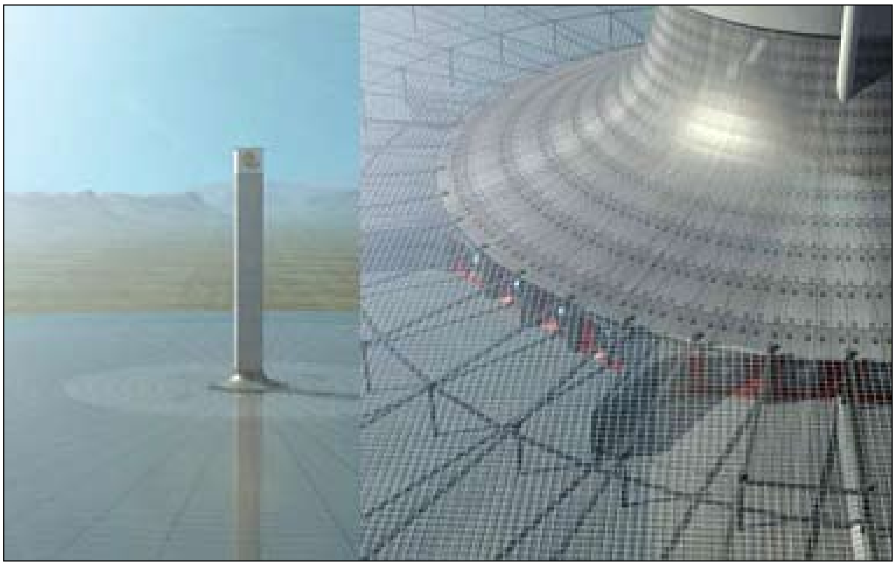
Towers of power: The solar updraft tower

by C M Meyer, Technical Journalist

After four years and 17 capital raisings, Enviromission is trying to grab an $80-million [Australian] federal government handout to keep alive its dream of building a giant hot-air powered tower in the Riverina. The company boasted to the Herald three years ago that it would have its plans to build a one-km high solar-heated, air powered tower at a "bankable" stage in 2003

Who is Enviromission? And what has happened to its plans to build a huge, 200 MW solar updraft chimney in Mildura, Victoria, Australia, launched with much hype in 2000? Is it just a lot of hot air that is slowly cooling down? Or are investors holding back from the huge costs and challenges of building the tower, hoping that someone else will take the risks, prove the concept, and let them follow?

Roger Davey, the executive chairman and chief executive of Enviromission, the company founded to build the solar chimney, is not an engineer. He was a futures trader on the stock market, and his approach is better understood if you bear this in mind. For he is still trading in futures. The only difference is that a very specific future is involved, the future of a futuristic project, the first solar chimney to be built since Manzanares. And this project is not a prototype, but has to pay its way in commercial terms.



An artists's impression of the proposed Mildura Tower.

While a conventional engineer would first build a small working prototype, and then demonstrate it to try and get interest and funding to build the full-scale version, Davey has gone another route: promotion. Seized with a powerful vision that grabs the imagination - a huge tower more than a kilometer high and with a collector several kilometers broad - Davey is trying to promote his vision and sell shares in a company that will make that vision a reality.

Whether he will make it only time will tell. Already, the original plans have been reduced from a 200 MW tower a kilometer high to a 50 MW one less than half that height. And funding that he hoped to raise from the Australian government's low emissions technology demonstration fund has so far gone to another solar technology, claimed to be the biggest and most efficient solar photovoltaic power station in the world.

Will Davey succeed? Only time will tell: and whether he manages to build his 50 MW tower. Let us now look at what has been said about the advantages and disadvantages of this type of tower, and what questions are still unresolved. For it appears that prof Jörg Schlaich was right in at least one thing. The world is slowly but surely starting to run out of fossil fuels like coal and oil, and the increasing prices, particularly of oil, pose serious problems even to rich countries.

