

# Hot stuff: CSP and the Power Tower

## 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 – below, and pages 52 and 54.

IN THE **THIRD ARTICLE** IN A SERIES OF ARTICLES ON CONCENTRATING SOLAR POWER (CSP), STEWART TAGGART LOOKS AT THE **POWER TOWER**, WHICH MANY EXPERTS THINK COULD BE THE WAY FORWARD.

Stewart Taggart

Tall, expensive and powerful, Power Towers could ultimately emerge as the most promising of all thermal CSP technologies. Why? Because the high temperatures they achieve and the low cost of electricity they produce. That is, of course, if current expert estimates prove correct.

The good news is that it shouldn't be long now before clues emerge as to whether the experts are right. Major investments are now flowing into Towers, and large flagship deployments should come on line in the next few years. When that occurs, the CSP industry will have a

real horse race between Parabolic Troughs, Dishes, Towers and linear fresnel reflectors – the four primary forms of thermal CSP. When all are operating commercially – under real world conditions – the market will sort them into winners, losers and niche players.

PS10 Power Tower at Sanlucar la Mayor, near Seville.



## Background to CSP

Parabolic trough and fresnel reflector CSP plants concentrate sunlight onto a thin pipeline to warm a heat liquid to around 400 deg. celsius (c). Solar dishes focus sunlight on a single point to create temperatures of about 750 deg. c. But Power Towers surround and bathe an elevated tower with reflective light from all sides, to generate temperatures around 1,000 deg. c. In all the cases, the heat is then used to drive traditional steam turbines, which in turn create electricity. In the case of Towers, whether or not the higher temperatures will offset the higher costs is the key question. Deep pocketed, risk-tolerant investors are now stepping up to the plate to find out.

## Fresh investment momentum

Probably the deepest pocketed are the green sheiks of Abu Dhabi. In mid-March 2008, the Emirate's renewable energy company MASDAR announced a joint venture (JV) with Spanish engineering group SENER, to roll out three 50MW parabolic trough CSP plants with molten salt storage in Spain, to be followed by Tower projects. MASDAR and SENER, through a JV called Torresol, aim to get 320MW of CSP plants up and running by 2012. They aim to get 1,000MW of CSP up and running by 2018.

To date, MASDAR/Sener/Torresol hasn't announced the specifics of how many Troughs and Towers it may build. It's quite possible they don't know yet. But with US\$15 billion to spend, MASDAR's entrance into CSP has sent Richter-scale-sized reverberations throughout the industry.

And in the Solar Concentration Off-Tower (SCOT) concept, from Tokyo Institute of Technology's

Professor Yutaka Tamaura – that is to be tested in Masdar – so-called cutting-edge “beam-down” technology will be tested. Experts believe this could be very exciting for CSP Tower technology; mirrors send the sunlight up to a concentrator that then reflects it back to a ground collector, which heats the liquid to make the steam to drive the turbine. According to the experts, this results in the highest MW potential for solar energy generation [for a detailed scientific study of the technology, see: [http://www.sener.es/EPORTAL\\_DOCS/GENERAL/FILE-cw6973af2d4aae4fcb37f/ANOVELBEAM-DOWNSYSTEM.pdf](http://www.sener.es/EPORTAL_DOCS/GENERAL/FILE-cw6973af2d4aae4fcb37f/ANOVELBEAM-DOWNSYSTEM.pdf)].

## Established expertise

But money isn't everything. Elsewhere, two hardened veterans of the early CSP days in California have also tossed their hats into the solar tower ring.

One is privately-held Brightsource Energy, which was founded by Israeli experts who in the 1980s built the world's first Parabolic Trough CSP plant in California. Brightsource now plans to build 400MW of Towers in California, scaling up technology now being tested on a pilot basis in Israel's Negev desert.

## New Tower projects that have been announced

### China

The Institute of Electrical Engineering (IEE) of the Chinese Academy of Sciences (CAS) recently ran an international design competition for a Power Tower, the key architecture of its planned first-ever solar thermal power plant, to be built near the foot of the Badaling Great Wall in a northern suburb of Beijing. The IEE solar thermal power plant will work as a model for China's other upcoming solar plants around the country.

This landmark solar Tower will be over 100 metres tall, and according to [iee.ac.cn](http://iee.ac.cn), the official website of IEE, the winners have recently been announced. First prize went to International Engineering Projects (I.E.P) of Italy (see <http://www.iee.ac.cn/Website/index.php?ChannelID=972&NewsID=4572> for other winners).

A key scientific project under China's 11th *Five-Year Development Plan*, the project is jointly financed by China's Ministry of Science and Technology, the CAS and Beijing's Municipal Commission for Science and Technology.

### South Africa

South African utility Eskom is planning to build a multimillion-rand, 100MW solar CSP Tower plant near Upington. Three possible sites have been identified on the Orange River near Upington in the Northern Cape, which reportedly has one of the world's best solar profiles.

Upington gets more solar radiation annually than any of the sites in California, Nevada and New Mexico in the US, as well as sun-splashed countries such as Jordan, Morocco, Crete, India and Spain.

The Upington project is the first major solar energy initiative on the continent. With South Africa's current electricity crunch, and the need for renewable power in an economy where 90% of power is generated by coal, the rationale for the plant seems to make sense. Eskom is reluctant to estimate how much it will invest in the technology over the next decade, saying this will depend on the success of the Upington project. A favourable environmental impact assessment (EIA) has already been completed for the department of environmental affairs and tourism.

