into Stirling, in exchange for a majority stake, making Stirling a player to watch.

The other main player to have emerged to date in solar dishes is Australia-based **Wizard Power**, which is commercialising solar thermal dish technology under development at the Australian National University for 20 years. Wizard is definitely thinking big, with dishes more than five times the size of Stirling's.

In early June 2008, Wizard laid concrete foundations for a 71-metre diameter, 500 m^2 dish, outside the rust belt Outback town of Whyalla, South Australia. Combining traditional solar thermal power with an innovative, ammonia based thermal storage system, Wizard hopes to be able to demonstrate the ability to produce power 24 hours a day as early as the end of 2009. Everything about this particular project is big. The dish itself is roughly the same height as a two story house, and Wizard claims its big dish can concentrate the sun nearly 1,500 times to create temperatures as high as 1,200 degrees centigrade.

A third major player in the solar dish field is Washington-state based newcomer **Infinia Solar Systems**, which recently raised US$50 million from investors, including venture capitalists such as Khosla Ventures and Idealab. Infinia's aim is to generate electricity through smaller, 8 metre diameter dishes. It isn't nearly as far advanced as Wizard Power or Stirling Energy Systems, and has announced no specific project deployments as of yet, but says it is involved in talks with potential backers and customers for plants ranging in size from 10MW-150MW. Like Stirling, Infinia has been testing prototypes at Sandia National Laboratories.

The European Union has dipped its toe into solar dish research, with dish technology trialled at the EU's major solar thermal research site at Almeria, Spain – alongside troughs and towers. But at present dishes appear to be a technology without a commercial dance partner in the EU, as companies like Abengoa move headlong into developing both parabolic trough and solar tower projects, and companies such as Solar Millennium move ahead in developing parabolic trough projects.

Even so, with three commercial players in the market stretched across two continents and with two of them well advanced towards developing real projects, the market should get some indication of the technical staying power of this technology as early as 2011. If Stirling can execute on its huge California solar farm, or Wizard Power can prove its big dish can deliver power (and the ammonia can store it), this middle position technology may yet prove a dark horse.

Two other things make solar dishes worth watching, and both involve the flexible, modular nature of the technology compared to troughs or towers.

The first intriguing element is the theoretical possibility that backyard or rooftop units no larger than, say, a satellite television dish, could come on the market for decentralised applications such as providing electricity to individual homes. Small scale, self contained units would also be easier and faster to deploy than long-lead time coal-fired power or natural gas plants, or even trough or tower plants.

With assembly-line units that can be installed within hours, solar dishes hold out the possibility of immense flexibility in meeting the needs of evolving grids at much shorter notice than big infrastructure projects like natural gas, coal or oil.

Taken further, dishes have often been mentioned as an ideal offgrid source of power for small communities, although energy storage still presents a hurdle. And lastly, solar dishes don't require the spaciously-contiguous, absolutely-level ground that are prerequisites for parabolic trough or tower constructions. That makes them more attractive for areas like hillsides or where there is uneven terrain – which may have few other uses.

The second intriguing element has even greater potential. Boosting the efficiency of solar PV (*see box above*). While traditional solar PV panels have been on an inexorable rise upwards in efficiency, solar dishes can help raise efficiency in solar PV panels by another means; increasing the number of "suns" pointed at them.

By using dishes to focus more sunlight onto traditional solar PV panels, more electricity can be yielded from each solar panel. There are hurdles, however. There's a limit to how large a solar panel concentrating sunlight can be directed at. And traditional solar PV panels already suffer from

CPV – an industry waiting for recognition

Concentrating photovoltaic technology (CPV) has passionate supporters – a hearty group that believes in the inherent viability of the technology – but it has yet to gain share in the global energy market. With the current interest in large investment installations (>10-MWp) that sell electricity, it is the perfect time for CPV to finally breakthrough and gain share in the US market for electricity.

Some of the reasons that concentrating PV technology has yet to scale are:

- CPV technology is not currently suitable for rooftop applications (over 90% of demand is for rooftop installations);
- The technology uses four times the area of flat plate installations;
- CPV requires direct concentration and must incorporate some form of tracking technology;
- The higher the concentration the more sophisticated (hence expensive) the system must be (examples are cooling, optics, tracking, among others).