Put another way, rising energy and food prices are already making poor countries even poorer. With this grim prospect, all possible means of using renewable energy, especially solar updraft towers, should be placed in the spotlight and those advocating them be allowed to state their case.

In the spotlight

"A proper green tower plant of 400 megawatt electricity needs to be 1,5 km high and 280 metres in diameter – but nowhere in the world has such a high structure ever been built", he admitted. (Ref. 30;2)

The speaker, Prof. Wilfried Kraetzig, hit on a very important point. And, as part of a team of German and South African engineers and university professors concerned with developing solar updraft towers for use in the African Namib and Kalahari deserts, he should know.

There are big risks, and costs, in building something completely new. To double the economy of a solar chimney, one can either double the size of the collector, or double the height of the tower. Either way, the building has to be built on a very large scale. This also means that the initial capital cost of such a plant is high, making it difficult to sell to potential investors and raise funding for the project.

In fact, this is why Roger Davey has had to downsize his original solar tower proposal, as the original concept 200 MW plant would have cost around 800 million Australian dollars (US$610-million). Some argue that this high initial cost is why such a solar updraft tower power plant can never be profitable, stating that the cost per each kilowatt installed is at least twice as expensive as a wind farm. On the other hand, the wind driving the turbine - or turbines - in a solar updraft tower should be steadier and slower than in a wind farm, cause less wear and tear, and allow turbines to last longer than on a wind farm.

But there is another problem that solar updraft towers experience. This is that their power output is not constant throughout the day or year. When the sun's heating power is strongest - at midday and in summer- the power output peaks. In other words, the times of peak power output (at midday, in summer) do not match the times when there is a peak demand for electricity (in the morning and evening, especially in winter). But, strangely, solar updraft towers can also work at night.

Power from the sun: at night?

"A solar power plant that generates electricity after sunset sounds like a contradiction in terms, but the Spanish experiment showed that the solar chimney has this rare talent." (Ref. 7;32)

One strange finding from Manzanares is that the solar updraft chimney can produce power at night, but not at the same levels as during the day. This is caused by the soil beneath the collector releasing the heat stored in it during the day at night, while the night air cools. In a modern simulation done at Stellenbosch University, roughly a sixth of the maximum power generated at midday is shown to be generated throughout the night.

To improve the amount of heat stored, Schlaich proposed placing coils of black plastic water-filled tubes under the collector. Water heated during the day would be pumped into an insulated store, and then returned to the coils at night, allowing the plant to work at full capacity for 24 hours a day.

There is a snag, however. While covering 25% of total collector area with water-filled bags would allow the plant to operate for 24 hours a day, at or close to nominal output in summer, there is a "significantly reduced output in winter. In another development to the Mildura saga, Davey mentions a new method that will enable the size of the collector to be reduced. The idea, apparently created by Enviromission, involves storing heat in brine ponds, so that on days of lower solar radiation we can bring in that stored heat to create the temperatures we need.

Exactly how this will be done is not very clear. Davey does not say much, except to state that in general terms the new design will enable Enviromission to operate with a much greater efficiency or capacity factor and get more from less out of the solar tower. What Davey does not say is that existing solar pond technology developed in Israel would probably generate electricity just as efficiently as a solar tower. In this technology, a pond of saline water, about 2 m in depth and 250 000 m^2 in area can power a 5 MW turbine for a few hours each day, typically during the morning and evening peak load periods.

While the efficiency is not very high, approximately 1% at best, this is still a lot better than the 0,08% or 0,11% measured at Manzanares. And the radius of a circular pond of 250 000 m^2 would be about 280 m, about twice the radius of Manzanares, but still a lot smaller than the huge collectors (with radii of several kilometers) originally envisaged by Enviromission for Mildura. While the ponds would need some kind of covering, presumably glass or plastic, they would no longer need a tall central tower, and all the complexities that go with it.

