Solar chimney plus bell jar …. a thought experiment

The solar chimney allows direct conversion of solar energy into electricity using natural convection [1]. A prototype of 50 kW capacity operated successfully at Manzanares, Spain in the 1980's. A commercial 200 MW solar chimney is currently being developed in Australia [2]. It involves a chimney of height 1000 metres and diameter 120 metres and a solar collector of diameter 7000 metres (Figure 1).

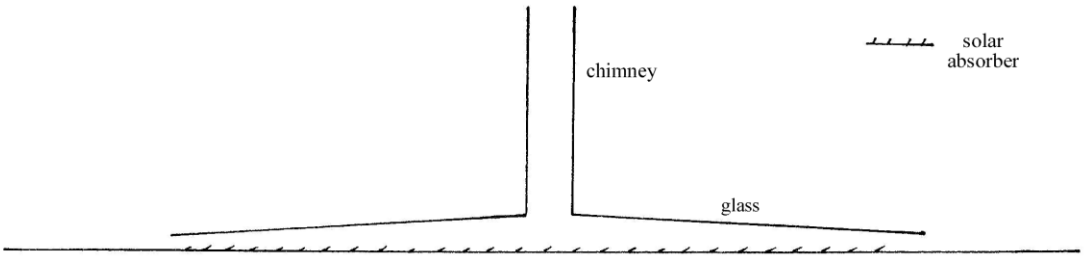

Figure 1 - the solar chimney

At ground level there is an efficient solar absorber. This takes up solar energy warming the air in its vicinity which rises, drawing in fresh air to replace from beyond the perimeter of the solar collector. The collector is gently sloped so that the warm air is directed through the chimney. Air turbines fitted at the base of the chimney generate electricity from this air flow.

The solar chimney is driven simply by natural convection and, for a 1000 metre height chimney, has an efficiency of about 3%. Where does the other 97% of the energy go? Some is lost through the glass and the walls of the chimney; but the large majority emerges from the top of the chimney as a stream of warm air up to 20 K above ambient temperature and with a velocity of up to 12 metres per second. This is simply dissipated into the atmosphere.

The author would like to present a 'thought experiment' to the reader. Quite simply, what would happen if a glass bell jar was placed over the above structure and sealed at ground level? Would there still be air flow and what would be the efficiency of conversion of solar energy into electricity? The configuration proposed is outlined in Figure 2.

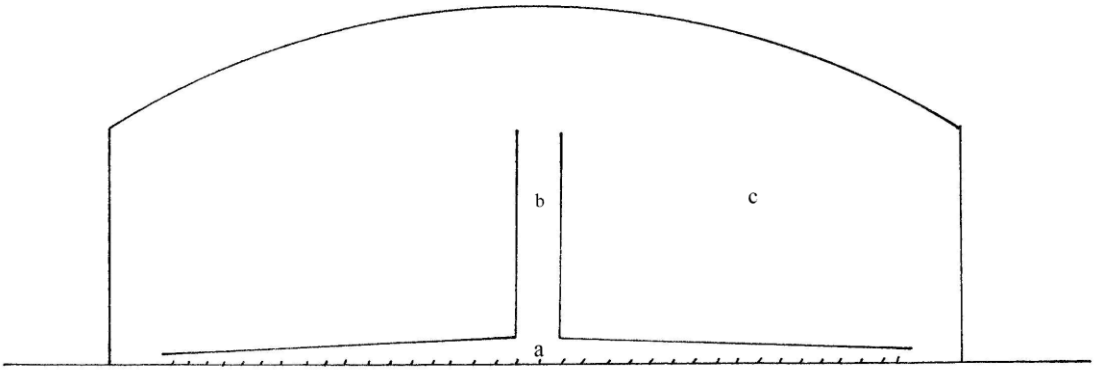

Figure 2 - solar chimney plus bell jar

In this case the warm air, previously lost at the top of the chimney, cannot escape. The reader may argue that the air will simply get hotter and hotter and that this will be lost through the walls of the bell jar. The temperature of the entire assembly will rise, the solar absorber will be damaged and there will be no useful air flow through the turbines. That may be true.

The author would like to present an alternative scenario. The solar absorber remains the driver of the system. In this closed configuration, as solar energy is taken up by the absorber, the total volume of air inside the bell jar cannot expand. A flow pattern will be established taking air from (a) to (b) to (c) and return to (a). This will transport energy from the absorber to the turbines which export energy and through the large expanse of the bell jar where some energy will be lost through the glass. Further it is the author's argument that, as the only loss of energy is through the glass of the bell jar, solar energy will be converted into electricity with very high efficiency.

If we consider the changes more fundamentally, solar energy is taken up by the absorber with high efficiency providing a HOT surface. Air molecules collide with this surface and rebound at higher velocity. The additional energy imparted is in the vertical direction and creates an air flow within the chimney. Since the volume of air is held under severe constraint ALL of the solar energy taken up by the absorber is converted into the vertical component of velocity of air molecules i.e. into a vertical air flow. The air flow strikes turbines at the base of the chimney. Air turbines can have an efficiency of over 90% in taking up the energy of air flow. The air molecules post turbine in (b) have lost nearly all of their directional kinetic energy and will be drawn through (c) and return to (a) to complete the cycle.

There is a precedent to the configuration in Figure 2. In the Science Museum, Exhibition Road, London, in the Heat Section (third floor) there is on display a Convection Mill [3]. It was invented in 1896 by Bennett and works on exactly the principles above. The flow of air by natural convection in a closed cycle converts solar energy into rotational energy. The Convection Mill responds to heat from the hand and is even sensitive to moonlight. Bennett adapted his instrument to provide a method for determining the specific heat of metals and concluded that, "Nearly all the introduced heat is expended in causing air currents" [4].

It is the author's assertion that the superimposition of a glass bell jar, rigorously sealed at ground level, on the solar chimney configuration will allow the conversion of solar energy into electricity with high efficiency.

This paper is being published with a request that individuals at research institutions investigate the above proposal using small-scale models of perhaps 10 metres or even just one metre dimension. The results could be very important.

References

[1] J. Schlaich et al., Journal of Solar Energy Engineering, 2005, 127 (1), pp 117-124.

[2] http://www.enviromission.com.au

[3] Science Museum, Heat and Cold Pt II, Descriptive Catalogue, 1954, page 27.

[4] A. R. Bennett, Engineering, London, 1897, vol. 63, pp 239-41.