The second is SolarReserve, a joint effort between New York Stock Exchange-listed United Technologies Corp., and NASDAQ-listed US Renewables Group. They plan to commercialise solar Tower and molten salt technologies developed in the 1980s and 1990s by onetime Boeing subsidiary Rocketdyne.

SolarReserve's aim is to build Tower plants capable of producing up to 500MW of afternoon high-priced peaking power – through combining real-time afternoon solar energy generation, doubled up with energy generated from molten salt heat reserves built up during the morning hours.

All the companies are looking to pluck low hanging fruit. That's because most fundamental research into solar Towers to date occurred in the 1980s and 1990s in California. During that period, two flagship 10MW research projects, Solar One and Solar Two, proved the technology worked, albeit at a high cost. But that's as far as things got. Low oil prices caused Government support to erode and industry players shelved the technology. Early in the new millennium, after 10 years of narcolepsy, EU-funded research into CSP started up in Spain.

As a result of this renewed interest and EU inducements, Madrid-listed Abengoa now operates a commercial 11MW solar Tower near Seville, Spain called PS10. A 17MW tower called Solar Tres is under development by privately-held SENER. Abengoa Solar is also building PS20, which it says will produce 20 MW.

So far, so good. But whether these new solar Tower bets provide long-term returns more akin to an oil strike or a subprime mortgage, remain to be seen.

### What questions need to be answered?

As with troughs and dishes, issues surrounding Towers revolve around **how soon, how big and how cheap?**

Regarding how soon, 2011-2012 seems a reasonable guess for plants from MASDAR, Brightsource or SolarReserve.

How big? Given that a major advantage of Towers is their scale and ability to generate high temperatures, it pays to build them big. But this leads to system complexity. It also vastly increases the importance of proper site selection, since small amounts of additional sun can have exponentially compounded

## Power Towers – technology in brief

In tower systems, a heliostat field comprising movable mirrors is oriented to reflect the solar radiation, and concentrate it up to 600 times on a receptor located on the upper part of the tower. This heat is then transferred to a fluid, with the purpose of generating steam that expands on a turbine coupled to a generator to produce electricity.

Tower technology operation is based on three main features: heliostats, receptor, and tower.

- **Heliostats** are designed to capture solar radiation and direct it to the receiver. They are composed of a reflective surface, a supporting structure and mechanisms used to orientate them, following the sun's movement (this involves systems for the heliostats' movement as well as control systems). The most widely-used reflective surfaces today are glass mirrors;
- The **receiver** transfers the heat to an operating fluid (which could be water,

molten salts, etc). This fluid transmits heat to other parts of the CSP plant, generally to a water store, in order to obtain high-temperature steam to produce electricity through a turbine. The latest R&D is aimed at creating high-temperature Towers, with heat transporting fluids such as air and salts.

- The **tower** acts as support for the receiver, which should be located at a certain height above the heliostats to avoid – or at least reduce – shading and blocking.

To install Tower technology CSP plants, there are certain requirements, such as:

- The site needs to be level;
- The direct normal insolation (DNI) should be as high as possible;
- Water is needed for cooling in the power block;
- Electric lines and transmission capacity are needed to convey solar power from the plant to the consumer.

Source: *Abengoa Solar*

impacts on the lifetime economics of a Tower plant. At present, optimum sizes are believed to lie somewhere between a rather vague 50MW-400MW.

How cheap? In a 2003 study, Chicago consultants Sargent and Lundy estimated solar Towers could become the lowest-cost form of CSP. They estimated that Towers might be able to generate electricity at a levelised cost of energy around US\$0.04 cents/kWhr by 2020.

### What happens next?

In the coming years, the pace of the Tower industry will be set in California and Spain, so these two markets are the ones to watch, as are any developments or announcements from MASDAR/Sener, Brightsource and SolarReserve.

It will also pay to keep an eye on society at large, for signs of community opposition to large, new and unfamiliar solar complexes. Further, given that Towers benefit from very strong sun found in isolated places, developments regarding extending grid access to remote generation sites will be important to monitor. Lastly, given that molten heat storage is a key element in the economics of Towers, research and deployment developments in this area also should be closely watched.

As money flows into solar towers, the biggest, most expensive and arguably most risky of

CSP technologies, the entire industry is reaching a durable, economic take-off phase.

With solar Towers now in the game, the CSP industry now has a complete suite of commercial technologies, all with an exciting future of technological and economic discovery ahead. Even though Towers appear to hold the greatest long-term promise for huge, new, low-cost electricity supplies, having an unambiguous technology winner in CSP may be just what the industry doesn't need. The best outcome may be a suite of technologies, engaged in long-term economic competition with each other. That way, the market can most fully do its work.

Were one CSP technology to emerge an unambiguous winner, it could foster a monoculture industry. This could, in turn, prematurely choke off research in Troughs, Dishes or Fresnel Reflectors, or even in Concentrating PV (CPV) and idiosyncratic cousins like solar chimneys.

However, a long-term, neck-and-neck race among stable mates would foster faster innovation in the industry. It would also be more fun to watch. In any event, the competitors are now all at the starting line. And that's good news.

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