If the entire photovoltaic industry is a start up, the CPV industry is even younger in its development and deployment life. US concentrator company Amonix, located in Torrance, California, is an early pioneer, while SolFocus, a relatively new high concentration technology developer, are committed to the future wide deployment of CPV. SunPower's high efficiency traditional crystalline technology has its roots in CPV. Low concentration continues to garner investment interest, with companies such as Solaria, Fremont, California, working to develop a lower cost rooftop module. Q-Cells, one of the PV industry leaders, has invested in Solaria.

Concentrating photovoltaic technologies (CPV) generate electricity by using mirrors or lenses to reflect (concentrate) solar radiation onto high efficiency PV cells. Concentrating PV technologies use significantly less semiconductor material than flat plate PV, and theoretically, less expensive components. Given that the cell is the most expensive component of a flat plate PV module, concentrating PV would appear to offer a viable route to module cost reduction, and thus, system cost reduction. However, as stated above, expensive optics, complex cooling schemes, and need for tracking are concerns that remain unanswered, particularly for high concentration technologies. Moreover, flat plate PV continues to improve in its use of silicon (thinner wafers, larger cells), module sizes (trending towards >200/Wp).

A CPV system with concentration intensity of 500 suns, or 500x, can produce approximately the same amount of energy using 1/500th the amount of semiconductor material as a typical solar cell. One sun is equal to the amount of energy the sun radiates onto the earth, which is about 1-kW per square metre.

In general, the materials used in concentrating PV systems are silicon, III-V (GaInP/GaAs/Ge, which increases its efficiency and energy output as concentration ratios are increased). Though III-V solar cells have advantages at higher light-intensity and temperatures (compared with silicon), the use of triple junction technologies significantly increases the complexity and sophistication of the system.

Silicon cells used for concentrations >500x are operating under high injection conditions, where the recombination current is dominated by Auger recombination resulting in lower efficiency. Auger recombination is a type of band-to-band recombination that occurs when two carriers collide, wherein one carrier loses energy and the other gains it. However, multi-junction solar cells are complex, consisting of several pn-junctions stacked on top of each other.

Fraunhofer ISE spin-off Concentrix Solar recently won a German innovation award for its CPV technology (pictured)

CPV developers do face challenges that are not trivial:

- That CPV is less expensive than flat plate has been demonstrated on paper for thirty years, but never in practice. A 500x CPV system uses 1/500th of the silicon or other semiconductor material than a flat plate. However, as the sun resource must focus directly on the cell, highly accurate tracking is required, and the system must be cooled (active or passive cooling) in order to function at highest efficiency. On the order of 5-MWp recently installed CPV in Spain affords the industry an opportunity to prove its cost story and gain traction;
- Using more exotic cell technologies at (possibly) a greater cost per cell unit area, CPV can be more efficient than flat plate per unit area of sunlight captured. However, considerable field experience has yet to establish lower cost of amortised investment plus operating cost per unit of power (KWh) produced. In the past, Arco Solar (low-level concentration), Entech, SunPower, PVI/Eco Energie, etc., et al, all reached a conclusion of higher cost when amortised investment and operating expenses are combined;
- CPV production is highly scalable when compared to traditional PV. However, this is not synonymous with more economical power production per unit time;
- CPV is younger in its market development (having not developed a market) than traditional PV, but as previously stated, the technology has passionate believers. In fact, in an industry of passionate believers (solar) those developing CPV are perhaps the most committed to their passion. In a holistic solar world, there is a place for all technologies, solar thermal, photovoltaic crystalline and thin film AND CPV. As for CPV, only time, and proof of low cost, will ensure success.

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(continued from page 53...) overheating under strong sun. Multiplying that number of suns tenfold would require very robust solar PV cells.

Among companies to watch in the CPV area are Australia's **Solar Systems** and smaller companies such as **SUNRGI**.

For those seeking to handicap solar dishes, therefore, the first to watch is Stirling Energy System's progress toward building out its California plant. The second thing to watch is Australia's Wizard Power, with its potentially ground-breaking "big dish" and ammonia energy storage. The third thing to watch is industry newcomer Infinia, as well as any other companies still in stealth mode who decide to break cover in the coming months and emerge into the sunshine, so to speak.

Lastly, keep an eye on CPV. There's a long way to run in that market.