Some rather obvious points

"Nevertheless, solar towers also have features that make them less suitable for some sites" (Ref. 11;6)

What other issues relate to solar updraft towers (called solar chimneys here)? At the end of his article, Schlaich lists three rather obvious points. Firstly, solar towers require large areas of flat land. Thus, land should be available at low cost. A desert area is an obvious candidate. But there is a complication, as Schlaich also notes that zones with frequent sand storms should also be avoided, as either collector performance losses or collector operation and maintenance costs would be substantial there.

Thus, the Sahara desert with its well-known sandstorms does not appear a very suitable area. But, the world's oldest desert, the Namib, and the Kalahari, could well be suitable, especially as they have no earthquakes. Deserts also link well with solar updraft towers, as these structures do not need water for cooling, and the surrounding sand could conceivably be made into the huge amounts of glass needed for the collector. The Namib could be an especially suitable site, as thunderstorms and storm strength winds occur less there than in the Northern Cape or the Kalahari.

Schlaich's observation that solar towers are not adequate for earthquake prone areas casts a doubt on two areas mentioned as possible sites for these structures. One, in the Thar desert of Rajasthan, on the boundary between India and Pakistan, does have some earthquake activity. But locals do not appear too worried about earthquakes, as a nuclear reactor in Pakistan has been located right above a geologically sensitive fault.

But China is better known for its devastating earthquakes. Therefore, Enviromissions' plans to consider building a tower of power in Shanghai could be risky, especially considering China's recent killer quake, and occasional typhoons that have struck the area. Other questions that remain to be answered in detail are:

- How are the collectors to be cleaned, as legions of squeegee-wielding window cleaners will clearly not be the answer
- If anything natural (i.e. high-speed winds) or unnatural (i.e. low frequency vibrations) could cause the tower to resonate,
- How could such a tower be protected against terrorists, including suicide bombers prepared to crash aircraft into it

By this stage, readers could well be thinking that solar chimneys are a non-starter. But, they do have advantages that need to be considered too.

Not all hot air

"At the tower base 32 turbines would be installed and driven by the "hot air to generate electricity. If constructed in the Namib desert, close enough to allow a pipeline to the Atlantic Ocean, seawater can be extracted and desalinated to allow large-scale agriculture like crop farming" (Ref.30;2).

One of the main problems facing anyone wanting to develop a solar updraft tower is its image. For more than eight years, Enviromission has failed to deliver, after promises and massive hype. Largely thanks to this, decision makers and potential investors are now more than slightly skeptical of proposals to build solar updraft chimneys more than a kilometre high in the Namib, Kalahari or the Northern Cape.

The case is muddied further when things that seem totally unrelated to power generation are included, and presented to electrical engineers and accountants used to boring, established proposals for power generation. The focus in articles on growing vegetables and fruit, fish farming, desalination and other strange activities that could take place beneath the tower's collector unfortunately creates the impression that the project's focus is not really power generation.

This is a pity, as a closer look will uncover several serious arguments for a solar updraft chimney in the Namib, Northern Cape or Kalahari. Just one of these is that the insolation for those areas is among the best in the world: and roughly double for the area where the Enviromission tower is planned. Other points are:

- Solar updraft chimneys have a cheaper unit cost than photovoltaics and solar concentrators: once the chimney has been built and is operating
- Unlike other solar-based power sources (like photovoltaics and solar concentrators), the drop in power output with cloudy conditions is less marked, as diffuse solar radiation can also be used. The solar updraft tower will still generate power under cloudy conditions, although at a reduced level
- Construction materials (glass and concrete) are reasonably straightforward to make, and producing them could be used for job creation. Once complete, the tower could aid tourism
- Being so simple, the technology is unlikely to become outdated easily
- Unlike wind power, there are no sudden power spikes when the wind abruptly starts and stops blowing. Changes in power output from a solar updraft tower are less

sudden and more continuous. In a good location with virtually no clouds (i.e. a desert), high intensity sunlight will produce energy reliably and continuously

- No fuel or cooling water is needed, and no carbon emissions are produced. Other than routine maintenance, a lifetime of over a century is a real possibility
- there really is a potential to use at least part of the huge collector area as a greenhouse to grow fruit, vegetables or even farm fish; these ideas are not as crazy as they sound.

A lot of very hard work has been done by the Institute of Thermodynamics and Mechanics at Stellenbosch University on problems in such a venture, and showing that serious solutions can be provided for many of these problems. While Stellenbosch doesn't have all the answers, an impressive number of topics have been quantified, and a far clearer idea gained of what still needs to be researched.

But, no matter how much research is done, the project remains a venture never carried out before and, for that reason, is still risky. Perhaps the only way this risk can be reduced is by first building a smaller, working version of the plant, as Enviromission is now apparently doing. If people driving through the Namib were to see an actual version of a working solar updraft tower there, then many of the problems of credibility could be resolved. If tourists could stop and see such a tower generating electricity, growing vegetables and fruit, farming fish, and providing fresh water from sea water by desalination, then selling the project would be far easier.

Never mind if the tower is less than 500 m high, and is not completely economical. The risk and problems of building such a demonstration tower would be far less than something 1,5 km high. And then, once the demonstration plant was working and everyone could see it was working, the real work of building far higher, far bigger towers could start.

To sum up, the solar chimney is a concept that is far ahead of its time. Perhaps the problem is that we are thinking too small. Maybe towers far taller than a km, or even the 1,5 km envisaged for the Northern Cape tower, will become possible or even commonplace once more advanced materials than reinforced concrete become available.

In the meantime, until they do, everyone is waiting for the first solar chimney to be built out of reinforced concrete. Perhaps a 750 m high concrete tower will be built in Spain, not too far away from where the Manzanares prototype once stood, if proposals displayed on the internet finally take shape. Or the Mildura tower might well be built after all, confounding the skeptics. Where a viable solar chimney will first be built, and when it will rise in the 21st century, is anyone's guess.

In the next article, we will examine another type of solar tower, which uses many mirrors to concentrate the sun's heat. This technology is far older than solar chimney, with a working model having already been demonstrated in the nineteenth century.

References

[1]. "Don Quixote". Wikipedia, (http://en.wikipedia.org/wiki/Don_Quixote) [Accessed May 2008].

[2]. "Solar updraft tower". Wikipedia, (http://en.wikipedia.org/wiki/Solar updraft_tower) [Accessed May 2008].

[3]. "Solar chimney". Wikipedia, (http://en.wikipedia.org/wiki/Solar_chimney) [Accessed May 2008].

[4]. Lorenzo, E "De los achivos históricos de la energía solar"(http://www.fotovoltaica.com/chimenea.pdf) [Accessed May 2008]

[5]. Johannes Pretorius, Personal communication.

[6]. Cobus van Dyk. Personal Communication.

[7]. Hattersley, L "Electric dreams". New Scientist. Vol 161 No 2176, pp 30-33.

[8]. Nowak, R "Power tower'. New Scientist. Vol 183 No 2458, pp 42-45.

[9]. Daviss, B "Our solar future'. New Scientist. Vol 196 No 2633, 32-37.

[10]. Schlaich, J, Bergermann, R, Schiel, W and Weinrebe, G "Sustainable electricity generation with solar updraft towers". Structural Engineering International 3/2004, 225-229.

[11]. Schlaich, J, Bergermann, R, Schiel, W and Weinrebe, G 2005. "Design of commercial solar updraft tower systems – utilization of solar induced convective flows for power generation." Journal of Solar Engineering 127(1), 1-9.

[12]. Haaf, W, Friedrich, K, Mayr, G, and Schlaich, J 1983. "Part I: Principle and construction of the pilot plant in Manzanares". Int. J. Solar Energy, Vol.2, pp3-20.

[13]. Haaf, W 1984. "Part II: Preliminary test results from the Manzanares pilot plant". Int. J Solar Energy, Vol 2., pp 141-161.

[14]. Pretorius, J P, Kröger, D G 2006. "Solar chimney power plant performance". Journal of Solar Engineering. Vol 128, 302-311.

[15]. Pretorius, J P, Kröger, D G 2007. "Sensitivity analysis of the operating and technical specifications of a solar chimney power plant". Journal of Solar Engineering Vol 129, 171-178.

[16]. Fluri, T P, von Backström, T W 2007."Comparison of modelling approaches and layouts for solar chimney turbines". Solar Energy 2007.07.006, 1-8.

[17]. van Dyk, C, Alberti, L, and Van Zijl, G P A G "The technology development methodology and solar chimney power plant wind-structure interaction: ongoing research". 4th CIDB Postgraduate Conference, Protea Hotel, Stellenbosch, South Africa, ITT 2006: 56-68.

[18]. Rousseau, J and van Zijl, GPAG. "Dynamic evaluation of the solar chimney". Concrete No 114, December 2006, 12-18.

[19]. Woody, T "Tower of power". 2 October, 2006. Business 2.0 magazine (http://money.cnn.com/magazines/business2/business2_archive/2006/08/01) [Accessed September 2007].

[20]. Rochfort, S "Enviromission seeks a handout". 6 December 2005. Sydney Morning Herald. (http://www.smh.comau/news/business/enviromission-seeks-a-handout/2005/12/05) [Accessed November 2007].

[21]. "Extension of the feasibility study for the greenhouse operation: the 200 MW solar power-station in the Northern Cape Province". Energy Management News, Vol 6 No 4, December 2000, pp 4-12 (http://www.eri.uct.ac.za/Energy%20Management%20News/Dec2000_3.pdf) [Accessed July 2007] .

[22]. "Enviromission Limited. Annual Report Year Ended 30 June 2007" (http://www.enviromission.com.au) [Accessed May 2008].

[23]. "Warsaw radio mast". Wikipedia (http://en.wikipedia.org/wiki/Warsaw_radio_mast) [Accessed May 2008].

[23a]. "Tacoma Narrows bridge", Wikipedia. (http://en.wikipedia.org/wiki/Tacoma_Narrows_Bridge) [Accessed June 2008].

[24]. "Brooklyn Bridge". Wikipedia (http://en.wikipedia.org/wiki/Brooklyn_Bridge) [Accessed May 2008].

[25]. "An earth without people."Scientific American. Vol 297 No 1, 58-63.

[26]. "Green Tower upwind solar power station". Krätzig & Partners (http://www.kraetzigundpartner.de/Green%20Tower%20mit%20Fig.pdf) [Accessed May 2008].

[27]. Stinnes, W W "Greentower: performance guarantees through insurance policies". 2004. Industrial and commercial use of energy conference 2004. (http://active.cput.ac.za/energy/web/icue/papers/2004/32_W_Stinnes.pdf) [Accessed May 2008].

[28]. Stinnes, W W "Discussion of the first report by the ITM regarding a 200 MW solar chimney in the Northern Cape Province, South Africa".2000.(http://www.greentower.net/UNIVERSITY%20STUDY.htm) [Accessed May 2008].

[29]. "Namibia: Green Tower not all hot air"(http://gsdi.org/newsletters/EIS_Africa/2007/February/2007.pdf) [Accessed May 2008].

[30]. Mc Laren, W "Solar tower project pipped at the post". 11 November 2006. (http://www.treehugger.com/files/2006/11/solar_tower_pro.php) [Accessed May 2008].

[31]. Dennis, C "Solar energy: Radiation nation". Nature 443, 23-24 (7 September 2006). (http://www.nature.com/nature/journal/v443/n7107/full/443023a.html) [Accessed May 2008].

[32]. "Efficiencies allow 50 MW to 200 MW solar towers". Waterville Investment Research. (http://watervilleresearch.com/companies/special/273-2.html). [Accessed May 2008].

[33]. Faiman, Prof. D "Solar energy in Israel". 26 November 2002. (http://www.mfa.gov.il/MFA/Facts%20About%20 Israel/Science%20…) [Accessed May 2008] Google "Solar energy in Israel to reach the internet reference.

Contact Chris Meyer, mc.journ@gmail.com ❖